Ontologies of Cree Hydrography: Formalization and Realization

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Abstract

The World Wide Web will be revolutionized as computers gain the ability not only to process data, but also to interpret it. This computer reasoning functionality will be enabled in large part through the widespread use of a new kind of metadata called ontologies, which are formal models of concepts which computers can use to interpret data. Ontologies give computers the ability to, among other things, infer new information from data, disambiguate similar terms, and draw inferences.

The concepts which different cultures use to understand the world are not the same, and so the development of ontologies to be used throughout the *World* Wide Web is quite problematic. One particularly stark contrast is between the geographical concepts of Western peoples, or those descended from Europeans, and indigenous peoples. Yet there has been no attempt to develop or implement a geographical ontology with an indigenous people. This thesis represents the first attempt to do this.

Research was conducted with the Cree of Quebec. A geographical ontology was developed with Cree concepts, implemented in software in three different ways, and this software was tested with Cree users. Results show that geographical ontologies developed with Cree concepts have unique design considerations. Cree users were interested in the implementation of the ontology as a feature-type catalog, though the uses of the ontology to tailor the responses of a map-based graphical user interface to user input did not improve any aspects of user experience.

Résumé

Le Web sera révolutionné par le fait que les ordinateurs gagnent en capacité de traiter non seulement des données, mais également de les interpréter. Cette fonctionnalité de l'ordinateur à simuler le raisonnement est en grande partie ce qui permettra l'utilisation répandue d'un nouveau genre de méta-données

appelé les ontologies; ce sont des modèles formels de concepts que les ordinateurs peuvent employer pour interpréter les données. Les ontologies donnent entre autres aux ordinateurs la capacité d'inférer de nouvelles informations à partir de données, de désambiguïser des termes semblables, et d'en tirer de nouvelles inférences.

Les concepts que l'on retrouvent dans différentes cultures pour décrire le monde sont tres différents , et compte tenu de cette réalité, le développement des ontologies à employer dans tout le Web est des plus problématique. Un bon exemple de contraste radical entre les concepts géographiques est celui des peuples occidentaux ou ceux descendus des Européens, et ceux des peuples autochtones. À ce jour, il n'y a eu aucun effort systématique pour développer ou mettre en application une ontologie géographique propre aux autochtones. Cette thèse en représente une première tentative.

Cette recherche a été entreprise avec les Cris du Québec et une ontologie géographique a été développée avec des concepts qui leur sont propres, mise en application de trois manières différentes avec l'aide de logiciel, et examiné par des utilisateurs Cris. Les résultats démontrent que les ontologies géographiques développés à partir de ces concepts ont des considérations uniques quant à leur conception. Les utilisateurs Cris étaient particulièrement intéressés par la réalisation de cette ontologie représentée par un catalogue avec types et attributs; cependant, l'usage de cette ontologie pour adapter les réponses de l'interface graphique en fonction des entrées de l'usager n'a amélioré aucun des aspects de cette intéraction.

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Contributions of Authors

Chapters 2 and 3 of this thesis represent papers to be submitted to scholarly journals. All methodology design, fieldwork, data collection, ontology formalization, and initial paper ideas are mine, though Dr. Renee Sieber provided input and framing ideas to both papers and so she is the second author on both.

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Chapter 3: Realizing Ontologies with the Cree of Quebec

Chapter 1: Introduction

In 2005, the World Wide Web contained over 11.5 *billion* static Web pages, and it was growing quickly (Gulli and Signorini 2005). Because this figure does not include database-driven dynamic Web pages, this is likely an underestimation of the quantity of information on the Web. To leverage such an unwieldy amount of information, we have turned to computers to index and retrieve relevant Web content, as there is simply too much information to effectively find anything manually.

Yet, computers have a very difficult time searching the unstructured Web due to the lack of standardization of terminology. This problem, cleverly called the 'tower of Babel' problem (Smith and Mark 2003), is one of the main foci of the World Wide Web Consortium (W3C). Rather than seek to apply some kind of standardized terminology across the multitude of users, languages, and cultures that use the Web, the W3C intends to use a new type of metadata – data about data – to allow computers to interpret the meaning of the contents of websites. This focus on the meaning of Web content has given the name of Semantic Web to this up-and-coming Web (Berners-Lee and Hendler 2001). The new type of metadata are called ontologies.

Ontology is a term from philosophy that refers to a study of being. Beginning with Aristotle's work 'Categories' in 340 B.C. (Mann 2000), ontology approaches the study of reality by breaking it down into categories, relationships, and rules (Audi 1995). In recent years, computer science has appropriated the term ontology to mean a "logical theory which gives a partial account of a conceptualization" (Guarino and Giaretta 1995, p. 32). This oft-used phrase means (in this thesis) a set of classes, properties, instances, and rules describing some topic. Properties are represented as binary (two member) relationships between classes, between instances, between classes and instances or between a class or instance and a literal, which is a piece of text or number data. Representing an ontology in digital form allows a computer to use the information in the ontology to aid in processing, querying, and reasoning operations.

Geographic Information Science (GIScience) has turned much of its attention to creating geospatial ontologies, or ontologies which formalize the meaning of geospatial categories (e.g. mountain, river) and relationships (e.g. inside, across from). Systems have been prototyped that use ontologies to allow computers to execute queries to, for instance, find the nearest airport that can land a Boeing 747 given the location of the plane, a query which combines spatial reasoning with semantic reasoning (Kolas et al. 2005, Lutz and Kolas 2007). Despite the likely ubiquity of geospatial ontologies in the near future, there has been little examination of how the conceptualizations of non-Western peoples (those not descended from Europeans) can be formalized into ontologies or how these ontologies can be realized, or implemented in software.

Indigenous peoples represent one group of non-Western peoples. Empirical research has shown that they have geospatial categories, relationships and rules distinct from those of Western peoples (Mark and Turk 2003).

Contrary to existing stereotypes as being 'backwards' or at least unconcerned with Geographic Information Systems (GIS) or the Web, indigenous organizations have used GIS for decades to secure and manage their territories (Poole 1995). The Web has been pivotal in the development of a sense of identity for the indigenous peoples' movement, and continues to be a tool for indigenous peoples' cultural expression (Niezen 2004; Denton 2006).

As the Semantic Web is implemented and ontologies become ubiquitous, indigenous peoples' organizations will need to develop ontologies using concepts in their own languages and cultures, lest they be shut out of the Semantic Web or forced to use Western ontologies when interacting with the Internet. This thesis is the first scholarly work to examine how digital ontologies can be developed with indigenous peoples, and then how these ontologies can be realized in software.

Research Strategy and Thesis Structure

To explore these issues, I partnered with the Cree peoples of Wemindji, Quebec. Wemindji is a Cree village on the east coast of James Bay. It is home to approximately 1,200 people. Cree is the most spoken of all Aboriginal languages among First Nations peoples, having about 87,285 speakers out of about 698,025 First Nations peoples, proportionally almost 13% (Statistics Canada 2008).

In addition to the significance of the Cree language to Canada, the study location was ideal for understanding the influence of geography on ontology. Ontology work with indigenous peoples conducted by Mark and Turk (2003) and Stea (2007) centered on indigenous peoples in desert environments. Because their work concluded that the environment in which the language and culture evolved impacted its geographical categories, the sub-arctic environment of James Bay provides an excellent opportunity to study this influence further.

The Cree are undergoing a process of rapid cultural change which began before the hydroelectric projects of the 1970's which accelerated that change, impacted Cree land, and eventually led to the James Bay and Northern Quebec Agreement (Preston 2002). Wemindji has been opened to road travel only since 1995 and still has a substantial hunting economy which employs approximately 22% of Wemindji residents full time and provides all of them with bush food (Benessaiah et al. 2003; Berryman et al. 2004). Land for hunting is parceled into family hunting territories called traplines. Hunting in each trapline is overseen by a hunting boss, called a tallyman (Scott 1988). See Figure 1.1 for a map of Quebec Cree territory and Figure 1.2 for a map of Wemindji Territory. Note that all boundaries are for illustrative purposes only and may not be used in any land tenure dispute.

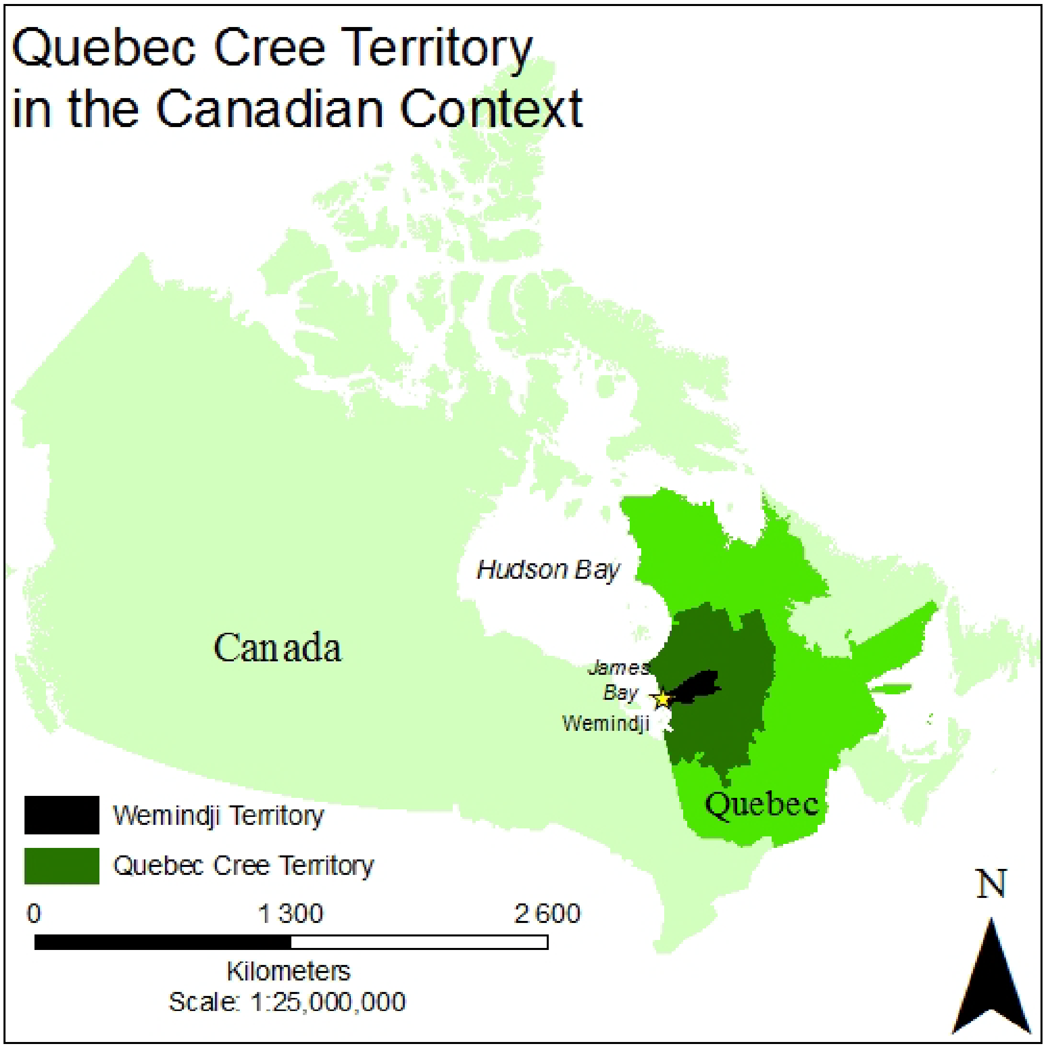


Figure 1.1: Quebec Cree Territory. Lambert Conformal Conic projection. Canadian boundary data obtained from the Government of Canada's GeoBase (Government of Canada 2008). Cree territory information obtained from the Cree Regional Authority (CRA) (Cree Regional Authority 2002).

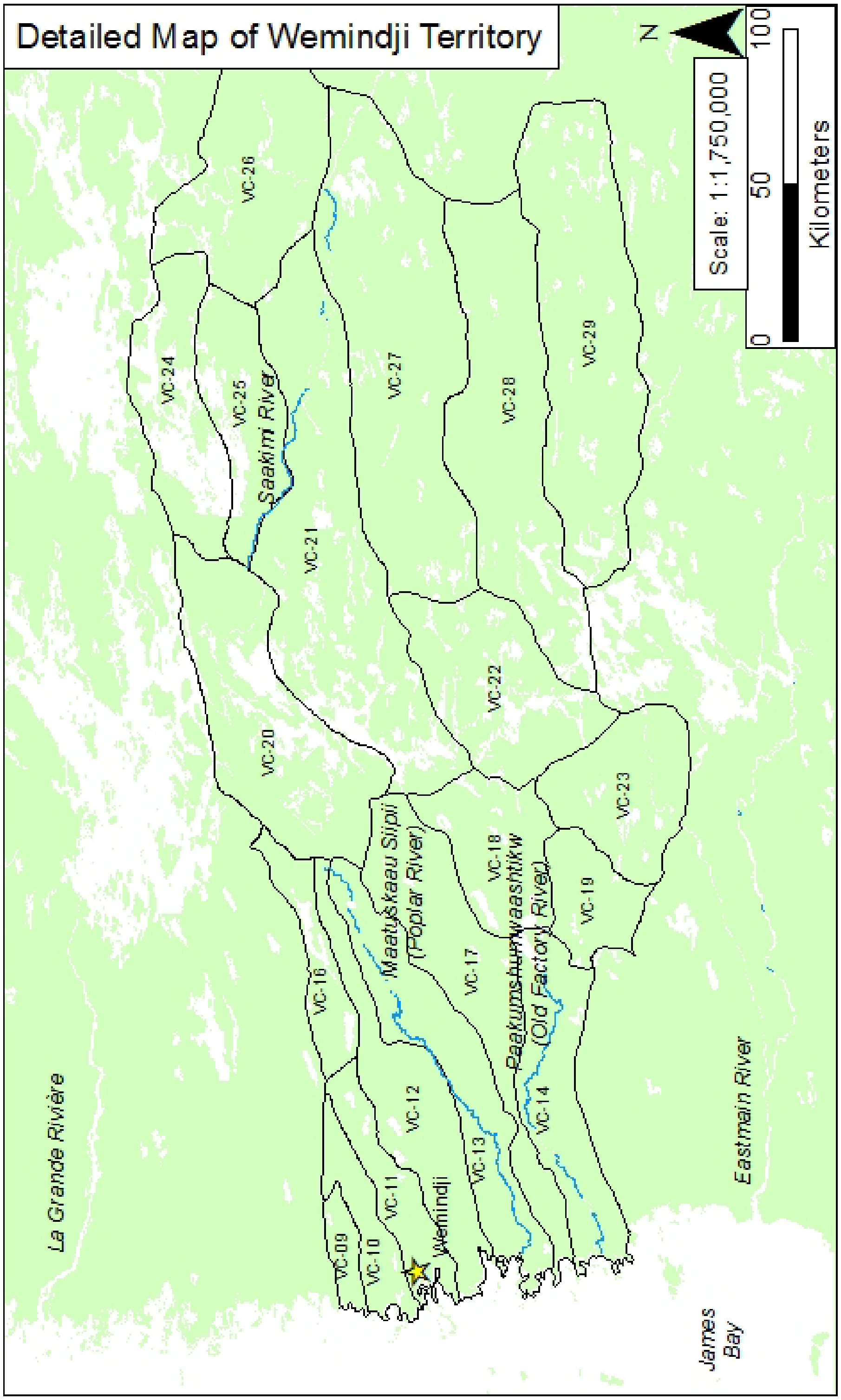


Figure 1.2: Map of Wemindji Territory. Created By Christopher Wellen on September 11th, 2008. Universal Transverse Mercator Zone 18 North. North American Datum, 1983. Wemindji Traplines from Cree Regional Authority (Cree Regional Authority 2002). Hydrography from Quebec Ministry of Environment (Quebec Ministry of Environment 2004).

The Cree of Quebec have recently established the Cree Cultural Institute for the purpose of preserving their culture for future generations (Cree Cultural Institute 2006). Geospatial tools, including an online digital gazetteer of Cree placenames, are forming an integral part of this preservation. Researchers working with the Cree of Quebec have established a language and oral history preservation Website (Junker and Luchian 2007).

The Cree of Wemindji operate a GIS of their own and the Cree School Board is actively engaged in exploring geospatial tools for training youth in language.

In Chapter 2 of this thesis I employ a variety of methods including archival research, interviews, and lab work to create a logical ontology of hydrography, or water bodies, from Cree concepts related to water bodies. A logical ontology refers to a set of classes, relationships, and rules describing conceptual categories which is implemented in a digital ontology-modeling language (Mizen et al. 2005). In Chapter 3 I use a similar set of methods, lab work, and interviews to realize this ontology, or use it as a component of a piece of software. Realization is important because while simply creating a logical ontology is a worthy academic goal, creating software applications which use those ontologies is necessary to ensure that indigenous communities, which are not composed solely of academics, reap some benefit from them. As Tobias (2000) said and others – notably Aberley and Sieber (2002) – echoed, it may be enough for academics to have purely academic research, but indigenous communities need some practical application of that research.

Both of these chapters will be submitted for publication as separate journal articles, so there is some repetition of material. The methodology section of Chapter 3 is quite brief concerning the formalization of the ontology, as this is the subject of Chapter 2. The published version of Chapter 3 will discuss the ontology formalization in more detail. The published versions of both papers will discuss the Cree of Wemindji, Quebec in more detail.

Chapter 2: Formalizing Logical Ontologies with the Cree of Quebec

Abstract

Logical ontologies, conceptual models represented in a computer-processable language that give a partial account of a conceptualization, will serve as a kind of metadata on the up and coming Semantic Web. Whereas there has been ample work in Geographic Information Science (GIScience) on the subject of ontologies, a relatively neglected area is the influence of language and culture on ontologies of geography. Though this subject has recently been investigated conceptually using indigenous words denoting geographic features, this paper represents the first attempt to develop a logical ontology with an indigenous group. The process of developing logical ontologies is here referred to as formalization. An iterative methodology for formalizing ontologies with indigenous peoples is presented. Unlike the bulk of previous ontology formalization methodologies, this methodology is not based on eliciting knowledge from technoscientific elites but from hunters and rural community members—lay scientists and experts within their community. A conceptual, or human readable, ontology was developed and verified and a logical, or computer processable, ontology was developed using this methodology. Research was conducted with the Cree of Quebec, Canada, the largest indigenous language grouping in Canada. Results show that geospatial ontologies developed from Cree geographic words have unique design considerations: ontologies are structurally flat due to the lack of intermediate concepts and they contain classes of Cree speakers that specify which Cree speakers use each class in the ontology.

1. Introduction

The World Wide Web Consortium (W3C) has envisioned a new kind Web: the Semantic Web. It consists of a suite of software technologies working together to allow computers to directly interpret and manipulate the contents of the Web.

Ontologies, an integral component of the Semantic Web, will allow interoperability at the semantic level (Berners-Lee 2001; Kolas et al. 2005). In computer science, ontologies are logical theories that give partial accounts of conceptualizations and consist of classes, properties, instances, and rules (Guarino and Giaretta 1995). They serve as a type of metadata, or data about data. The geospatial community has taken substantial interest in the Semantic Web, and has declared the beginnings of the Geospatial Semantic Web, of which ontologies will form an integral part (Egenhofer 2002; Kolas et al. 2005; Lutz and Kolas 2007).

To properly account for the myriad of conceptualizations on the Web, many ontologies must be used, and at different levels of specificity (Kolas et al. 2005). For ontologies to work together, they must inherit or extend concepts from some sort of shared framework of high-level, abstract concepts (e.g., point or boundary). Such concepts would be reposited in standardized top-level and mid-level ontologies (Pease and Niles 2002; Smith and Mark 2003). Top level ontologies are developed and maintained by standards organizations such as the W3C. The Web transcends cultural boundaries and so any culture whose concepts are not compatible with these standard ontologies will be unable to use concepts from their culture when interacting with the Semantic Web. This exclusion is especially likely to happen to non-dominant cultures, as they are likely lack the resources to develop logical ontologies. Thus there is a need to develop logical ontologies of concepts found in non-dominant cultures before the Semantic Web is locked into using standard ontologies which exclude certain cultures.

In North America one of the most prominent cultural and linguistic divides is that between Euro-American and indigenous peoples. Indigenous cultures in many parts of the world are marginalized and oppressed by the dominant cultures in which they live. Consequently, they are in some danger of being excluded from or colonized on the Semantic Web, despite their use of geospatial and Web technologies (Poole 1995; Niezen 2004). Empirical work on the geographical categories of indigenous peoples has found that indigenous categories do not correspond to English language ones in a one to one manner (Mark and Turk 2003; Stea 2007). This conceptual mis-match means that indigenous peoples' geographical categories will not be represented in standard geospatial ontologies if they are not directly engaged in the logical ontology development process.

Ontologies have a range of formality, though most researchers recognize two main kinds of ontologies. The first kind are called conceptual ontologies, which are specified in natural language. The second kind are called logical ontologies, and use a type of artificial language, either analog, such as first order predicate calculus, or digital, such as the Web Ontology Language (OWL), to specify them (Uschold and Gruninger 1996). Conceptual ontologies aid humans in communicating with each other and inform the design of logical ontologies, and logical ontologies allow computers to draw inferences from a body of information and are used in a number of operations including query and analysis. Logical ontologies will be used by many types of software including intelligent agents, search engines, and aggregators on the Geospatial Semantic Web to help people find relevant information. Formalization here refers to the creation of a logical ontology from a conceptual ontology. As will be discussed, several researchers have broached the conceptualization of indigenous ontologies (Mark and Turk 2003, Stea 2007; Mark 2008). However, no one has formalized a logical ontology with an indigenous group.

The aim of this chapter is to take this next step and formalize a logical geospatial ontology with an indigenous group. I first review the background literature. Then I present my method of ontology formalization. It consists of developing a conceptual ontology, developing a logical ontology, and then verifying the conceptual ontology. My method addresses difficulties such as the use of ethnography and participant observation as opposed to the highly structured software-centric methods used in computer and information sciences. I also make use of placenames as a method of grounding, or ensuring fidelity of the ontology to the concepts it represents by making use of texts in which the concepts represented in the ontology are embedded (Kuhn 2001). I accomplish this by treating placenames as instances of geographical categories. The ontologies developed from this methodology are presented in the results section. Finally, a discussion ensues concerning how the logical ontology formalization proceeds differently with an indigenous group and the implications of the results concerning the place of indigenous peoples on the Semantic Web.

2. Theoretical Background

2.1 Ontology in GIScience

Ontology research in GIScience and in general has two paradigms: the philosophical paradigm and the information science paradigm (Agarwal 2005). Ontology in its original philosophical sense refers to a study of being, and seeks to explore and understand what kinds of things can exist and what their natures are. Philosophical ontologists study the existence of all kinds of entities, abstract and concrete, that make up the world (Agarwal 2005; Sowa 2000). They use as analytical units classes, instances, and properties (Agarwal 2005; Uschold and Gruninger 1996). Classes are categories or more appropriately sets of objects. Instances, or individuals, are members of one or more classes. Properties define classes and instances, and are usually treated as binary relationships which link classes together, classes to instances, instances to other instances, or either classes or instances to numerical or textual values such as a number or a name. Occasionally, philosophical ontologists make use of axioms, which are logical rules that enable the creation of new information.

Information science has appropriated the term ontology to refer to a "logical theory which gives an explicit and partial formalization of a conceptualization" (Guarino and Giaretta, 1995, p. 32). For information science, an ontology is not meant to specify a theory of reality, but to make explicit some kind of shared conceptualization of that reality using a vocabulary of terms.

Ontologies in both paradigms have a range of formality, though most researchers recognize two main kinds of ontologies. The first kind are called conceptual ontologies, which are specified in natural language, and can include concept hierarchies, feature catalogs, and concept lattices (Uschold and Gruninger 1996; Mizen et al. 2005; Frank 2001). The second kind are called logical ontologies, and use some kind of artificial language, either analog, such as first order predicate calculus, or digital, such as the Web Ontology Language, to specify them (Grenon and Smith 2004; Uschold and Gruninger 1996). Ontologies in both paradigms have a range of specificity. Ontologies about specific subjects, such as chemistry, are called domain ontologies. Ontologies meant to describe the whole of reality are called top-level ontologies (Agarwal 2005).

GIScience abounds with ontology research from both the philosophical paradigm and the information science paradigm. These two paradigms are distinct but by no means separate. Philosophical ontology research informs information science research with appropriate design principles. To be effective, an ontology must not only be logically consistent but also represent with some degree of accuracy the world people think about (Smith and Mark 2003).

At the core of philosophical ontology research is the distinction between Primary and Secondary Theory (Horton 1982; Smith and Mark 2003). According to this distinction, human thought has two components. The first, called Primary Theory, is the result of natural selection and hence universal to the human species. The second, called Secondary Theory, is learned and hence socially constructed (Horton 1982). Philosophical ontology places landforms at the interface between these two components. Landforms, for instance mountains, are thought of as having little existence in and of themselves, being somewhat arbitrary demarcations of a continuous landscape.

It is when studying animal (including human) behavior that it becomes necessary to refer to concepts such as mountains and rivers. These objects, however, are regarded as a component of Secondary Theory, hence socially constructed (Horton 1982, Smith and Mark 2003, Gibson 1986). This philosophical framework allows for the possibility of multiple ontologies of landforms. As the empirical work reviewed below will show, there are not only multiple ontologies of landforms, but the categories contained therein cannot be reduced to a core set (Mark and Turk 2003).

Conceptual and logical ontology research in geography shall be reviewed, and it will be shown that while conceptual ontology research has begun to examine indigenous peoples' geospatial ontologies, there are still many issues to be examined. Further, there has been no formalization of indigenous peoples' geospatial ontologies in GIScience.

2.2 Conceptual Ontology Research in GIScience

Conceptual ontology research in geography attempts to understand how people think about geography, which includes the abstract idea of space and the more concrete one of landforms, by breaking down their thoughts into classes and relationships between the classes (Agarwal 2005; Mark et al. 1997; Smith and Mark 1998).

Conceptual ontology researchers in geography point out that geographic objects are fundamentally different from many of the tabletop artifacts cognitive scientists study. The fundamental properties of space itself – topological relationships such as connection and containment, as well as part/whole relationships which are referred to as mereological relationships – are fundamental to objects existing at geographic scales (Smith and Mark 2001; Smith 1996).

There has been empirical investigation into these ideas. Smith and Mark (2001) surveyed first-year university students to name geographical categories. The researchers interpreted their results to "yield an ontology of geographical categories – a catalogue of the prime geospatial concepts and categories shared by *human* subjects independently of their exposure to scientific geography" (emphasis mine). This early work had little discussion of the influence of culture and language of their subjects on their results. Later empirical work, however, addressed this issue directly by studying the geographical categories used by certain indigenous peoples to refer to landscapes. Mark and Turk (2003) interviewed the Yindjibarndi of Australia to study the nouns and noun phrases for these categories. The researchers made a basic inventory of topographic and hydrographic features of the Yindjibarndi language and found the features to be quite different from those used by AUSLIG, the English-language Australian Gazetteer standard. The word **yinda**, for instance, refers to a permanent pool in a seasonal riverbed. This word could be translated into the Australian Gazetteer terms lake, pond, or soak, depending on the size of the pool.

Stea (2007) demonstrates the importance of spirituality in Yindjibarndi landscape categories. According to Yindjibarndi myth, the **wundu** were created by a serpent (a **warlu**) as he slithered across the land. These **warlu** protect and live in the **yinda**. Thus a property of the category **yinda** is distinctly spiritual, something likely to be overlooked if indigenous ontologies were presumed to be identical in form to Western ontologies. Continuing the above example, translation of the term **yinda** into one of the Australian Gazetteer terms would neglect this spiritual component.

This work demonstrates that people from different cultural and language groups use different categories to make sense of the geographic world, and that these different sets of categories do not map onto each other in a straightforward manner. Simply put, different groups of people "cut" the world at different joints. Mark and Turk (2003) interpret an environmental influence at play in these differences in ontology between cultures. Most conceptual ontology research has focused on the Yindjibarndi, an indigenous group from northwestern Australia, and the Navajo, an indigenous group from the southwestern United States, both desert areas (Mark and Turk 2003; Stea 2007; Mark 2007).

In addition to geospatial classes or categories, ontologists are interested in the relationships which define classes – for instance, part of the definition of a river is that it flows into a body of water. Mark and Egenhofer (1995) examined topological relationships (e.g. crosses, contains, connected to) used by English speakers and Spanish speakers when describing pictures of a road going through a park. The topological relationships used by speakers of each language were not the same. This implies that people from different cultures and languages make sense of the world by using different spatial relationships as well as different geospatial categories. Yet, there has been no research on spatial relationships in an indigenous context.

A major research effort in the conceptual geospatial ontology field is the creation of a top-level ontology for geography (Agarwal 2005). There are candidates for this ontology, including Frank's (2001) tiered ontology comprised of human-independent reality, observations of the physical world, objects with properties, social reality, and subjective knowledge, and Grenon and Smith's (2004) SNAP/SPAN. Mark's (2008) recent work towards creating a conceptual ontology of landforms marks a significant departure from these top-down approaches, and it also takes much of its input from the Yindjibarndi language. Despite these efforts, geospatial ontology research conducted with other indigenous groups is still required, as due to the socially constructed nature of landforms those of one indigenous group cannot represent those of all indigenous groups.

A thorough understanding of the benefits of a top-level ontology requires an examination of the other side of ontology research in geography: logical ontologies.

2.3 Logical Ontology Research in GIScience

Ontologies can be created to guide human communication and ensure its effectiveness, or they can be implemented in an artificial language to enable computer processing. Ontologies created for the former purpose are in information science called conceptual ontologies. Ontologies created for the latter purpose are called logical ontologies, and they require some kind of artificial language to implement (Uschold and Gruninger 1996; Mizen et al. 2005). Logical ontologies are often developed from conceptual ones. The process of developing a logical ontology from a conceptual one is called formalization.

Logical ontologies have many applications. The UK Ordinance Survey is experimenting with logical ontologies of topography to automatically recategorize topographic data features according to their potential for flood defense (Dolbear et al. 2005). Raskin and Pan (2005) used a logical ontology of geoscience to enhance the precision of a search engine of articles of geoscience.

A central goal of creating an ontology is to ensure semantic interoperability, or the ability of different systems to exchange information (Agarwal 2005). Automated semantic interoperability can be supported by using a logical ontology as what Uschold and Gruninger (1996) called an interlingua, a shared repository of knowledge formalized into an artificial language. Classes in databases can be mapped to the classes in the interlingua, and data and queries can be automatically translated between the databases without standardizing the structure and contents of every database. Logical ontology research in GIScience has spawned many data integration systems based on using domain ontologies as interlingua. Fonseca et al. (2000) proposed such a system designed to integrate urban infrastructure data. Fonseca et al. (2002) proposed a similar system designed to integrate raster land cover data. Broderic (2004) designed and implemented a system that integrated data from field geologists using a logical ontology as an interlingua. No logical ontology has included any indigenous concepts.

Extending this system of automated translation to the Internet is the intent of the W3C's Semantic Web working group, which to this end has created their own logical ontology language, the Web Ontology Language, or OWL (Berners-Lee et al. 2001; McGuinness and van Harmelen 2004). Universal semantic interoperability of geographic information is also a major driver of ontology research in GIScience (Egenhofer 2002). Achieving this would require a top-level logical ontology of geography. There are candidates, including the Suggested Upper Merged Ontology (SUMO), which has been extended to include geographical concepts (Pease and Niles 2002); and Grenon and Smith's (2004) SNAP-SPAN, a top-level ontology for geographic concepts. The Open Geospatial Consortium has successfully prototyped a system to execute a distributed query using a system of ontologies, one of which is a top-level geospatial ontology (Kolas et al. 2005). There has been no input from indigenous cultures into top-level logical ontologies. If indigenous cultures are to be represented on the Semantic Web, then it will be necessary to formalize ontologies using concepts from their culture. This paper is the first study to formalize a geospatial ontology with an indigenous group, a process that must occur if indigenous peoples' ontologies are to be included in the Semantic Web.

3. Methodology

The contributions of this chapter are as much methodological as analytical, as the methodologies used to develop conceptual and logical ontologies are specialized to working with technoscientific elites and are not appropriate when working with indigenous communities. All fieldwork was done with Cree people in Wemindji, Quebec. The reader is referred to Chapter 1 for an introduction to the Cree of Wemindji, Quebec.

Ontology formalization generally proceeds from the conceptual to the logical. The creation of a conceptual ontology must involve experts in the knowledge to be formalized, though the role of experts can vary from the use of texts authored by experts to ground the ontology (Kuhn 2001), to periodic input from consultants into the development of a conceptual model, to the total authoring of the conceptual ontology by the experts themselves (Mizen et al. 2005). Once the classes and relationships comprising the conceptual ontology are determined, they are logically formalized by information engineers using an artificial language such as the analog first order predicate calculus or the digital OWL (Goodwin 2005).

The methods used by ontologists in Western contexts may be incompatible with indigenous communication styles. Indigenous styles of communication are very different from Western ones (Nadasdy 1999). Those in Western contexts solicited for their knowledge for an ontology project tend to be technoscientific elites such as chemists or hydrologists, likely somewhat familiar with computer programming already, and naturally at ease talking to, and trusting of, computer or information scientists. In an indigenous context this is not generally the case. Indigenous knowledge holders may speak very little English and may not be comfortable with computers. They will likely not have any sort of disciplinary rapport with computer or information scientists – a relationship must be built. Depending on the indigenous context, there may be a history of distrust of white elites. Kuhn's (2001) method of using texts could not be applied without modification in an indigenous context because the texts of indigenous peoples tend to be oral. Mizen et al.'s (2005) method, which has the knowledge experts author the entire conceptual ontology, would be disrespectful in certain indigenous contexts because it would be seen as being inappropriately commanding. Methods of eliciting knowledge successfully used in indigenous contexts tend to be qualitative ones from anthropology – ethnography, participant observation, and interviews (Nadasdy 1999; Scott 1996).

I therefore based my methodology on the linguistic-centric approach used in previous ontology work done with indigenous groups (Mark and Turk 2003; Stea 2007; Mark 2008). These studies elicited nouns and noun-phrases to study the conceptual categories present in a language. Language is a natural choice for investigating ontologies within a culture because it is an excellent way to make introductions in an otherwise abstruse investigation, and it allows an investigation to be grounded, which otherwise could be prone to unrestrained speculation. Language also allows for a bottom-up approach, where the ontology begins with concrete, specific concepts and later moves on to general, abstract ones. Such an approach is more likely to yield consensual ontologies that reflect how people who use those concepts think (Agarwal 2005). This bottom-up approach is especially important in indigenous contexts, where misrepresentation and appropriation have occurred in the past, because it is less likely to impose Western (or, from the point of view of the Cree, Southern) concepts or superordinate concepts onto Cree ones. Finally, in a Cree context attempts by Southern researchers to learn Cree language engenders trust and respect.

My methodology had three stages. First, I constructed a conceptual ontology. Then I formalized the conceptual ontology into a logical ontology. Finally, I verified the conceptual ontology. Feedback from Cree speakers, my domain experts, was obtained at multiple steps throughout the investigation, giving an iterative quality to the methodology. The methods employed will be described after some introductory comments on the methodology as a whole. How these methods were employed at each stage in the methodology will then be described.

I decided to focus on hydrography, or water bodies. Hydrography is quite important to the Cree because it serves as a method of transportation (Berryman et al. 2004; Denton 2006). In one placenames survey covering the entire Wemindji territory, nearly 80 percent of the names pertained to hydrography (MacKenzie 1977). Water bodies have been a fruitful domain for spatial ontologies in Western contexts and have a host of mereotopological issues to explore (Hart et. al. 2004).

The three stages of the methodology, and the methods employed at each, will now be described. Figure 2.1 diagrams the three stages of the methodology.

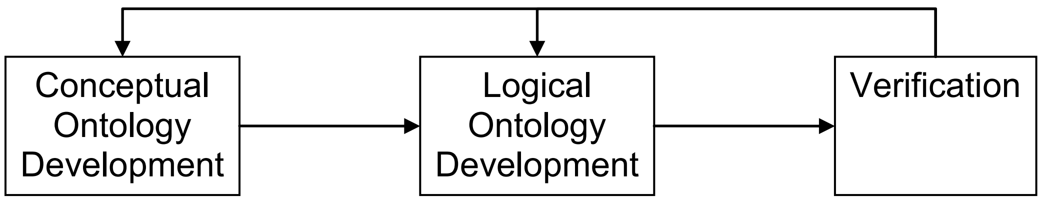


Figure 2.1: Methodology stages for developing Wemindji Cree ontology of hydrography. Backwards arrows indicate feedback.

3.1 Conceptual Ontology Development

My methodology begins with the creation of a conceptual ontology. Conceptual ontologies themselves have a range of formality (Uschold and Gruninger 1996). Common to all conceptual ontologies is the exclusive use of natural language, though this language may be restricted somewhat to increase precision. My conceptual ontology began with a glossary of Cree hydrography, which I later turned into a list of Cree classes and their essential relationships.

Three methods comprised the development of the conceptual ontology. They were archival research, followed by unstructured interviews and then semi-structured interviews. These methods together allowed for triangulation of findings.

3.1.1 Archival Research

An ontology is a model of knowledge and texts that record that knowledge offer an excellent source when formalizing an ontology (Kuhn 2001). Indigenous texts are almost always oral, but to facilitate an ontology investigation with indigenous peoples it is important to read available written information. I relied on four secondary sources to aid my investigation.

My field preparation began with a thorough review of the Cree School Board's dictionary of the Northern Dialect of East Cree, the language spoken in Wemindji (Bobbish-Salt et al. 2005). I used English keywords pertaining to hydrography such as river, lake, and rapids to search for Cree words on this dictionary's Web version. I made a list of Cree hydrographic terms from this. The second source of secondary information is a short book entitled Lake Formations by George Fireman (2005). This book is about types of lakes and lake formations, features which involve multiple lakes. This emic text is a valuable source of information on how a native Cree speaker categorizes water bodies.

Toponymy is extremely important to indigenous cultures as a way of knowing the land, and the Cree are no exception to this (Nieminen 1998, Denton 2005). My third and fourth sources of secondary information were two collections of Wemindji Cree toponyms. One covers all of Wemindji territory and was collected by linguist Margurite MacKenzie in 1977. The other is a set of placenames of river features along *Paakumshumwaashtikw*, a major river in Wemindji territory (Berryman et al 2004). The placenames used in this investigation served as instances of Cree categories and were essential during the verification phase.

3.1.2 Field Methods

Fieldwork involved participant observation and unstructured interviews followed by semi-structured interviews. Fieldwork was necessary because ontologies are not focused on words, but on the concepts that words evoke (Kuhn 2005). It was necessary to talk to Cree key informants to interpret the words archival research was able to provide. The hope was that this interpretation would yield categories.

The use of key informants is thoroughly explored in the anthropology literature (Poggie 1972; LeCompte and Schensul 1999). Rubin and Rubin (1995) describe three qualities that should be possessed by key informants. They must be recognized as being knowledgeable about a domain; they must be willing to talk about the domain and articulate the domain in a manner understandable to the researcher; and together they must represent the full range of perspectives in the domain. I chose Cree hunters and elders as key informants to the domain of hydrography.

Participant observation occurred during a canoe trip down one of Wemindji's main rivers, *Maatuskaaw Siipii*, with four Cree guides familiar with the river. Examples of participant observation include navigating the river, camping, and fishing with the Cree guides. This trip also provided ample opportunity for short, unstructured interviews concerning Cree words for fluvial features such as sandbanks, islands, rapids, meanders, and bends, as well as different types of waterways. A number (22) of placenames of locations encountered along *Maatuskaaw Siipii* were also recorded.

After the canoe trip I conducted semi-structured interviews in Wemindji to understand the meanings of the Cree words in more depth. People in Wemindji familiar with the land are typically intimately familiar with a section of one trapline. Because Crees feel quite uncomfortable asserting claims about others' traplines, interviews focused on an area the participant knew, and used Canadian National Topographic System maps of that area at a scale of 1:50,000 as visual aids. Cree people with various levels of familiarity with the land were consulted. These were my domain experts. My sampling procedure was a version of the snowballing technique that mainly included Cree people familiar with two traplines: *Paakumshumwaau* and *Maatuskaau*. These traplines were chosen because they had the longest rivers unmodified by hydroelectric development. My interviews began with the tallyman of these two traplines. After the interview, I asked the tallyman to recommend anyone knowledgeable about the Cree language or the land on their traplines. These people were approached for interviews.

Table 2.1: Interview informants.

Community Member	Age	Gender	Knowledgeable about
Tallyman: Maatuskaau	35	M	Maatuskaau, Paakumshumwaau
Elder	60	F	Maatuskaau, Paakumshumwaau
Hunter/Elder	60	M	Maatuskaau
Tallyman: Paakumshumwaau	60	M	Paakumshumwaau
Hunter	50	M	Paakumshumwaau
Tallyman	40	M	LaGrande Reservoir 3
Elder	65	F	Maatuskaau
Tallyman: Sakami Lake	60	M	Sakami Lake, Paakumshumwaau
Cree Language Expert	60	F	Cree Language

I asked for Cree words used to describe particular named features on their land, and often selected other examples of that feature to ensure a correct understanding of the term. The meanings of the terms on the list created from the dictionary investigation were also checked, and this process resulted in a larger list of Cree terms. Appendix E contains the interview guide used, and Appendix H contains the information sheet given to research participants. Additional placenames were recorded at this stage in an ad-hoc manner. A verification interview was then conducted with a Cree language expert in Wemindji to ensure that the spelling of each word was correct. The compiled list of Cree terms is presented as Appendix A. Table 2.2 of this chapter contains the definition of the Cree term **siipii**.

Table 2.2: Glossary definitions.

Term	Definition
Shiipaashtikw	A side channel of a river which breaks off and re-joins the main channel.
Shiipiish	A creek or a stream. One may be able to canoe down it.
Shikaapishii	A very small creek. One cannot canoe down it.
Siipii	A large river which one can canoe down.

When developing a conceptual ontology of a domain, it is important to employ a bottom-up approach (Mizen et. al. 2005; Agarwal 2005). A bottom-up approach imparts no initial hierarchy to the classes. It first focuses on defining the classes using relationships. After the classes are formally defined, it will become clear that certain classes have all the relationships of certain other classes, in addition to more relationships. The classes that are able to 'contain' the other classes are designated superordinate classes of those classes they can contain (Horridge et al. 2004).

In addition to subclass-superordinate class relationships, I used mereotopological relationships to define classes. Mereotopology refers to part-whole relationships (mereology) and connection-containment relationships (topology). These relationships geographical objects inherit from space itself, and according to GIScience theory they form the heart of any geospatial ontology (Smith and Mark 2003; Smith 1996). Basing their work on these principles, the United Kingdom's Ordinance Survey has created an ontology of hydrography which uses a set of mereotopological relationships to define classes (Hart et al. 2004). In addition to these mereotopological relationships, I found it necessary to include three other ones: connected to, upstream of, and downstream of. The use of mereotopology in this study is meant to assess its appropriateness in the process of formalizing an ontology with the Cree, as mereotopology will be a key aspect of geospatial ontologies on the Semantic Web. I also found it necessary to include a Cree naming convention called Big Brother-Little Brother as well as relationships regarding which class of Cree speaker uses each class and relationships regarding what material hydrographic landforms are composed of. This is further discussed in the results section.

The essential relationships I sought to capture from each Cree term were then recorded. The full list of these relationships is presented as Appendix B. An example is presented in Table 2.3 below. Note that this conceptual ontology is expressed in English.

Table 2.3: Essential relationships.

Cree Term	Essential relationships
Shiipaashtikw	• Feeds from waterways. • Empties into waterways. • Connected to a waterway. • Part of a waterway. • Feeds from and Empties into the same waterway.
Shiipiish	• Feeds from waterbodies. • Empties into waterbodies. • Smaller than siipii
Shikaapishii	• Feeds from waterbodies. • Empties into waterbodies. • Smaller than shiipiish
Siipii	• Feeds from waterbodies. • Empties into waterbodies.

3.2 Ontology Formalization

In the second phase of my investigation, I set out to formalize the ontology. This involves using the terms in the knowledge glossary as classes and using an artificial language to formalize the definitions of the classes, which include their relationships to each other.

I chose to use the W3C's Web Ontology Language (OWL) as my artificial language for a number of reasons. First, it is the standard ontology language of the W3C and the Semantic Web (McGuinness and Harmelen 2004). Using OWL will maximize the applicability of my work to the Semantic Web. OWL also has an open-source graphical user interface (GUI) tool called Protégé (Horridge et al. 2004).

OWL defines classes using the restriction ($\forall$) and existential ($\exists$) operators of first order logic (Horridge et al. 2004). The restriction operator controls with which classes another class can have a given relationship, but does not require that class to have that relationship with the other class. Thus if the ∀ operator were used with the class river, the relationship feeds from, and the class lake, this would be the equivalent of saying that if a river feeds from any feature, that feature must be a lake. This does not require any river to feed from any lake. The existential operator requires a given class to have a relationship with another class. If the ∃ operator were used with river, feeds from, and lake, this would be equivalent to saying that each river must feed from at least one lake. In the Cree ontology, the class **siipii**, which was found to be very similar to the English class of river, was defined using the relationships shown in Table 2.4. The terms in bold are classes of Cree waterbodies.

Table 2.4: Formal relationships of siipii, a Cree class that is very similar to the English class of river.

Predicate Logic Statement	Natural Language Translation
∀ EmptiesInto (**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)	If a **siipii** empties into anything, it only empties into one of the following features: (**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
∃ EmptiesInto (**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)	Every **siipii** empties into at least one of the following features: (**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
∀ FeedsFrom (**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or	If a **siipii** feeds from anything, it only feeds from one of the following features:

aa_mushaapaayaach or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)	(**aa_aschipuutaakinuwich** or **upikimaau** or **wiinipaakw** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **awiiwaach** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)

In keeping with the bottom-up methodology, there was no initial hierarchical structure imparted to the ontology at all. However, after the relationships were formalized, it became clear that some classes had the same set of relationships as others, but with additional relationships. The Cree terms which then became subclasses often resemble the terms of their superordinate classes. For instance, the term awaashaashich, a small marine bay, is very similar to the term waashaau, a more general category of marine bay. The RACER reasoning engine was then used to ensure that the classes were logically consistent (RACER Systems 2007).

Value partitions were used to formalize certain attributes of features (Horridge et al. 2004). Value partitions serve to define attributes of classes which are not relationships to other classes by providing a set of values that the attribute can take on. For instance, a value partition may specify the material of which a landform is composed. To create value partitions I created a class to contain as subclasses values a certain attribute may have, and a specific property to specify which classes of features have those attributes. For instance, a class called MaterialValuePartition was used to specify which materials certain hydrographic landforms were composed of. It contained as subclasses Rock and Earth, which were defined to be disjoint (sharing no instances). A property called hasMaterial was created to specify that certain landforms had Rock or Earth as materials. A value partition was also used to formalize which trapline a term was associated with, if it was associated with a trapline, as well as which speaker group.

After the classes were finalized, the placenames located during the archival research were manually entered as instances of these classes. This categorizing process relied on my interpretation of the Cree categories and placenames. Many of the placenames consisted of a generic, a word denoting a category, as well as a specific (e.g. the Mississippi River has the generic 'river' in the name, as well as the specific term Mississippi). This aided in correctly and objectively classifying the instances. As will be argued, it was necessary to create relationships at the instance level. The relationships of the classes served as a template to guide the creation of instance-level relationships, though instance level relationships were not restricted to those specified at the class level. See Figure 2.2 for a UML-like diagram of the relationship of the class and instance level.

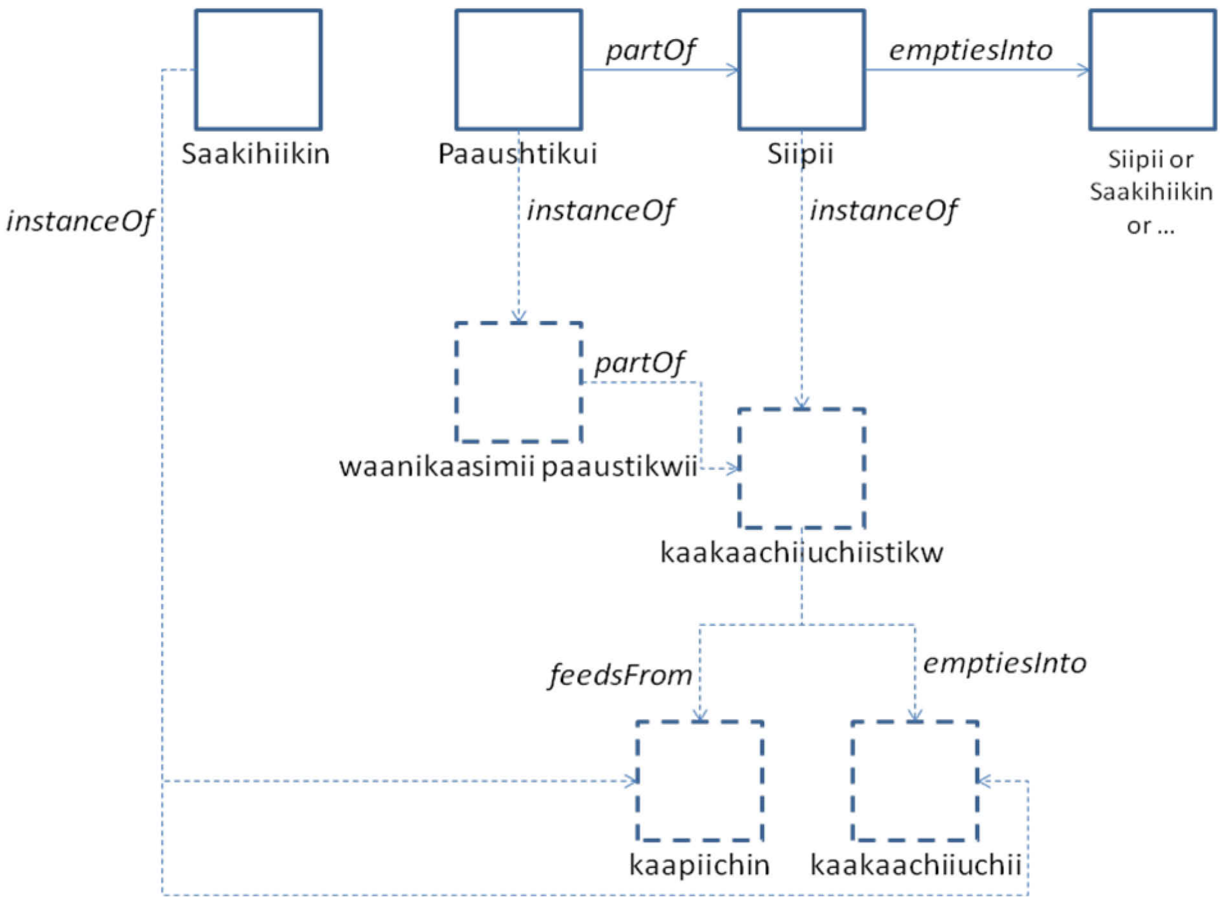


Figure 2.2: UML-like diagram of class and instance level. Dashed lines indicate instances or relationships at the instance level. Note that the instance level may contain more relationships than the class level, as is the case here with the instance kaakaachiiuchiistikw, which has the requisite emptiesInto relationship specified at the class level but also the feedsFrom relationship. This relationship was not specified at the class level because it is possible that a Siipii is fed by groundwater and not a water body.

3.3 Ontology Verification

Verification, or checking the content of the ontology with domain experts, is a key part of any ontology formalization, as the ontology modeler may have distorted the meaning of, or entirely missed, some categories (Mizen et al. 2005). Methods of verification are often not well documented. One fairly authoritative text states only that it must be found whether the domain experts believe the ontology "represents [their] own interpretation of the domain, task or application" (*ibid*., 11) but offers no further information. One can imagine ontology modelers simply sitting down to chat with hydrologists or chemists about the content of their ontology, but with Cree hunters and elders another method was needed.

My verification method was designed to clarify ontologies to research participants by approaching the subject through placenames. Cree participants were asked if certain placenames (instances) could be described by the Cree word into which they were classified (classes). Participants were only asked about instances on their traplines for which there was no general in the name, as names with a general would obviously fit in the category indicated by the general. Participants were only asked about instances on parts of their traplines with which they were familiar. Appendix F contains the interview guide used. This method is not intended to verify the predicate logic statements of the logical ontology, only the relationships of the conceptual ontology. I decided to verify the conceptual ontology to document where meaning had been lost or distorted through data gathering or formalization.

Four people, described in Table 2.5, were consulted for verification purposes. These people were chosen because of their authority with the Cree language or a section of Wemindji territory. I branched out somewhat from the sampling cohort used to develop the conceptual ontology to triangulate findings with other Cree familiar with the Wemindji territory. While the Tallyman of the *Maatuskaau* trapline and the Cree Language Expert were included in both sampling cohorts, the other two were not included in the original cohort.

Table 2.5: Verification interview participants.

Community Member	Age	Gender	Knowledgeable about
Local Government Worker	40	M	Inland Trapline
Tallyman: Maatuskaau	35	M	Maatuskaau, Paakumshumwaau
Tallyman: Coastal Trapline	35	M	Coastal Trapline
Cree Language Expert	60	F	Cree Language

4. Results

The results section first presents an overview of the conceptual Cree ontology of hydrography, first at the class level and then, for reasons discovered during the course of this research, delves into the instance level. The results of the formalization phase are presented, followed by the results of verification.

4.1 Conceptual Ontology of Cree Hydrography

4.1.1 Class Level

This section will briefly discuss the content of the conceptual ontology, though for the sake of brevity the main focus will be the differences between Cree and English hydrographic ontologies that most impact formalization. See Appendix B for the conceptual ontology.

The Cree categorize waterways using mainly the same criteria as the English language: size. In Cree, a large river is referred to as a **siipii**, a smaller river as a **shiipiish**, and a small stream a **shikaapshi**. An intermittent stream is called a **shikaapshish,** and is always very small and due to a rain event. Size is also important in categorizing still waterbodies. A lake is called **saakhihigan** in Cree, and a pond **saakhikanish**, or 'little lake.' However, the landscape context in which a waterbody exists can decide its definition. A watercourse in a swampy area would be called **mischaakushtikw** (swamp stream), and a still water body in a swampy area would be called **mischaakusaakihiikin** (swamp lake).

The Cree also denote part/whole relationships of waterbodies fairly different from English ones. To a Cree, the larger, navigable waterways (**siipii** and **shiipiish**) are punctuated by rapids, or **paausktikkui,** which are obstacles encountered when traveling. The sections between rapids are called **aanatoyach**. The Cree have a detailed terminology of parts of **saakhihigan**. One such part is a **yaatiwaakimii**, a bay-like sheltered area. Another, **aa upaach**, is where a **saakhihigan** (or **siipii** or **saakhihigan**) narrows. Still another is where a **saakhihigan** empties into (**aa uchihchich**) or feeds from (**aa saachiiuch**) a **siipii**. The Wemindji Cree designate a number of lake formations that are unlike anything in English. An **upikimaau** is a formation of two lakes connected by a narrow channel. When two lakes look like they are mirror images of each other they are called **iihthuwikimaauh**.

Features of this conceptual ontology made formalization challenging. The first is the lack of any clear superordinate classes such as watercourse or waterbody. This meant that relationships could not be specified for one superordinate class and inherited by subclasses, but that redundant relationships had to be specified. The second is the prevalence of synonymy, or the use of multiple terms to indicate the same category, in Cree landscape terminology. This is exemplified in the way Crees speak of a confluence, or where one **siipii** flows into another. Two Cree words were found for such a hydrographic formation. The general term, **aamaataamapiich** could be used to denote one feature emptying into another. The more specific word, **aamaataashtikwaayaach**, refers to a joining of rivers. Cree interview participants used either term depending on the trapline, and hence their family, though both terms 'point to' the same water form.

The third challenge to formalization concerns the diversity of categories among the Wemindji Cree, mainly along generational lines. This is exemplified in their terminology for points, or small peninsulas. One research participant explained that his generation, those in middle age now, used the terms **aanayapskaach** to describe a rocky point, and **aanayaach** to describe an earthen point. However, the Cree School Board's Cree Dictionary uses the term **naaskimikaau** to describe points of land. When asked about the meaning of this discrepancy, he replied that each generation has different words for features. Because meaning varied by trapline and by generation, terms in certain archival texts (Fireman 2005) were not included in the ontology unless they clearly had instances in Wemindji territory. For further challenges during the formalization phase, we turn our attention to the instance level.

4.1.2 Instance Level

Whereas previous studies on indigenous ontologies restricted their investigation to the class level, this study included the instance level. There were two findings of relevance.

First, a number of Cree categories appear to straddle the boundary between class and instance. A number of terms appear in the Fireman (2005) book as categories, but similar terms appear in MacKenzie's (1977) placenames dataset as placenames, or instances. For instance, the Cree have a term **pikutaauhkw**, which means a spring or rain fed lake in a hill with no streams entering or leaving. Interestingly, every such lake is named *pikutaauhkw*. Thus the class and the instance seem to be one. I call such classes hazy classes, as they seem to straddle the line between class and instance. In many cases, hazy classes have only one instance. Table 2.6 lists all such classes, their meaning, and the number of instances contained within the classes. The appearance of these lake formations in two Cree communities suggests they are fairly common among speakers of Cree. Classes like this question the sharp division in ontologies between the class and the instance, at least for the Cree (Agarwal 2005).

Table 2.6: Hazy classes.

Class	Meaning	Instances
aapiitukamaach	A lake parallel to another	1
pikutaauhkw	A lake or pond with no inlet or outlet, often in the hills	1
waawaachikimaau	A very windy lake	2
shiipaashtikw	A side channel of a river	1
wiinipaakw	James and Hudson Bay	1
mischaakusaakihiikin	A lake in a swampy area	11
awaashaashich	A small inlet in James Bay	10

Secondly, it was discovered that there was a Cree naming convention that could be modeled as a relationship at the instance level. Crees often name geographic features in pairs. When there is a pair of named features they are of the same class (e.g. both are **siipii**) and one is the diminutive of the other. The diminutive of the pair is indicated by adding an "-s" or "-sh" sound to the name of the larger one. *Paakumshumwaau*, a large lake in the Wemindji territory, has a smaller version named *Paakumshumwaash*. This relationship was described by one informant as a 'Big Brother – Little Brother' relationship. This find is significant, as it is a uniquely Cree relationship having relevance in the geospatial domain which has significance only at the instance level, not at the class level.

4.2 Logical Ontology

4.2.1 Design and Structure of Logical Ontology

The logical version of the Cree ontology has a total of 44 classes. No mid-level classes such as watercourse are present, as no Cree terms were found for such general classes. Using the bottom-up approach to formalization described in the methodology, only six classes subsumed other classes. The ontology is a total of two classes deep (excluding the class 'thing,' OWL's arbitrary top-level class).

The challenges to formalization outlined above were met with three design features of the ontology. The first was redundancy. Though some terms, such as the two for confluence, **aamaataamapiich** and **aamaataashtikwaayaach**, indicated the same geographic feature, both were included as separate classes, as they were used by people in different traplines. This was necessary to avoid enshrining either term as the definitive Cree term of that landscape feature. The second design feature was synonymy, where terms that were different words for the same class had a formal relationship indicating that. This was implemented by creating a relationship (object property in OWL terminology) called sameConcept and linking these two classes together. While it would have been preferable to follow OWL's standard equivalence protocol by declaring that each class was a subclass of the other, this would not have let me declare each class as belonging to a different trapline, as each class would have inherited the property of belonging to both traplines!

A third design feature in the logical ontology is what is called a 'value partition' (Horridge et al. 2004). A value partition is a class that has as subclasses values a certain attribute may have. Value partitions serve to define attributes of classes which are not relationships to other classes by providing a set of values that the attribute can take on. Value partitions were used to specify which generation of Cree speakers used a certain class of feature, any trapline specificity a feature type had, as well as substance meronyms – terms describing the material comprising certain features. A property called Has Material was used to define the substance meronym of hydrographic landforms, a property called hasTrapline was used to define trapline specificity of a feature type, and a property called Has Speaker was used to define the type of Cree speaker who uses a class of feature. Portages Around was used to define which features a portage may avoid. See Table 2.7 for a list of all relationships used to construct the logical ontology.

Table 2.7: All relationships used.

Relationship Type	Relationships	Source
Topological	Empties into, Feeds from, Contained by, Contains, Crosses, Next to	Hart et al. 2004
Topological	Connected to, Upstream of, Downstream of	Common Knowledge
Mereological	Part of, Has part, Has Material	Hart et al. 2004, Fellbaum 1998
Other	Big Brother/Little Brother, Has Speaker, Has Trapline, Same Concept As, Portages Around	Fieldwork

I found that formalizing the meaning of the hazy classes required no special consideration – they are formalized using mereotopological relationships just like the other classes. I also formalized the 'Big Brother – Little Brother' relationship. There was, however, some information I was not able to formalize.

4.2.2 Information Loss

It is important to document information loss during formalization (Mizen et al. 2005; Uschold and Gruninger 1996). There was one type of information lost in formalizing the Cree ontology: information concerning fuzzy geometric relationships such as relative size. For instance, I was not able to formalize the difference between **siipii** and **shiipiish**, classes analogous to river and creek. The difference is that **siipii** tends to be larger than **shiipiish**, but there was no clear way to formalize such a fuzzy distinction. The difficulty in formalizing relationships pertaining to relative size has been reported by others formalizing geospatial ontologies in Western contexts (Goodwin 2004). I also was unable to formalize specific geometric properties such as the changing of shape that would define the windiness of a windy lake, which is another problem common to geospatial ontologies (Roy and Stell 2002). See Appendix B for a detailed list of specific properties which could not be formalized.

4.3 Verification of Classes

I interviewed domain experts to verify the classes. Interview participants generally recognized the classes used and, when presented with instances of the classes, agreed that the instances had been classified correctly. Not every class was verified, but the verification we were able to achieve gives confidence to my method. Table 2.8 lists the classes verified.

The generational differences in hydrographic terminology were recognized during verification. One research participant explained that his generation, those in middle age now, did not use the term **naaskimikaau,** but had two terms to describe points of land. They used the term **aanayapskaach** to describe a rocky point, and **aanayaach** to describe an earthen point.

Table 2.8: Verification results.

Community Member	**Age (within 10 years)**	**Classes verified**	**Classes not recognized**	**Classes added**
Local Government Worker	40	**yaatiwaakimii**		
Tallyman: Maatuskaau	30	**aa upach** **aawaashich**	**naaskimikaau**	
Tallyman: Coastal Trapline	30	**waashaau** **mischaakusaakihiikin**	**naaskimikaau** **yaatiwaakimii**	**aanayapskaach** **aanayaach**

The results found during the verification phase suggest that Cree speakers familiar with different parts of Wemindji territory likely use different categories. The Coastal Trapline Tallyman did not recognize the term **yaatiwaakimii,** a bay on a lake; whereas the Local Government Worker was able to verify my interpretation of the term. This is likely because the Coastal Trapline Tallyman uses the coastal area of a trapline adjacent to James Bay, an area where there are no large lakes. The Local Government Worker uses a trapline far inland, where large lakes are common.

The verification of the relationships used to define each class did not go well. Participants were asked how they would say a mereotopological statement such as "the narrows is part of the lake" in Cree. The answer typically given was that they did not know how to translate that statement, or that there were many ways to say that in Cree. Consequently, the Cree language expert was consulted mainly to attempt a verification of the relationships, not the classes.

5. Discussion

The discussion section begins with the challenges to conceptualizing, formalizing, and verifying ontologies with indigenous groups, suggests a way to address the information loss pertaining to who uses each concept in the ontology, and then discusses the implications of this ontology for semantic interoperability.

5.1 Challenges

Working with indigenous hunters and elders as domain experts in an ontology investigation proved to be difficult but fruitful. Indigenous hunters and elders are not part of the sort of organizational structure Western domain experts would be in an ontology formalization project. The participation of indigenous hunters and elders in my investigation was strictly voluntary – they are neither employed by a superior common to us, nor paid as consultants by me, nor enrolled in classes in my university. This limits the amount of interaction, which in turn limits the depth of that interaction. Because ontology elicitation is lengthy, it also makes unavailable both the survey-based methods of elicitation (Mark and

Egenhofer 1995; Smith and Mark 1998) as well as spreadsheet based methods (Mizen et al. 2005) used with other groups of domain experts. My only option was to engage the domain experts in mutually interesting discussion about the Cree language, and through that come to an understanding of Cree geographic categories. My methods to do this were ethnographic and participatory methods often used in anthropology. These methods lack the precision of the survey or spreadsheet methods used to date, though they proved sufficiently precise to elicit geographical categories from Cree participants.

The bottom-up approach ensured that the structure of the ontology was not forced into a hierarchy simply for convenience. No Cree terms appropriate for the middle or top of a hierarchy were found so I did not attempt to create mid-level classes.

Mereological and topological relationships borrowed from a Western context were used to define the classes in the conceptual and logical ontology. Cree verbs could provide a window into Cree geospatial relationships, much as Cree nouns did for geospatial classes. For instance, the Cree verb *mischaakuhtin* is used to denote the act of a **siipii** (river) going through a **mischaakw** (muskeg or swamp). It is an example of a topological relationship, but one that only a river can have in relation to a swamp, not one that any feature can have to any other. A detailed study of mereotopological verbs in Cree would be quite interesting, and may lead to a uniquely Cree set of relationships in a hydrographic ontology.

Verifying an ontology with an indigenous group was found to be difficult due to generational differences, language barrier, computer literacy barrier, issues of trust, and, particularly with the Cree, barriers in terms of cultural modesty or deference. If, for instance, an informant was asked if a class was appropriate for a particular Cree placename, they might say yes even if another class was preferable, because the one posed to them was adequate. Cree territoriality posed another challenge. Elders and hunters would express that they were capable of describing only features and placenames on their own territories. They declined to respond to questions about features and placenames that were not located on their land. The verification method used here, based on questioning informants only about areas with which they are familiar, and approaching the meaning of terms through placenames, overcomes some of these barriers, though it might not result in information as detailed as the techno-centric methods used in Western contexts (e.g., see Mizen et al. 2005).

Whereas my method verified a number of the classes originally collected and found new ones during this phase, my verification was limited to classes and instances, and I was only able to verify the glossary definitions with Cree speakers (glossary definitions are contained in Table 2.2). It proved to be difficult to obtain feedback on the more formal definitions of the conceptual ontology (the kind of material found in Table 2.3), let alone the predicate logic statements of the logical ontology. When one informant was asked how to translate one of the mereological statements used to define a narrows, 'the narrows is part of the lake,' into Cree, she replied that there were many ways to translate it. This richness of the Cree language makes verifying the relationships used to define each class difficult. Cross-linguistic studies have found much the same to be true when comparing one Western language to another (Bowerman and Pederson 1992). It also means that the relationships used to define each class of the ontology are traditionally derived through the interpretation of the individual—the ontology formalizer—and are not scrutinized by local knowledge experts. Further enhancing the role of the local knowledge experts in the ontology formalization and verification process is an area of study that is challenging and called for. For any language or domain, whether indigenous or not, these enhancements will likely be adapted from ethnographic and qualitative methods. In my case, it will likely focus on Cree verbs. The verification stage of the methodology requires further development.

5.2 Namespaces

A set of terms upon which a certain group or subgroup of individuals draws is called a namespace and the need to indicate that a certain term belongs to a certain group is increasingly common on the Web. During the latter stages of the research, it became clear that some type of namespace scheme was called for when formalizing Cree hydrography. The meaning of features clearly varied by trapline and by generation. Value partitions were used to indicate to whom certain classes belonged to. As the Cree create more digital archives to record and preserve their culture, it is increasingly possible that they will wish to incorporate some Semantic Web components. If they do, then a system of user accounts could interface with this dimension of the ontology, and the categories most pertinent to whoever logs onto the system could be used.

An ontology should be sufficiently inclusive to move with the generations but also should preserve the cultural knowledge of the elders of the community. It is an open question as to whether every generation should be given equal representation in the ontology. Rundstrom (1995) demonstrates that indigenous epistemologies are fundamentally different from Western ones, and one difference concerns what one must do to be worthy of knowledge and why one should defer to those with knowledge. It is unclear how the classes used by elders would be given priority over the classes of the rest of the community, should that prove to be desirable. Nonetheless, should the need for namespaces prove to be the norm in indigenous societies, it will likely be important that communities within an indigenous society have some representation in an ontology that would represent their particular community, culture, and language on the Semantic Web.

5.3 Implications for Semantic Interoperability

The results of this investigation corroborate those of earlier investigations into geographic ontologies of indigenous peoples. Indigenous concepts do not translate easily into English ones (Mark and Turk 2003). This idea makes an ontological approach both valid and necessary for an inclusive semantic interoperability. However, complications could arise should semantically interoperable geospatial databases be constructed using Cree ontologies.

A difficulty lies in the data needed to adequately re-classify instances from English to Cree, which may not be part of the English database. For instance the **minishtik** and the **minishtikuchuun** are islands in still and moving water, respectively. The Canadian National Topographic Database (NTDB) does not record whether a given water body is flowing or not, and so there is no way to know from NTDB data whether a given island would be a **minishtik** or a **minishtikuchuun.** Simply having formal ontologies of GIS databases would prove insufficient to ensure semantic interoperability. Of course, attempting semantic interoperability between any two languages likely will produce this problem. Machine learning techniques and data mining would be required to adequately translate instances between ontologies.

My use of value partitions may prove to hinder semantic interoperability. Whereas my Cree ontology models Elders and Middle Aged people as subclasses of the AgeSpeakerValuePartition class, it is not likely that any other ontology would so model them! Most likely, they would be subclasses of a People or a CreePeople class. Additionally, classes in a value partition are not intended to have any instances (Horridge et al. 2004), while an ontology of people or Cree people would have instances. Methods of ensuring semantic interoperability when value partitions are involved should be the subject of future research.

The structure of top-level ontologies such as the Suggested Upper Merged Ontology (SUMO), whose primary division is between physical and abstract entities, may prove incompatible with the worldview of the Cree or other indigenous groups. Stea (2007) presents the example of the Yindjibarndi categories of **wundu**, a dry river bed, and **yinda**, a waterhole that does not dry up in the dry season. According to Yindjibarndi myth, the **wundu** were created by a serpent (a *warlu*) as he slithered across the land. These *warlu* protect and live in the **yinda**. An inexorable component of the definition of the categories **wundu** and **yinda** is spiritual. Designating **yinda** as subclasses of a physical category, as SUMO would do with these landforms, may strip them of their spiritual significance. We would do well to heed Rundstrom's (1995) profound advice that we tread lightly and sensitively where it concerns the ontologies of indigenous peoples.

6. Conclusion and Future Work

Ontology comprises a large portion of GIScience research and represents a significant component of the Geospatial Semantic Web. To create the Geospatial Semantic Web, ontologies of the geospatial domain must be created from multiple cultures. This paper represents the first attempt at formalizing a geospatial ontology in collaboration with and for an indigenous culture. It presents an iterative method for formalizing an ontology of hydrography with indigenous peoples and offers a number of improvements to the method. This work should aid future research in developing ontologies with indigenous societies.

In addition to confirming previous ontology work that indigenous geographical categories do not clearly map onto English language categories, this paper demonstrates the unique challenges to formalizing ontologies with indigenous groups. These include methodological challenges such as researching quickly evolving languages, issues of meaningful participation in what is often a highly technical exercise, importance of instance level relations, the inevitable loss of information, and a lack of intermediate concepts typically used to organize a class hierarchy.

Possible solutions to these problems are suggested and these solutions demonstrate unique aspects of a fully-developed Cree geospatial ontology. Value partitions clarify from which group of Cree speakers each geospatial class derives. This need for classes that defines the users of concepts stems, in part, from the quickly evolving nature of the Cree language, and offer an important design feature to ontologies from other indigenous languages if they also were evolving quickly. A second unique aspect concerned the relatively flat hierarchy of the ontology that was developed with Cree speakers. If no indigenous concepts function adequately as intermediate classes and if they are not identified by the Cree informants then none should be used.

Lastly, the Cree language appears to have a hazier boundary between class and instance than is traditionally assumed in ontology. This could be a consequence of a quickly evolving, plastic Cree language but also likely if only one instance of a class exists in a trapline. Future studies using more complete placenames data could be undertaken to explore and substantiate this finding.

Future work could also include the development of Cree spatial relationships. Except for the Big Brother/Little Brother relationship, those used here are all drawn from the topographic ontology developed at the UK Ordinance Survey, which relies on English language predicates. A methodology similar to the one we proposed here could be used with Cree verbs associated with the Cree categories in this ontology, such as *mischaakuhtin*, the act of a river going through a swampy area. The formalization of ontologies from the geographical conceptualizations of Cree people and indigenous peoples the world over, an important topic given the future trajectory of the Web towards semantic interoperability through the use of logical ontologies, is not yet complete.

Connecting Statement

In Chapter 2 of this thesis I formalized an ontology of Cree hydrography. While as yet incomplete, I made great progress towards developing a logical ontology of Cree hydrography. However, such a logical ontology is of no use to Cree people unless software can be created which uses the ontology.

In Chapter 3, the next chapter, I evaluate different ways of realizing the logical domain ontology developed in Chapter 2, or implementing it in software. Though ontologies have the potential to be useful to Cree people by formalizing aspects of their culture, the development of these ontologies into software applications will not happen automatically and is itself a worthy research topic.

Note that the thesis version of Chapter 3 contains an abridged methodology section to enhance readability. While details of the development of the conceptual and logical ontologies are relevant to Chapter 3 and will appear in the publication version, they do not appear in the thesis version. The reader is referred to Chapter 2 for information concerning the development of the ontologies.

Chapter 3: Realizing Ontologies with the Cree of Quebec

Abstract

The World Wide Web will be revolutionized by a new kind of metadata called ontologies, which are formal models of concepts computers can process, query, and reason with. Recent work in Geographic Information Science has revealed that language and culture strongly influence conceptual geographical categories, which is what ontologies of geography seek to model. It has been found that indigenous peoples possess unique geospatial categories, so it will be important to identify methods to include indigenous peoples on the Semantic Web. This paper represents the first attempt to realize an indigenous ontology, or implement it in software.

Research was conducted with the Cree of Quebec, Canada; Cree is the most spoken indigenous language in Canada. A conceptual geospatial ontology of hydrography was developed, refined, and tested with the Cree. A logical ontology was developed as well. The ontologies were then realized, or implemented in software. A decision was made to reveal the ontologies to the Cree users of the software due to their value for cultural preservation. Three approaches to realization were chosen to test the applicability of both the conceptual ontology, which is written in natural language, and the logical ontology, which is written in an artificial language, to the Cree context. These three approaches also test map based and attribute based methods of revealing the ontology to the Cree users. The three approaches were then evaluated with Cree users. Results show that the Cree users were most receptive to the realization of the conceptual ontology and less receptive to the realizations of the logical ontology. Unique aspects of a realized Cree ontology of hydrography are then discussed.

1. Introduction

The dream of the World Wide Web is, and has always been, sharing of information (Hanseth and Monteiro, forthcoming). However, the sheer volume of information on the Web, more than 11.5 billion pages in 2005 (Gulli and Signorini 2005), demands the use of computers to index, search, and retrieve information on the Web. Yet, the proliferation of information on the Web has led to what has been called the 'tower of Babel' problem (Smith and Mark 2003) – the multitude of terminologies across the Web makes it very difficult for computers to effectively index, search, and retrieve information.

In response to this problem, the World Wide Web Consortium (W3C) has envisioned the Semantic Web (Berners-Lee and Hendler 2001). Rather than standardize the terminology found on the Web, the strategy of the Semantic Web is to create computer-processable models of the concepts embedded in the terms found on Web sites and in databases. The Semantic Web should allow individuals to effectively search and manipulate the contents of the Web using computers employing these models, called ontologies, as a type of metadata, or data about data.

This chapter concerns the place of indigenous peoples on the Semantic Web. Indigenous peoples have been a significant portion of the GIS and Web user base (Poole 1995; Niezen 2004). Like many, indigenous peoples have used the medium of the Web to communicate their culture both within their communities and to the rest of the world, and have employed Web-based geospatial technologies to assist in this process (Niezen 2004; Junker and Luchian 2007; Denton 2006). Empirical research has shown that indigenous peoples often have geospatial concepts that do not easily translate into Western ones (Mark and Turk 2003). Yet, no one has examined how an ontology of geospatial concepts from an indigenous culture could be realized, that is, implemented in software. This paper, the first to do so, reports on the results of realizing an ontology of hydrography with the Cree of Canada, whose language is the most spoken indigenous language in Canada (Statistics Canada 2008).

After reviewing the relevant literature, the paper describes the methodology, which first developed a conceptual ontology of hydrography in partnership with the Cree, and then formalized a logical Cree ontology of hydrography. A conceptual ontology is a set of classes (i.e., categories of concepts); properties, usually modeled as relationships; instances, or members of classes; and rules that define a domain of knowledge in an unambiguous, human readable manner. A logical ontology encodes these classes, properties, and rules in a digital language computers can process (Uschold and Gruninger 1996). The ontologies were then realized in an application which combines a digital gazetteer and oral history. A digital gazetteer is a database of placenames, feature types, and spatial footprints (Hill 2000). For the Cree, placenames are intimately bound up with stories, and so the application included audio recordings of elders recounting stories about the places in the gazetteer. The application realizes the ontology in an explicit manner, that is, as content the user interacts with. This is to contrast with the manner in which ontologies have mainly been realized to date, as part of an application's database backend to enable semantic interoperability.

It is difficult to determine how useful native peoples will find realized ontologies. To assess this, three different approaches to ontology realization in the application were developed. Each realized the ontology differently: (1) using the conceptual ontology as the feature type catalog of the gazetteer; (2) controlling the attribute output when a user queries the data; and (3) controlling the response of an interactive map to user input. The approaches were evaluated with Cree users. Whereas it was found that the first approach was of interest to the Cree users, the other two approaches held less utility. The implications of these findings are then discussed. I conclude that ontologies are likely valuable components of geospatial applications developed for indigenous peoples. Conceptual ontologies possess sufficient specificity to enhance geospatial applications. Logical ontologies are unnecessary, at least as of now, though new, more effective approaches to realizing logical ontologies could be developed.

2. Theoretical Background

The following sections explain how ontology research proposes to construct models of concepts and implement these models in a computer readable form. The coming ubiquitous position of ontologies on the Web is then explained.

2.1 Ontology in GIScience

Ontology in its original philosophical sense referred to a study of being, and began with Aristotle's work 'Categories' in 340 B.C. (Mann 2000). Ontology approaches the study of reality by breaking it down into categories, properties, and rules (Audi 1995). Geospatial ontologies are ontologies of objects that exist at geographic scales, such as mountains, rivers, and nations. Geographic objects have unique properties such as vague boundaries, and are characterized by unique relations, primarily topology and mereology (the latter referring to parts and wholes, see Smith 1996).

Empirical ontology research in GIScience highlights that geographic categories and spatial relationships are not universal to all people, but instead are socially constructed (Mark and Egenhofer 1995; Smith and Mark 2003; Mark and Turk 2003). The geographical categories of certain indigenous groups have been found to have no clear equivalents in western cultures (Mark and Turk 2003), suggesting the importance of conducting ontology research in a plurality of cultures.

In addition to categories, ontologists are interested in the defining properties and relationships of classes. Mark and Egenhofer (1995) examined the topological relationships (e.g. crosses, disjoint, connected to) used when English and Spanish speakers were describing pictures of a road going through a park. The topological relationships used varied by language.

Geospatial categories and relationships vary by culture. As I said in Chapter 2, "different cultures cut the world at different joints" (p. 14).

Information science, and its associated discipline GIScience, has taken this ontological approach from philosophy in the hopes that frameworks may be created to unify these pluralities of digital information. In information science, an ontology is not a theory of reality but a "logical theory which gives an explicit and partial formalization of a conceptualization" (Guarino and Giaretta, 1995, p. 32). Ontologies in information science codify the concepts latent in databases, software objects, or users of these digital artifacts. They are not primarily concerned with the relationship of these concepts to reality.

Ontologies have a range of formality. Uschold and Gruninger (1996) noted that artificial languages have traditionally characterized what they call formal ontologies, referred to in this chapter and in much of the geospatial literature as logical ontologies (Mizen et al. 2005). This artificial language is usually designed for coding concepts and relationships, as is the case with the World Wide Web Consortium's Web Ontology Language (OWL, McGuinness and van Harmelen 2004), though non-digital artificial languages such as first order predicate logic also have been used for this purpose. Representing an ontology in digital form allows a computer to use the information represented in the ontology in processing, querying, and reasoning.

A logical ontology specifies meaning using an artificial language; a conceptual ontology specifies meaning using a natural language (Uschold and Gruninger 1996). Conceptual ontologies often inform the design of logical ontologies. The effort required to create a logical ontology is higher than the effort to create a conceptual one, so it is generally best practice to formalize as little as possible (Goodwin 2005), a lesson important for indigenous organizations and any other organization that possesses limited access to money and technical expertise.

2.2 Realization of Ontologies

To use a logical or conceptual ontology on the Web, one needs to implement, that is, realize, that ontology in an information system, meaning that an application must be developed of which the ontology will be a component. Realization thus becomes a component of a software development methodology. After the application itself is decided upon, the purpose, or role, of the ontology in the software, and scope of the ontology, or subject matter and amount of detail, must be established (Uschold and Gruninger 1996; Dolbear et al. 2005). Ontology realization should begin with a conceptual ontology, then move on to a logical ontology in a process called formalization, if a logical ontology is necessary for the application (Uschold and Gruninger 1996). The process of formalization may be aided by Graphical User Interface (GUI) tools such as Protégé (Horridge et al.

2004) which allow users to create logical ontologies without directly interacting with the code. There must then be some kind of evaluation of the ontology at both the conceptual level, which would be focused on how well the content of the ontology captures the knowledge it intends to, and the logical level, which would be focused on how logically consistent the ontology is. There are a number of software components such as reasoning engines, query processers, and instance stores specifically designed to use a logical ontology in an application (RACER Systems 2007). Not all ontology realizations require a logical ontology. A conceptual ontology, for instance, may be used to restrict data entry for an attribute to a specific list of agreed-upon values.

The main aim of ontology realization has been semantic interoperability, which ensures that heterogeneous meanings of terms within the information systems (as opposed to heterogeneous structure or syntax of the information systems) do not hinder the exchange of data between systems (Agarwal 2005). If a logical ontology (or system of logical ontologies) is used the databases need not adopt the same terminology to effectively share data.

The pursuit of semantic interoperability has guided ideas about realization of ontologies in GIScience. Fonseca et al. (2000) realized an ontology of urban features in an information system designed to integrate geospatial data about urban features from multiple sources, each of which contains its own conceptualization of the features. Broderic (2004) realized an ontology of geology in a system to be shared by field geologists to automatically integrate their disparate field data into a single database. Fonseca et al. (2002) realized another system, this time using ontologies of land cover types to integrate data across scales. Common to all of these systems is the goal of semantic interoperability without standardization of databases.

The Semantic Web Project of the World Wide Web Consortium (W3C) seeks nothing less than to achieve universal semantic interoperability across the Internet (Berners-Lee and Hendler 2001). GIScience has adopted this aim of universal semantic interoperability (Egenhofer 2002), which has motivated most of the research on ontologies in GIScience. Significant progress towards this goal has been made. The Open GIS Consortium has successfully prototyped a Geospatial Semantic Web system that serves as a proof of concept for a modular architecture of ontologies for universal semantic interoperability (Kolas et al. 2005). Included in this architecture of ontologies is an ontology of geospatial data and an ontology of the types of geographic features encoded in the geospatial data.

These ways of realizing ontologies are opaque to the user – much if not all of the ontology is embedded in the database or software objects of the information system and the users do not interact with the ontology directly, or at all. However, very recent work in GIScience by Scharl et al. (2007) realizes ontologies in a transparent manner as information landscapes and concept graphs. Clicking on a concept in the graph or landscape sends a query to retrieve content related to the concept, and so the ontology is not part of the backend of the system, but the front-end.

The emergent Geospatial Semantic Web likely will realize ontologies in a modular manner hidden from the user in applications intended to allow semantic interoperability. Ontologies also will be realized in ways transparent to the user to enable searches based on concepts instead of keywords. It is important that ontologies be realized with indigenous peoples' categories, as they are a significant minority throughout the world with unique conceptualizations of the world and of geospatial categories (Niezen 2004; Mark and Turk 2003) and they should not be blocked from the Geospatial Semantic Web.

2.3 Use of GIS by Indigenous Peoples

As the Internet has become ubiquitous, indigenous peoples have endeavoured to construct what Niezen (2004) calls a 'virtual selfhood' – a digital representation of indigenous identity. Language preservation is often a component of this effort, and a number of Websites are dedicated to preserving indigenous languages by offering online services such as dictionaries, language lessons, and chat rooms in indigenous languages (Junker and Luchian 2007). In addition to language preservation, indigenous peoples have long used GIS for securing land rights and land management (Poole 1995; Harmsworth 1998). It is hardly surprising that GIS comprises part of creating a virtual selfhood, often serving to geo-locate placenames, photographs, or multimedia representations of traditional knowledge (Denton 2006; Corbett et al. 2008; Elliott 2008).

Questions have been raised about incompatibilities of the ontological commitments of the data model of GIS and those of traditional knowledge (Rundstrom 1993, 1995). Numerous counterexamples of indigenous organizations suggest that GIS is used to resist colonization and cultural loss (Poole 1995, Chapin 2006, Denton 2006). In an effort to resolve this tension, there has been extensive investigation into how the traditional knowledge of indigenous peoples can be encoded in a GIS.

Poole's (1995) survey of indigenous mapping and GIS applications was among the first documentation of indigenous organizations seeking to encode their knowledge in a GIS. Particularly pertinent is the GIS developed jointly by the Ditidaht Band Council and the Government of British Columbia. Rather than devise a scheme of attribute codes to digitize all aspects of the knowledge of the hunters and elders of the Band, they utilized a data model that linked areas on a map to audio or video accounts about the significance of that area told by elders. Though the clips are extracted from their original context of oral history (i.e., each story is neither preceded nor followed by a story the elder would have chosen), they nonetheless retain more of their cultural context than had the stories been reduced to text attribute codes. Most efforts at encoding indigenous traditional knowledge into GIS have followed this multimedia model, and with good reason, as Poole (1995) noted that it was fairly successful.

Harmsworth (1998) integrated into this model a system of user accounts and access limitations that respected Maori values of sensitivity to information. Not only was access to sensitive information restricted to certain family groups, but some information was deemed so sensitive that it was not explicitly stored in the GIS. In some cases information was limited to specifying a certain community member who was knowledgeable about an area.

More recent implementations of GIS with indigenous peoples have included Web 2.0 practices such as tagging digital multimedia resources and mashups (Verran et al. 2007; Corbett et al. 2008). Elliott (2008) has developed a system with the Halfway River First Nation in northern Canada which enables Halfway River First Nation users to easily enter georeferenced multimedia clips. Yet there have currently been no realizations of ontologies in these systems or any like them.

Some proposals for realizing ontologies with indigenous peoples have been published, though not under the banner of ontology. Laituri and Harvey (1995) proposed to create a conceptual ontology of Maori ethnobotanical categories and realize that ontology in a GIS. Calamia (1999) had a similar proposal to create GIS layers of coral reef habitat types based on those of indigenous Hawaiian categories. Neither of these proposals resulted in actual applications.

I argue that the realization of geospatial ontologies of indigenous concepts has the potential to help indigenous organizations construct a virtual selfhood. It follows the trajectory of engagement of GIS use among indigenous communities. As the Semantic Web becomes a reality, realization of ontologies with indigenous peoples will ensure that indigenous communities will be able to use Semantic Web technologies in the construction of virtual selfhoods.

3. Methodology

Investigation of the potential to realize indigenous geospatial ontologies was conducted in cooperation with the Cree of Wemindji Quebec. The reader is referred to Chapter 1 for a detailed description of the Cree of Wemindji, Quebec.

I employed a three stage iterative methodology to test realizations of a Cree ontology. The first stage consisted of formalizing a Cree geospatial ontology, which in turn had three sub-stages: conceptual ontology development, formal ontology development, and ontology verification. The second stage of the methodology consisted of realizing the ontology, which entailed constructing an application ontology. The third stage consisted of evaluating the realized ontology with Cree users, which in turn had two sub-stages, one in Wemindji and one in Montreal. All stages contained iterative feedback loops, which allowed Cree multiple opportunities for comment. Figure 3.1 depicts the methodology graphically.

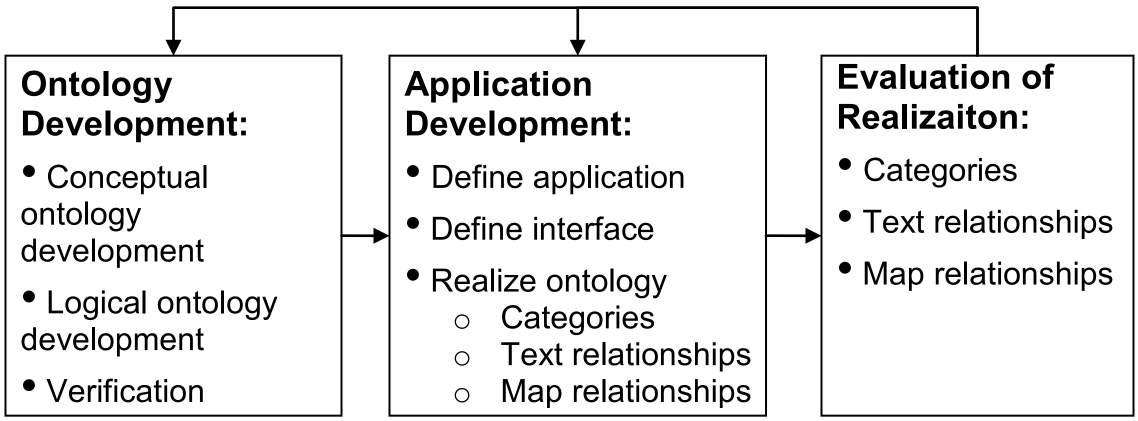


Figure 3.1: Methodology of geospatial ontology realization with the Wemindji Cree.

I decided to focus on a specific domain, hydrography. Hydrography is an appropriate domain to focus on for two reasons. First, it is very important to the Cree. In one sample of Cree placenames, nearly 80 percent of the names pertain to hydrographic features (MacKenzie 1977) and waterbodies comprise an essential component of the Wemindji transportation network. Second, hydrography is interesting from an ontological point of view. Hydrographic features are rich in part-whole relationships and connection-containment relationships, so the extensive GIScience theory on mereotopology is applicable to the domain of hydrography. Each stage of the methodology will now be discussed in detail.

3.1 Ontology Development

The overall design of the ontology development phase of my methodology is based on previous work (Uschold and Gruninger 1996; Mizen et al. 2005), which emphasized that terms to be included in the ontology should first be captured into a conceptual ontology in a natural language and second encoded in an artificial language designed to represent ontologies. When an ontology is encoded into such an articifial language it is called a logical ontology. The logical ontology must then be evaluated or verified to ensure the knowledge is formalized correctly and appropriately (Uschold and Gruninger 1996). The ontology formalization stage of this investigation is described in great detail in Chapter 2 of this thesis, and the reader is referred there should they desire to know more.

3.2 Application Development

This section describes the development of the software in which the ontology is realized. It is divided into two parts. The first describes how the ontology was realized in software. The second section describes the technical details of the software.

3.2.1 Ontology Realization

Ontology realization refers to the implementation of the ontology in software. It involved the following four steps: build a digital gazetteer; build an initial interface of the gazetteer; develop the database, which included a set of recordings of Cree elders taken from Wemindji's archives, a set of photographs of Cree categories of hydrographic features, and three sets of placenames data: the first collected by linguist Margurite Mackenzie (1977), the second by a team of undergraduates from McGill University working under the supervision of anthropologist Colin Scott (Berryman et al. 2004), and the third by myself during my fieldwork; and realize the ontology as particular aspects of the information in the database or the functionality of the interface.

I decided to realize the ontology within a digital gazetteer. A digital gazetteer is defined as a database of placenames, feature types, and spatial footprints (Hill 2000). It seemed appropriate to build a gazetteer due to the presence in Wemindji of suitable data (e.g. the placenames collected by MacKenzie (1977) and Berryman et al. (2004)) and the interest of the Cree Cultural Institute in digital gazetteers. Cree interview participants during the ontology formalization phase were capable map readers. Often they had annotated their maps with their knowledge of their territory. This shows familiarity with maps, so I opted for a map-based interface coupled with search functionality. When a user clicks on the map, attributes of placenames are returned. The basic set of attributes includes the place's Cree name in Roman orthography (table field Cree Name), the name's English translation (table field English Translation), additional information about the place (table field More Information), the Cree feature type (table field Cree Feature Type), and links to stories involving the place (table field Stories). Feature types are linked to photographs of examples I acquired during fieldwork and English language explanations of their meaning. Stories are linked to their oral equivalent, stored in .mp3 files acquired from Wemindji's archives. The user may also search for names using a search box, which searches across all the attribute fields.

The gazetteer is accessed with a Web browser. The user is first presented with a basic map of Wemindji territory customized with a search tool and a tool that allows a user to zoom to a particular trapline. Figure 3.2 shows the initial interface. Figures 3.3 and 3.4 show simple interface interaction. Figure 3.3 shows the interface zoomed to a particular trapline. Figure 3.4 demonstrates the search functionality. Users may query the map by clicking the map or by typing a search term into the search box. When a user queries the map, an attribute table of the named places is returned. Figure 3.5 shows an attribute table.

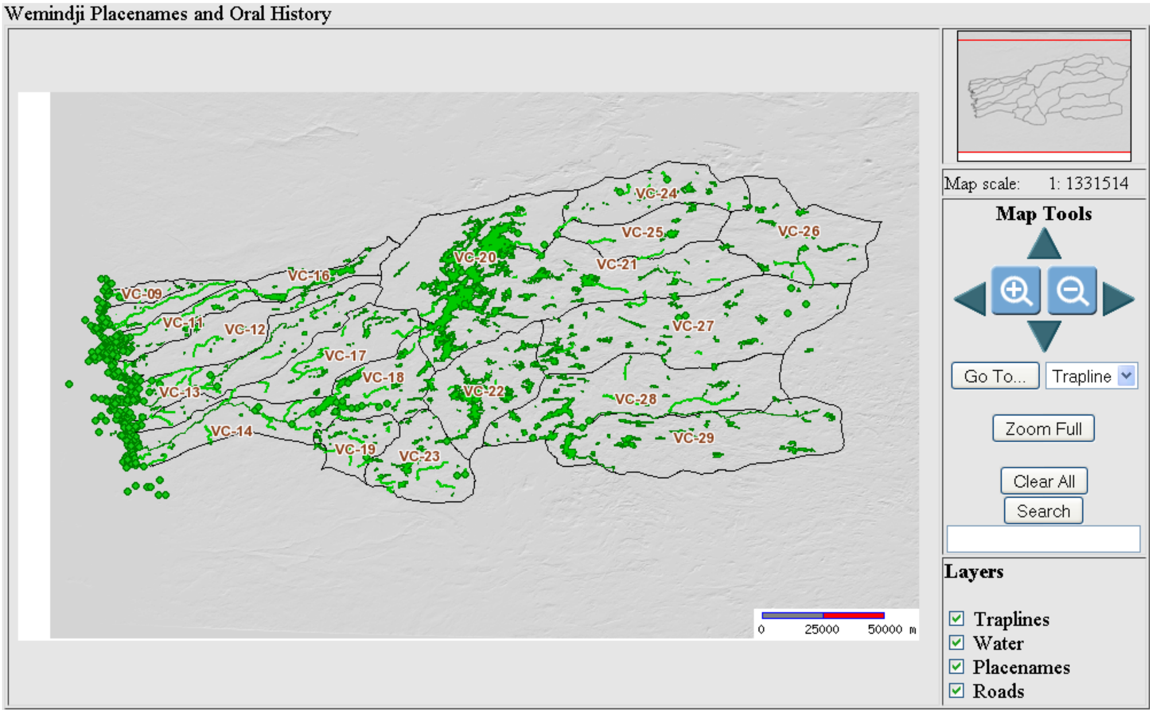


Figure 3.2: Initial screen showing the Wemindji Cree territory (annotations are trapline designations), an inset map (upper right), the map tools used to browse the map, the search box, and the layers (only placenames are visible at this scale). Green points, lines, and areas designate placenames.

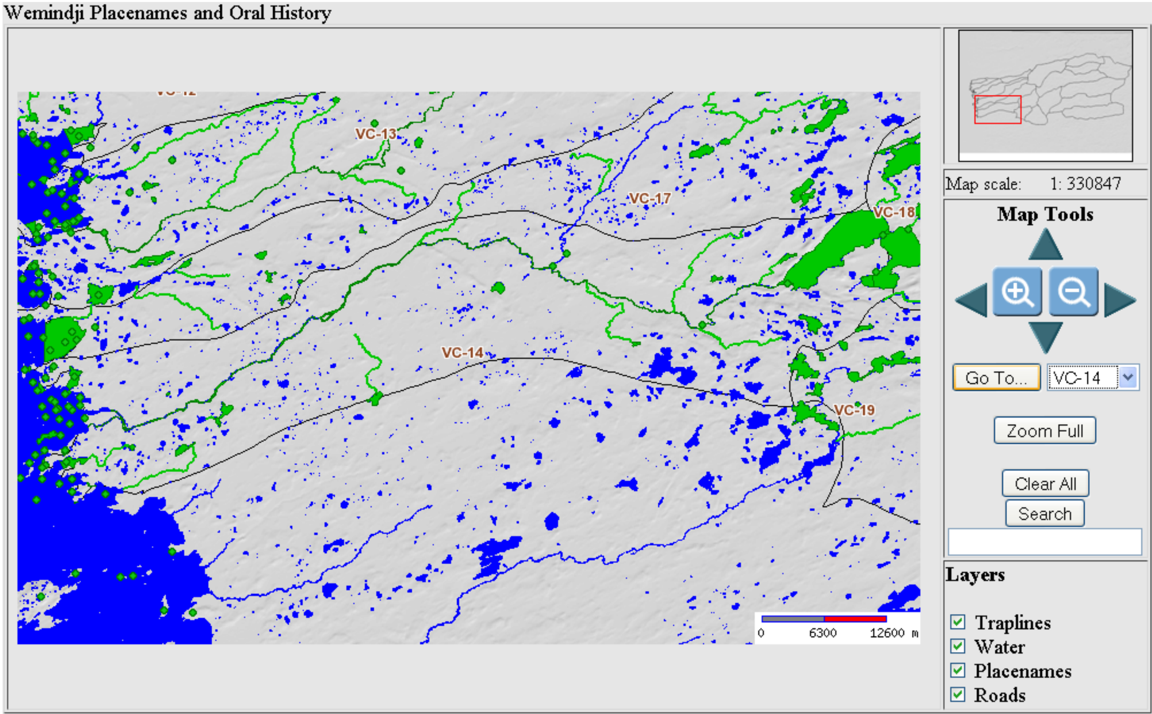


Figure 3.3: A screenshot after zooming to a trapline (either via “Go To” or magnifying glass). At this scale, the unnamed water (blue) has become visible.

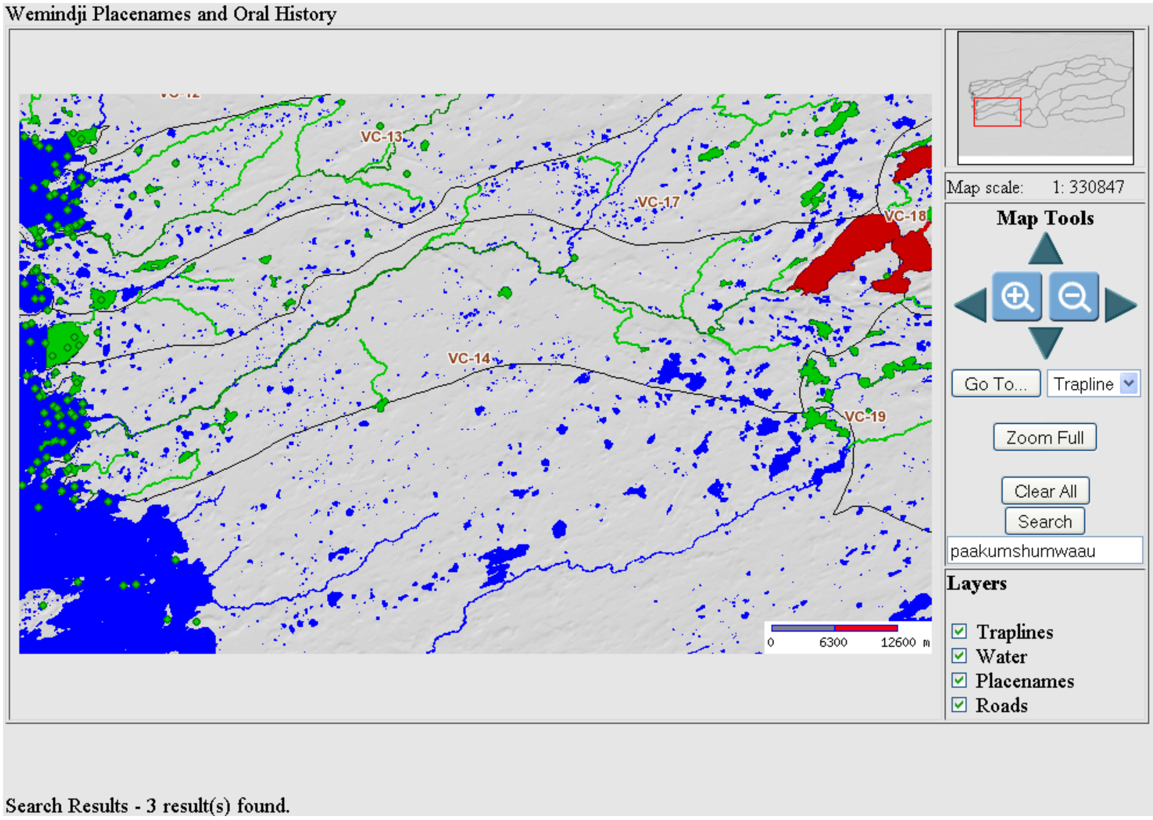


Figure 3.4: Search Function (search result for 'paakumshumwaau' in red).

Cree Name	Cree Feature Type	English Translation	More Information	Stories	Related Stories
paakamisimuwaas	saakihiikin	Little Old Factory lake	Lac McNab	About paakumshumwaaush and paakumshumwaau. by Sinclair Matches Chiinistumchiaschuu story with the waatinaakan. by Sinclair Matches	LittleBrotherOf paakumisimuwaaw - Why Paakumshumwaau got its name. by Sinclair Matches LittleBrotherOf paakumisimuwaaw - About paakumshumwaaush and paakumshumwaau. by Sinclair Matches LittleBrotherOf paakumisimuwaaw - winter near old factory lake. by Sinclair Matches LittleBrotherOf paakumisimuwaaw - Atush at Old Factory by Sinclair Matches
paakumisimuwaaw	saakihiikin	...	.	Why Paakumshumwaau got its name. by Sinclair Matches About paakumshumwaaush and paakumshumwaau. by Sinclair Matches winter near old factory lake. by Sinclair Matches Atush at Old Factory by Sinclair Matches	BigBrotherOf paakamisimuwaas - About paakumshumwaaush and paakumshumwaau. by Sinclair Matches BigBrotherOf paakamisimuwaas - Chiinistumchiaschuu story with the waatinaakan. by Sinclair Matches
wiyaaschuunis	shiipiish	little ... current	.	Describes how the river flows down to paakumshumwaau. by Sinclair Matches story with an atush. by Sinclair Matches Atush at Old Factory by Sinclair Matches	LittleBrotherOf wiyaaschuun - Chiinistumchiaschuu story with the waatinaakan. by Sinclair Matches

Figure 3.5: An attribute table from interface 2 or 3, which shows the stories related ontologically to those chosen by the user query. Interface 1 displays the same results table minus the related stories column.

Whereas earlier Semantic Web applications hid the ontology from the users within the code or database of the application, some newer applications reveal the ontology to the user as a form of content (Scharl et al. 2007, Jasper and Uschold 1999). Because this latter use of ontologies seems more immediately applicable to indigenous efforts to create a 'Virtual Selfhood' (Niezen 2004), I chose to concentrate on realizations that revealed the ontology to the users instead of hiding it to enable semantic interoperability.

I chose to realize the ontology in three ways: as a feature type catalog for the placenames, as a type of attribute output showing stories of related places, and as a control on the map's response to user queries. The first realization requires only a conceptual ontology, while the second two require a logical ontology. Also, the three realizations impact both the attribute components if the gazetteer as well as the map components. Evaluating all three realizations will give some indication as to whether a logical ontology, which is more difficult to develop than a conceptual one, will give return on the resources required to develop it. Evaluating all three realizations will also give some indication as to which components of the gazetteer (database, attributes, map) Cree users are most receptive to realizing ontologies in. The realizations themselves will now be discussed in greater detail, as will the reasons for these three realizations.

The first realization of the ontology is as a catalog of Cree feature types. Each placename in a digital gazetteer is typically categorized according to some catalog of feature types (Hill 2000; Randall 2001). This is the simplest way to realize an ontology in a gazetteer, and this type of realization requires only a conceptual ontology. The Cree feature type of each placename was included in the list of attributes returned as the result of a query. Users are able to click on the feature types to obtain an English definition and a photo of the type of feature, where available. Figure 3.6 shows the result of clicking on the feature types.

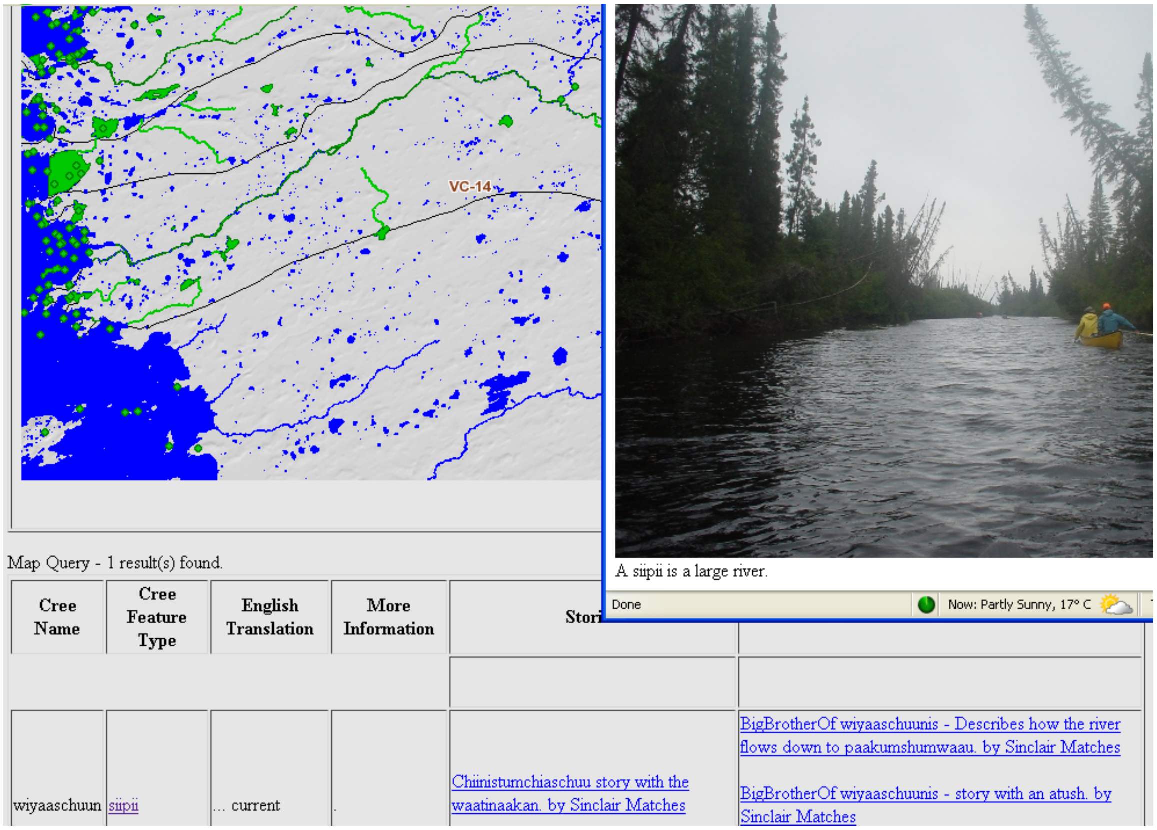


Figure 3.6: Results of clicking on the Cree feature type in the attribute table, showing an example and an English explanation of the feature type.

The second realization allows the users to interact with the relationships of the logical ontology directly as a type of attribute output. The placenames of Wemindji exhibit ample topological and mereological relationships. Attaching a story to a place that it explicitly mentions may neglect significance the story has to related places. A story about an **aanayach** (a type of peninsula), for instance, may have significance for the **saakhikin** (lake) that it is connected to. To capture this significance, included with the attribute table returned from a query is a list of relationships each place has to other places (Table 3.2 contains a list of relationships used). Each relationship is a hyperlink to a story associated with the related place. All stories associated with all related places are included. Figure 3.5 shows the attribute table returned by this realization.

The third realization uses the logical ontology to configure the map to show features that were parts of those features the user queries, as well as those features of which the queried features were a part. Because of the many parts of some water bodies (e.g. bays, narrows, islands, rapids), it became apparent that some way of showing part-whole relations on the map may facilitate map-reading.

Using the digital gazetteer platform, I embedded these realizations differently in three slightly different interfaces. Acquainting research participants with the basic interface, which included taking time to listen to many stories, tended to take an average of 45 minutes. It quickly became apparent that I would only have time to show one or two interfaces to each research participant, so embedding each realization into a separate interface would likely mean that the user would not see all three realizations. Therefore a cumulative embedding strategy with three interfaces was employed, where the first realization was embedded in all three, the second realization in two interfaces, and the third realization in only one. This strategy allowed me to remove some realizations from the user if time allowed, or simply to show all the realizations if time did not. Table 3.1 contains an overview of the different interfaces and the realizations each one embodies. Figures 3.7, 3.8, and 3.9 show the same area in interfaces 1, 2, and 3.

Table 3.1: Interfaces, their realizations, and their ontology requirements.

Interface #	Realization Types	Ontology Requirements
1	• Attribute Shows Feature Type Catalog	• Conceptual
2	• Attribute Shows Feature Type Catalog • Attribute Shows Stories of Related Places	• Logical
3	• Attribute Shows Feature Type Catalog • Attribute Shows Stories of Related Places • Map Shows Part/Whole Relationships	• Logical

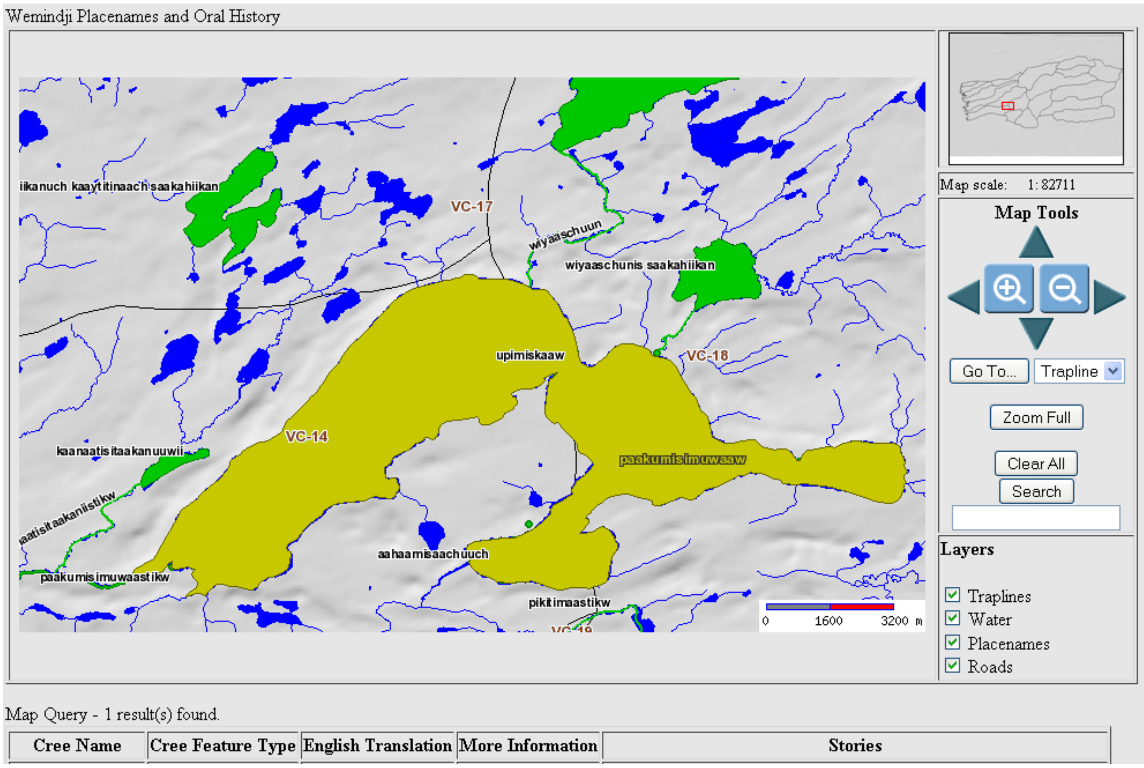


Figure 3.7: Interface 1 after zooming in to Paakumshumwaau (the large lake in the middle of the map) and selecting it. Note the presence of the Cree Feature Type column and lack of the Related Stories column.

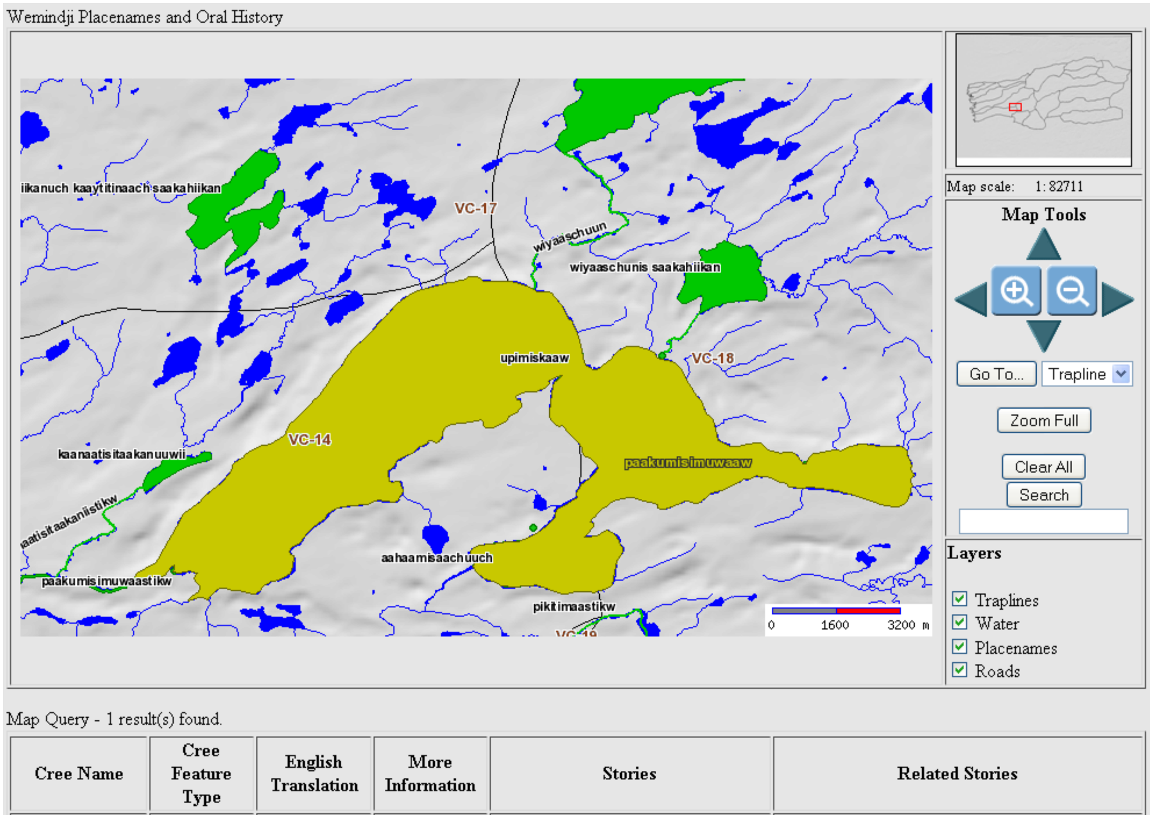


Figure 3.8: Interface 2 after zooming in to Paakumshumwaau (the large lake in the middle of the map) and selecting it. Note the presence of the Cree Feature Type and Related Stories columns.

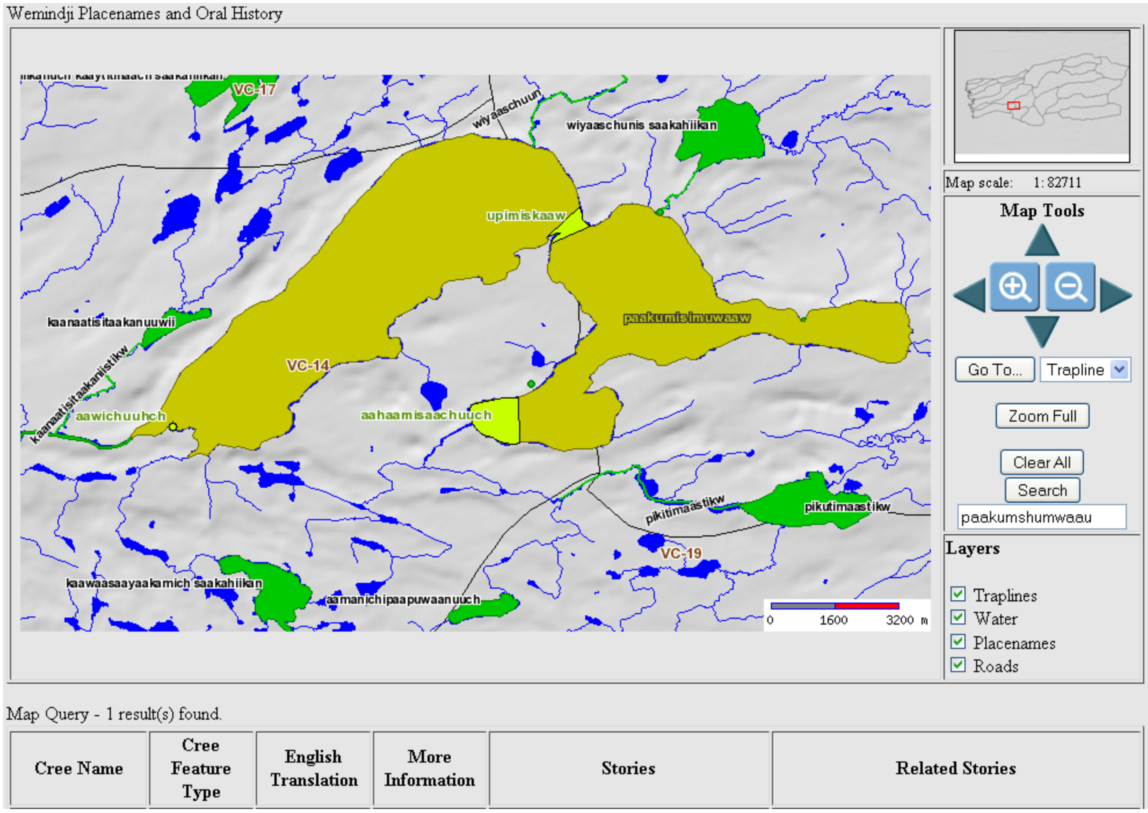


Figure 3.9: Interface 3 after zooming in to Paakumshumwaau (the large lake in the middle of the map) and selecting it. the large lake in the middle of the map. Note the presence of the Cree Feature Type and Related Stories columns as well as the parts of Paakumshumwaau.

3.2.2 Technical Details of Application

Building the application requires an Internet map server and map engine, a user interface development environment, a database management system to store the attributes and multimedia files, and a web server. Open source software was chosen due to its flexibility and low cost. I used the University of Minnesota's Mapserver software (Lime 2008), PHP-Mapscript to build the interface (McKenna 2008), the MySQL database engine (MySQL AB 2008), and the Apache Web server (Apache 2008). The logical ontology was exported from Protégé as a set of RDF triples and loaded into MySQL as a data table. All spatial data and their attributes, including the Cree feature type, are stored as ESRI shapefiles to facilitate relatively easy maintenance.

The application is currently running locally on a computer in a museum in Wemindji and available only within the community. It is designed to be installed on any server and access given to anyone in Wemindji through the Internet (the site allows for password protection). The system was also built to be maintainable with ArcGIS, the software Wemindji's GIS technician is trained in. See Appendix D for the database schema. For the PHP code, see (Wellen 2008).

3.3 Evaluation of the Three Realizations

I tested the three different versions of the digital gazetteer with two groups of Cree users. The objective was to ascertain to which realizations of the ontology Cree users were receptive to. The testing procedure was simply to let Cree users interact with the three versions of the interface (and hence the three realizations of the ontology) and give verbal feedback. I also asked specific questions about what they thought of how the ontology was realized in each interface. Figure 3.10 shows the structure of the evaluation. Appendix F contains the interview guide for evaluating the realizations.

To guide people through the three interfaces, I used the technique of chauffeuring, where an experienced computer user 'drives' the computer for less experienced users, who interact with the computer via the chauffeur (Haklay and Tobon 2003). The testing phase of the application with the different interfaces was divided into two sub-stages: one in Wemindji and one in Montreal at the Cree Teachers' Symposium of 2007. Assessment was qualitative. Research participants' answers to questions regarding the interface were written down by myself after each interview. No quantitative analysis of the interview results was attempted, as none was needed.

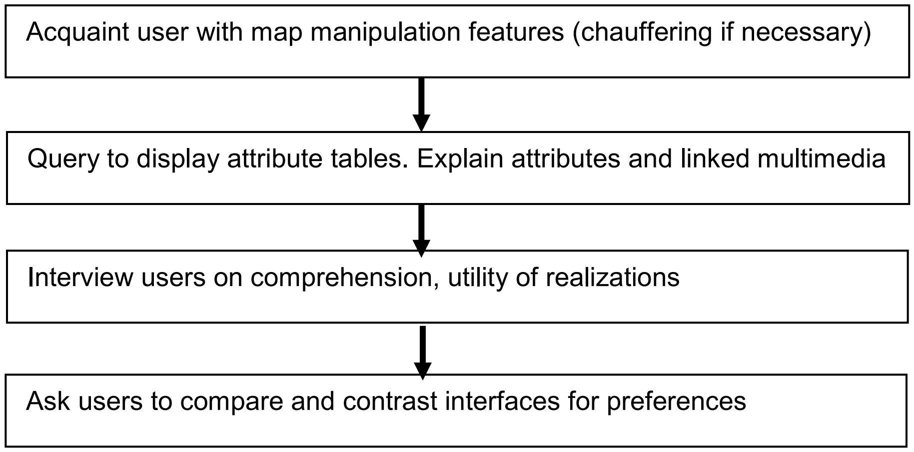


Figure 3.10: Evaluation methodology.

Though I encountered many of the same challenges during application testing that I had during conceptual ontology development (including cultural reticence and deference, different communication styles between myself and my research participants, and low computer literacy of my research participants) these were significantly lessened when interacting with the application. Many residents of Wemindji have Internet access and so were comfortable using a Web browser. Also, when my intent became clear to my research participants and when my research participants themselves were presented with oral history and digital placename maps they became much less reticent.

3.3.1 Wemindji Testing

Application realization testing in Wemindji involved a total of nine Wemindji Cree residents. These research participants were chosen to represent full time hunters as well as town workers, and involved many of the same people consulted during the ontology development phase. Table 3.2 contains a list of those consulted for evaluation purposes.

Evaluation usually involved visiting a Wemindji resident, bringing the application on a laptop, explaining the use of the application, letting him/her use it if he/she was comfortable with it and acting as a chauffeur if not, asking questions about the application, and gathering feedback. Interfaces 1 and 2 were evaluated. Findings from this evaluation led to the development of interface 3. Respondents showed a lack of connection with the textual realization of the ontology in interface 1 and 2.

Feedback also refined the elements common to all the interfaces. It was during this phase that desire for certain Cree-specific features such as a zoom-to-hunting territory feature was expressed, and these features were implemented in all three interfaces.

Table 3.2: Wemindji evaluation participants.

Community Member	Age	Gender
Tallyman: Maatuskaau	35	M
Elder	60	F
Hunter/Elder	60	M
Tallyman: Paakumshumwaau	60	M
Hunter	50	M
Tallyman	40	M
Local Government Worker	40	M
Tallyman: Coastal Trapline	30	M
Cree Language Expert	60	F

3.3.2 Montreal Testing

A second sub-stage of application testing was undertaken in Montreal at the Cree Teachers' Symposium in October of 2007. The application has potential value as a teaching resource, so it was deemed important to inform teachers of its existence as well as ensure that it was appropriate for teaching purposes. A total of seven people comprising the Coordinator of Cree Programs, her department of the Cree School Board, and a Wemindji Cree language expert tested the application in one group session where I acted as the chauffeur. At this time the map was configured to show part/whole relationships, and as in the previous sub-stage the attribute field of stories of related places was implemented. Only interface 3 with all three realizations of the ontology was tested at this time.

4. Results

This section describes the results of the evaluating of the application with different interfaces (and hence different realizations of the ontology). All Cree users were extremely excited to see a digital map of their placenames, and even more excited to see that names were linked to audio recordings of their relatives, many of whom had passed on. However, the Cree users had different responses to the three realizations of the ontology. When I explained the different attribute fields, all users in Wemindji and teachers in Montreal expressed appreciation and interest in the use of Cree categories of landscape features. The Cree reaction to the first realization of the ontology, present in all three interfaces, was positive.

However, the results of the other two realizations of the ontology – showing stories of related places in the attributes returned after a query, present in interfaces 2 and 3 and showing part/whole relationships of places queried on the map, present in interface 3 only – were less enthusiastic.

Wemindji residents were shown only interfaces 1 and 2. When asked whether they preferred to use interface 1 or 2, no respondents expressed a preference. Indeed, when one Wemindji user was asked during an interview about the utility of the realizations whether he thought the stories in the related places column (Attribute Shows Stories of Related Places realization) were related to the place on which he had clicked, he replied that it depended on the story. A geospatial ontology proved to be an ineffective way to link Cree stories to places, although an ontology focusing on the stories themselves would likely be an effective way to link stories to each other, as information pertaining to, for instance, whether one story references the same place, character, or theme as another could be encoded.

Montreal respondents were shown only interface 3, which had all three realizations of the ontology. Again, as in Wemindji, when asked about the field of related stories and the part/whole relations shown in the map, the respondents indicated that these text and map-based relationships were unimportant. These results should be interpreted cautiously due to the small sample size and the lack of an alternate interface. For instance, because many of the Montreal respondents were familiar with coastal areas, the group tended to concentrate on those areas. Compared with inland areas, coastal areas have few large lakes and rivers with many parts. Consequently this realization may have been found useful by those familiar with inland areas of Wemindji territory.

Ample feedback about elements common to all three interfaces was obtained, and many improvements were suggested, such as a tool to zoom to a particular trapline. None referred to the ontology or how it functioned, though some of the improvements, such as a zoom to trapline function, were unique to a Cree understanding of Wemindji territory. Not unexpectedly, certain aspects of Cree knowledge important to creating a GIS interface were not addressed by the ontology, such as the feature to zoom to a particular trapline. These emerged during the process of conducting the research and underscores the importance of an iterative methodology to realizing ontologies with indigenous communities.

5. Discussion

The discussion is separated into two sub-sections. The first sub-section discusses the implications of the results of application testing. The second sub-section discusses how the content of the ontology influenced its realization.

5.1 Implications Of Response To Realizations

Realization has its benefits. The logical ontology developed in Chapter 2, while of great academic interest, was found to be of no interest to the research respondents from which it was formalized. The realized ontology, as well as the application it was embedded in, was of interest to the Cree users. Not all realizations were found by the Cree users to be of equal of value, however. This will now be discussed at length.

The Cree users in this study did see value in the Cree feature type catalog, a realization of the conceptual ontology. Use of Cree landscape categories instead of English categories may be interpreted as a symbolic acknowledgment of Cree sovereignty of their territory, much as a map of Cree placenames is itself such an acknowledgement. Also, use of Cree landscape categories increases the applicability of the system as a Cree language and geography teaching aid, as pointed out by two residents of Wemindji and all the respondents in Montreal. In my case it is unnecessary to formalize an ontology to realize it in a manner meaningful to Cree users. This is very good news to indigenous organizations, who are often short on resources and the extremely specialized technical skill required to formalize an ontology. Simply developing a controlled list of feature types in an indigenous language could be a component of a placenames collection project, common in indigenous communities. This would add value to the efforts many indigenous organizations are undertaking to create a 'Virtual Selfhood.'

By contrast, the users I interviewed failed to find value in the realizations that required a logical ontology. Though the results pertaining to showing part-whole relations on the map are inconclusive, those pertaining to using a geospatial ontology for linking stories to related places strongly indicate that using an ontology of stories to link one story to another would be a design Cree users would respond to more positively than using a geospatial ontology of hydrography to link one place to another.

The results of application testing do not prove that Cree users would be uninterested in any realization that required a logical ontology. For instance, they may be interested in representing a logical ontology as a concept net. A concept net is a graphical representation of a set of concepts where each concept is a node and relationships between the concepts are edges. In this case, users could click to get instances of the concepts that may be interesting to Cree users.

The Cree language is evolving very quickly with time. For instance, certain terms for landscape features the elders use are no longer in use by the middle aged in Wemindji. Chapter 2 documented this aspect of the Cree language and how the conceptual and logical ontology captured it. This aspect of Cree hydrography could be realized by adding another attribute column. Alternately, it could be realized by implementing a system of user accounts. When a user logs on, the system could use hydrographic classes specific to the class of the user, or to allow users to see how different classes of users would categorize hydrography by using that other user class's hydrographic classes. This would allow, for instance, youth to browse the digital gazetteer using classes the elders would use. It is important to ascertain whether this rapid linguistic change is a feature common to indigenous cultures or unique to the Cree.

Most improvements suggested by Cree users during the testing of the application with the realized ontology had to do with general usability, and included eliminating the need to select tools used to click on the map (e.g., zoom in, zoom out, re-center map) in favor of simply having buttons to perform those functions and locking in an identify function when the user clicks on a map. Cree users were also interested in having a mouse-over function for obtaining the names of places, thus eliminating the need for clicking to simply obtain the name of a place. The response of our users to the interface functionality was similar to the responses obtained by Haklay and Tobon (2003), whose work in the U.K. found that a similar simplified, push-button interface was requested by users. This similarity suggests that the interactions of the Cree users in this study with the GIS were likely limited by the usability of the interface. This would indicate that any realization of an ontology with Cree users would have to respect (and ideally address) this need for usability. Hence, realizations of ontologies in complex, abstract forms such as the information landscapes used by Scharl et al. (2007) may be inappropriate for Cree users even though they are focused on revealing ontologies to the users.

It is unclear whether an ontology of stories would be the most appropriate means to link stories to each other. Unstructured tagging to create a folksonomy, or a hierarchically flat metadata vocabulary constructed by users, may be more appropriate, as this method has been successfully used with indigenous peoples recently (Verran et al. 2007). Junker and Luchian (2007) have successfully conducted story tagging workshops with Cree School Board users, so realizing some kind of Cree folksonomy of stories is feasible. This effort would require a methodology involving chauffeurs to enable less computer literate Crees to participate, as hunters and elders, the Crees with the most knowledge of the land and hence most qualified to give input into a folksonomy of Cree stories, tend not to have a requisite level of computer literacy.

5.2 Application Development, Maintenance and Sustainability

Sustaining an application or a part of it refers to ensuring that, after the initial implementation, it can continue to be used and maintained instead of succumbing to changes in operating system versions, browser versions, data entry difficulties, or any number of difficulties commonplace in digital technology. This concern is of importance to most organizations, and of paramount concern to organizations with limited access to money and technical expertise such as conservation groups and indigenous communities (Sieber 2006).

Selecting an appropriate development infrastructure is essential to the sustainability. The Protégé graphical user interface (GUI) helps programming novices author a logical ontology. Like GIS, there is still a very steep learning curve with ontology development, and someone with no formal mathematical or computer science training would likely find it quite difficult to author or maintain a logical ontology despite the Protégé tool and the availability of training manuals.

The maintenance of a conceptual ontology from Wemindji seems more feasible. A list of the classes in the ontology and a set of guidelines for classifying each placename were included in a manual for the application. If those in Wemindji who have the task to add classes to the ontology, they may do so with minimal knowledge of ontologies.

Though maintaining the conceptual ontology may be feasible from a technical point of view, the findings regarding multiple terminologies in Wemindji interrogate what it means for an ontology to be sustainable. The ontologies and their realizations must be open to revision, and, in certain instances, Cree must have access only to terms used by their group. Ontology maintenance in general is a topic of current research interest in information science (Clark and McCabe 2006). Given the recognized need for research relevant for indigenous communities (Tobias 2000), maintaining an ontology in an indigenous context would be a valuable contribution to knowledge.

6. Conclusion

This research is the first to realize a geospatial ontology in a software application (a digital gazetteer) with an indigenous culture. My results of testing various realizations of a Cree geospatial ontology with Cree users show that a conceptual ontology can be a valuable component of a GIS. My research also suggests that developing a conceptual ontology of geospatial features in an indigenous language would require little specialized skill beyond fluency in such a language and GIS competency, skill sets not uncommon among indigenous communities.

I was unable to realize a logical ontology in a manner of interest to Cree users. Nonetheless, software developers and researchers are constantly creating new applications with logical ontologies. As the Semantic Web becomes a reality it is likely that a number of applications will be of interest to indigenous peoples. This research points out design features that a realized Cree ontology could incorporate, such as user accounts based on groups of Cree speakers. Software could either employ classes familiar to the user or show classes familiar to another group of Cree speakers the user may be interested in learning more about, such as the elders.

In the future, realization of ordinary peoples' (as opposed to experts') geospatial ontologies likely will become a prominent research theme within GIScience. And, as indicated by the research, non-geospatial ontologies will likewise become important. This research will hopefully be the first of many efforts to ensure that indigenous peoples are included in research on ontologies.

Chapter 4: Summary Conclusion

Ontologies of the geospatial domain will form an integral part of the Geospatial Semantic Web (Kolas et al. 2005). Globally people do not share identical understandings of the geospatial domain (Mark and Turk 2003). Geospatial ontologies must be formalized from a variety of cultures if the Geospatial Semantic Web is to be open to all. Indigenous peoples are a significant part of the GIS and the Web user base (Poole 1995; Niezen 2004), and so formalizing ontologies with indigenous cultures and realizing these ontologies in software will become an important research theme. This thesis, conducted in partnership with the Wemindji Cree, speakers of the most spoken First Nations language in Canada (Statistics Canada 2008), represents the first effort to do that.

An iterative methodology for formalizing a geospatial ontology of Cree hydrography was developed. This methodology incorporates archival information as well as primary information from Cree speakers. Eliciting knowledge from Cree hunters and elders proved to be a challenge, and required different methods from those used with technoscientific professionals, with whom most ontology research has been conducted thus far.

This methodology was able to produce a logical ontology and test its contents with Cree speakers. Aspects of a formalized Cree ontology of hydrography include support for instance level relationships such as the Little Brother/Big Brother naming convention, synonymy, and information regarding the source of geospatial classes.

This ontology was then realized, or implemented in software, as a component of a digital gazetteer. The ontology was realized three different ways: as a feature type catalog, as a control on the attribute output when a user queries the map, and as a control on the response of the map itself to user queries. Three interfaces were developed. The first included only the feature type catalog, the second included the feature type catalog and the attribute control, and the third included the feature type, attribute control, and map control. These three interfaces, and hence the realizations of the ontology, were then tested with Cree users. The realization as a feature type catalog, which required only a conceptual ontology, was of interest to Cree users. The other two realizations, which required a logical ontology, had little success. This indicates that indigenous organizations, which likely have limited access to money and technical expertise, need not formalize an ontology to realize it in a way meaningful to users.

Future Research

Future work should incorporate spatial relationships from a Cree perspective. Cree verbs would likely be an effective source of these relationships, much as Cree nouns provided an effective source of geospatial classes. It is possible that words for generic spatial relationships such as ‘crosses’ won’t be found in Cree, as I was not able to find them during a dictionary search (Bobish Salt et al. 2005). What the dictionary search did reveal was terms that embody spatial relationships between particular feature classes, such as the verb *mischaakuhtin*, the act of a river going through a swampy area. A methodology similar to mine could be employed with a focus on Cree verbs instead of Cree nouns to elicit and formalize Cree spatial relationships.

Better methods of ontology verification are needed. My method was not able to obtain feedback from the Cree on the logical or the conceptual ontology I developed, only on the glossary created as a precursor to both. However, using Cree spatial relationships to construct a conceptual ontology would make it easier for Cree speaking research participants to have meaningful input into the conceptual ontology.

Feedback from Cree users concerning the interfaces developed was focused on improving usability. Future research should examine how an ontology could be realized to provide additional usability. Possibilities include developing concept nets, graphical representations of ontologies where classes are nodes in a network and relationships are edges. Users could click on a node and a database of placenames would be queried for the feature type represented by the node. An ontology of stories could also be represented and used as a user interface in this way.

The Cree language is evolving very quickly. A system of user accounts based on types of Cree speakers could be a way of realizing an ontology in the future.

Literature Cited

Aberley, D., and R. E. Sieber. 2002. Public Participation GIS (PPGIS) Guiding Principles. In First International PPGIS Conference. Rutgers University, New Brunswick, New Jersey.

Agarwal, P. 2005. Ontological considerations in GIScience. International Journal of Geographical Information Science 19 (5):501-536.

Apache Software Foundation. 2008. Apache HTTP Server Project 2008 [cited March 6th 2008]. Available from http://httpd.apache.org/.

Audi, R. 1995. The Cambridge Dictionary of Philosophy. Cambridge: Cambridge University Press.

Benessaiah, K., A. Bennett, S. Boyce, E. Crawford, V. Demers, M. Forrest, E. Lagace, C. Lemoine, C. Peloquin, J. Sayles, S. Schiff, and K. Scott. 2003. Final report: AA-Wiichaautuwiihkw: Creating a Culturally Appropriate Watershed and Adjacent Marine Coastal Protected Area in Paakumshumwaau (Old Factory Wemindji, James Bay, Quebec. Montreal: McGill University.

Berners-Lee, T., J. Hendler, and O. Lassila. 2001. The Semantic Web: A new form of Web content that is meaningful to computers will unleash a revolution of new possibilities. Scientific American 284:34 - 43.

Berryman, N., J. Burt, J. Fortier, E. Lotter, B. Mackay, C. Paquin, A. Quock, M. Stock, T. Teitelbaum, and C. Wellen. 2004. Aa-Wiishaautuwiihkw (Coming Together to Walk Together): Creating a Culturally Appropriate Protected Area in Paakumshumwaau (Old Factory) James Bay, Quebec: Year 2 Montreal, Quebec: McGill University.

Bobbish-Salt, L., E. Duff, M. MacKenzie, and B. Jancewicz. 2005. Northern EastCree Dictionary: Cree School Board.

Bowerman, M., and E. Pederson. 1992. Crosslinguistic perspectives on topological spatial relations. In 91st Annual Meeting of American Anthropological Association. San Francisco.

Brodaric, B. 2004. The design of GSC FieldLog: ontology-based software for computer aided geological field mapping. Computers & Geosciences 30 (1):5-20.

Calamia, M. 1999. A methodology for incorporating traditional ecological knowledge with geographic information systems for marine resource management in the Pacific. Traditional Marine Resource Management and Knowledge Information Bulletin 10 (February).

Chapin, M. 2006. Mapping Indigenous Lands: Issues & Considerations: Center for the Support of Native Lands.

Clark, K. L., and F. G. McCabe. 2007. Ontology schema for an agent belief store. International Journal of Human-Computer Studies 65 (7):640-658.

Corbett, J., J. Love, M. Evans, and BC Métis Mapping Initiative Project. 2008. Spatializing the Métis Historical database using Google Maps API. In Spatial Knowledge and Information Canada. Fernie, B.C.

Cree Regional Authority. 2002. Cree Trapline Boundaries. Obtained on March 1st, 2003.

Denton, D. 2006. Cree Culture Resources - Cree Placenames. http://www.creeculture.ca/e/resourcew/places.html. Accessed on March 1st, 2006

Dolbear, C., J. Goodwin, Mizen H., and J. Ritchie. 2005. Semantic interoperability between topographic data and a flood defence ontology. Southampton, UK: Ordnance Survey Research & Innovation.

Egenhofer, M. J. 2002. Toward the semantic geospatial web. Proceedings of the tenth ACM international symposium on Advances in geographic information systems:1-4.

Elliot, N. 2008. Including Aboriginal Values in Resource Management Through Enhanced Geospatial Communication. Spatial Knowledge and Information Canada. Fernie, B.C. February 16, 2008.

Fellbaum, C. 1998. WordNet: An Electronic Lexical Database. Cambridge, MA: MIT Press.

Fireman, G. 2005. Lake Formations. Cree School Board.

Fonseca, F., M. Egenhofer, P. Agouris, and G. Camara. 2002. Using Ontologies for Integrated Geographic Information Systems. Transactions in GIS 6 (3):231-257.

Fonseca, F. T., M. J. Egenhofer, C.A. Davis Jr., and K.V.A. Borges. 2000. Ontologies and Knowledge Sharing in Urban GIS. Computers, Environment, and Urban Systems 24:251-271.

Frank, A. U. 2001. Tiers of ontology and consistency constraints in geographical information systems. International Journal of Geographical Information Science 15 (7):667-678.

Gibson, J. J. 1986. The Ecological Approach to Visual Perception. Hillsdale, NJ: Lawrence Erlbaum.

Goodwin, J. 2005. Experiences of using OWL at the ordnance survey. In OWL: Experiences and Directions. Galway, Ireland: Ordinance Survey.

Government of Canada. 2008. GeoBase Administrative Boundaries Level 0 - Canada. Available from http://geogratis.cgdi.gc.ca/framework/framew_e.html. Accessed on September 11th, 2008.

Grenon, P., and B. Smith. 2004. SNAP and SPAN: Towards Dynamic Spatial Ontology. Spatial Cognition and Computation 4 (1):69-104.

Guarino, N., and P. Giaretta. 1995. Ontologies and Knowledge Bases: Towards a Terminological Classification. In Towards Very Large Knowledge Bases: Knowledge Building and Knowledge Sharing, edited by N. Mars. Amsterdam: IOS Press.

Gulli, A, and A Signorini. 2005. The Indexable Web is more than 11.5 billion pages Available from http://www.cs.uiowa.edu/~asignori/web-size/. Accessed April 1st, 2008

Haklay, M., and C. Tobón. 2003. Usability evaluation and PPGIS: towards a user-centred design approach. International Journal of Geographical Information Science 17 (6):577-592.

Hanseth, O., and E. Monteiro. forthcoming. Understanding Information Infrastructure.

Harmsworth, G. 1998. Indigenous values and GIS: A method and a framework. Indigenous Knowledge and Development Monitor 6 (3):3–7.

Hart, G., S. Temple, and H. Mizen. 2004. Tales of the River Bank - An Overview of the First Stages in the Development of a Topographic Ontology. In GIS Research UK 12th Annual Conference. East Anglia, Norwich: Ordinance Survey. April 28 - 30, 2004.

Hill, L. 2000. Core Elements of Digital Gazetteers: Placenames, Categories, and Footprints. In Research and Advanced Technology for Digital Libraries. Berlin / Heidelberg: Springer. Pages 280-290

Horridge, M., H. Knublauch, A. Rector, R. Stevens, and C. Wroe. 2004. A Practical Guide To Building OWL Ontologies Using The Protégé-OWL Plugin and CO-ODE Tools Edition 1.0. Manchester. Available from http://www.co-ode.org/resources/tutorials/ProtegeOWLTutorial.pdf. Accessed March 1st, 2007.

Horton, R. 1982. Tradition and Modernity Revisited. In Rationality and Relativism, edited by M. Hollis and S. Lukes. Oxford: Blackwell.

Jasper, R., and M. Uschold. 1999. A framework for understanding and classifying ontology applications. Paper read at IJCAI-99 Workshop on Ontologies and Problem-Solving Methods. Volume 99, pages 16-21.

Junker, M. O., and R. Luchian. 2007. Developing Web Databases for Aboriginal Language Preservation. Literary and Linguistic Computing 22 (2):187.

Kolas, D., J. Hebeler, and M. Dean. 2005. Geospatial Semantic Web: Architecture of Ontologies. Paper read at Geospatial Semantics: First International Conference, November 2005, at Mexico City, Mexico.

Kuhn, W. 2001. Ontologies in support of activities in geographical space: Taylor & Francis.

Laituri, M., and L. Harvey. 1995. Bridging the space between indigenous ecological knowledge and New Zealand conservation management using GIS. In Nature Conservation: The Role of Networks, edited by D. Saunders, J. Craig and E. Mattiske. NSW: Surrey Beatty and Sons. Pages 122–131.

LeCompte, M. D., and J. J. Schensul. 1999. Designing and Conducting Ethnographic Research. 7 vols. Vol. 1, Ethnographer's Toolkit. Oxford: AltaMira Press.

Lime, S. 2008. Mapserver 2008. Available from http://mapserver.gis.umn.edu/. Accessed March 6th 2008.

Lutz, M., and D. Kolas. 2007. Rule-Based Discovery in Spatial Data Infrastructure. Transactions in GIS 11 (3):317-336.

MacKenzie, M. 1977. Cree Toponyms: A report on the geographic names used in four Cree communities in the James Bay Region.

Mann, W.R. 2000. The Discovery of Things: Aristotle’s Categories and their Context. Princeton, NJ: Princeton University Press.

Mark, D. M. 2007. Defining Indigenous Landscape Categories Using General Principles from an Ontology. In Association of American Geographers. San Francisco, CA. April 17th, 2007.

———. 2008. Defining Indigenous Landscape Categories Using General Principles from an Ontology. In Association of American Geographers. Boston, MA. April 16th, 2008.

Mark, D. M., and A. Turk. 2003. Landscape Categories in Yindjibarndi: Ontology, Environment, and Language. Paper read at Spatial Information Theory: Foundations of Geographic Information Science., at Ittingen, Switzerland.

Mark, D. M., and M. J. Egenhofer. 1995. Topology of Prototypical Spatial Relations Between Lines and Regions in English and Spanish. Paper read at Auto Carto 1995, March 1995, at Charlotte, North Carolina.

Mark, D. M., M. J. Egenhofer, and K. Hornsby. 1997. Formal Models of Commonsense Geographic Worlds: Report on the Specialist Meeting of Research Initiative 21. October 30th – November 3rd, 1997.

McGuinness, D. L., and F. van Harmelen. 2004. OWL Web Ontology Language Overview. W3C Available from http://www.w3.org/TR/owl-features/. Accessed March 1st, 2007.

McKenna, J. 2008. PHP/Mapscript Class Reference. Available from http://mapserver.gis.umn.edu/docs/reference/phpmapscript-class. Accessed March 6th, 2008.

Mizen, H., C. Dolbear, and G. Hart. 2005. Ontology Ontogeny: Understanding How an Ontology is Created and Developed. Paper read at GeoSemantics 2005, 2005. Lecture Notes in Computer Science 3799 pages 15 – 29.

MySQL AB. 2008. MySQL 5.1 Reference Manual. Available from http://dev.mysql.com/doc/refman/5.1/en/index.html. Accessed March 6th 2008.

Nadasdy, P. 1999. The politics of TEK: Power and the integration of knowledge. Arctic Anthropology 36 (1-2):1-18.

Niezen, R. 2004. Digital Identity: The Construction of Virtual Selfhood in the Indigenous Peoples' Movement. Comparative Studies in Society and History 47: 532-551.

Pease, A., I. Niles, and J. Li. 2002. The Suggested Upper Merged Ontology: A Large Ontology for the Semantic Web and its Applications. In AAAI-2002 Workshop on Ontologies and the Semantic Web. Edmonton, Alberta Canada. July 28, 2002.

Poggie, J. J. 1972. Toward Quality Control in Key Informant Data. Human Organization 31 (23-30).

Poole, P. 1995. Indigenous Peoples, Mapping, and Biodiversity Conservation. In Biodiversity Support Program Peoples and Forest Program Discussion Paper Series: Biodiversity Support Program.

Preston, R. J. 2002. Cree Narrative: Expressing the Personal Meanings of Events: McGill-Queen's University Press.

Quebec Ministry of Environment. 2004. Hydrographic Spatial Data. Obtained on March 1st, 2003.

Racer Systems GmbH & Co. KG. 2007. RacerPro Reference Manual Version 1.9.2: Racer Systems GmbH & Co. KG.

Randall, R. R. 2001. Place Names: How They Define the World--and More: Scarecrow Press.

Raskin, R. G., and M. J. Pan. 2005. Knowledge representation in the semantic web for earth and environmental terminology (SWEET). Computers & Geosciences 31 (9):1119-1125.

Roy, A. J., and J. G. Stell. 2002. A Qualitative Account of Discrete Space. In GIScience 2002. Boulder Colorado: Springer.

Rubin, H. J., and I. S. Rubin. 1995. Qualitative interviewing: The Art of Hearing Data. Thousand Oaks, CA: Sage Publications.

Rundstrom, R. A. 1993. The Role of Ethics, Mapping, and the Meaning of Place in Relations Between Indians and Whites in the United States. Cartographica 30 (1):21-28.

———. 1995. GIS, Indigenous Peoples, and Epistemological Diversity. Cartography and Geographic Information Science 22 (1):45-57.

Scharl, A., A. Weichselbraun, A. Hubmann-Haidvogel, H. Stern, G. Wohlgenannt, and D. Zibold. 2007. MediaWatch on Climate Change: Building and Visualizing Contextualized Information Spaces. In Sixth International Semantic Web Conference. Busan, Korea. November 11th – 15th, 2007.

Scott, C. 1988. Property, Practice and Aboriginal Rights Among Quebec Cree Hunters. In Hunters and Gatherers: Property, Power and Ideology, edited by T. Ingold, D. Riches and J. Woodburn. New York: Berg Publishers.

Scott, C. 1996. Science for the West, Myth for the Rest? The Case of James Bay Cree Knowledge Construction. In Naked Science: Anthropological Inquiry Into Boundaries, Power, and Knowledge, edited by L. Nader: Routledge.

Sieber, R. 2006. Public Participation Geographic Information Systems: A Literature Review and Framework. Annals of the Association of American Geographers 96 (3):491-507.

Smith, B. 1996. "Mereotopology: A theory of parts and boundaries." Data and Knowledge Engineering 20(3): 287-303.

Smith, B., and D. M. Mark. 2001. Geographical Categories: an ontological investigation. International Journal of Geographical Information Science 15 (7):591-612.

Smith, B., and D. M. Mark. 2003. Do mountains exist? Towards an ontology of landforms. Environment and Planning B: Planning and Design 30:411 - 427.

Smith, B., and D. M. Mark. 1998. Ontology and Geographic Kinds. In International Symposium on Spatial Data Handling. Vancouver, BC, Canada. July 11-15, 1998.

Sowa, J. F. 2000. Ontology, Metadata, and Semiotics. In ICCS'2000. Darmstadt, Germany: Springer-Verlag Notes in AI #1867, pages 55-81.

Statistics Canada. 2008. Aboriginal Peoples in Canada in 2006: Inuit, Métis and First Nations, 2006 Census: Findings. Ottawa, Canada: Government of Canada. Retrieved June 15th 2008, 2008, from http://www.statcan.ca/Daily/English/080115/d080115a.htm.

Stea, D. 2007. Towards a Theoretical Basis for Ethnophysiography. In Association of American Geographers. San Francisco, CA. April 17th, 2007.

Tobias, T. 2000. Chief Kerry's Moose: a guidebook to land use and occupancy mapping, research design, and data collection: Union of BC Indian Chiefs. Ecotrust Canada.

Uschold, M., and M. Gruninger. 1996. Ontologies: Principles, Methods and Applications. Knowledge Engineering Review 11 (2).

Verran, H., M. Christie, B. Anbins-King, T. van Weeren, and W. Yunupingu. 2007. Designing Digital Knowledge Management Tools with Aboriginal Australians. Digital Creativity 18 (3):129-142.

Wellen, C. 2008. Wemindji Ontology and Placenames and Oral History Mapping: a Report. Montreal, Qc: McGill University.

Wemindji. 2008. Cree Nation of Wemindji. Available from http://www.wemindji-nation.qc.ca/index.html. Accessed May 21, 2008.

Appendix A: Glossary of Cree Hydrography

Cree Class	English Definition
Aa Aschipuutaakinuwich	A Reservoir.
Aa Saachiiuch	Where a river empties into lake.
Aa Uchihchich	Where a river drains lake.
Aa Upaach	Where a channel narrows.
Aa Upaachich	Very narrow part of a water body.
Aamaataamapiich	Empties. Used to describe confluence.
Aamaataashtikwaayaach	A joining of rivers.
Aanayaach	An earthen point.
Aanayapskaach	A rocky point.
Aapiitukamaach	A lake parallel to another.
Anatwaayach	A river section between two rapids.
Awaashaashich	A small marine bay.
Iihthuwikimaauh	A pair of lakes where one is a mirror image of another.
Kapataakan	A portage.
Minaakuwamskau	A sand bar.
Minaapiskaau	A larger rock island.
Minaapiskw	A rock island.
Minaauhkw	A big sand bar.
Minishtik	An island in a lake or James Bay.
Minishtikuchuun	An island in a river.
Minishtikush	A small island.
Minishtikuuschuukaau	A mud bar.
Mischaakusaakihiikin	A lake or pond in the muskeg.
Mischaakushtikw	A small stream or river in a swamp.
Mischaakw	A muskeg; a bog.
Muschiwinipaakw	A spring of water.
Naasipaatimihch	A lake edge, a riverbank, a stretch of shore.
Naaskimikaau	A point of land.
Paaushtikui	A rapids.
Paaushtuguiiat	A very steep rapids.
Pikutaauhkw	A lake with no surface inlet or outlet, often made by a spring.
Saakihiikin	A lake.
Saakihiikinish	A small lake; a pond.

Shakaapishiish	A very small, bushy creek. This is usually intermittent.
Shiipaashtikw	A side channel of a river which breaks off and re-joins the main channel.
Shiipiish	A creek or a stream. One may be able to canoe down it.
Shikaapishii	A very small creek. One cannot canoe down it.
Siipii	A large river which one can canoe down.
Sischutaauhkaach	A mud bar.
Upikimaau	Two lakes connected by a narrow channel.
Waashaau	A marine bay.
Waawaachikimaau	A very windy lake.
Wiinipaakw	James and Hudson Bay.
Yaatiwaakimii	A bay on a lake.

Appendix B: Conceptual Ontology of Cree Hydrography

Cree Class	Properties
Aa Aschipuutaakinuwich	• Feeds from waterbodies. • Empties into waterbodies.
Aa Saachiiuch	• Feeds from a waterway. • Empties into a still waterbody. • Connects a waterway to a waterbody.
Aa Uchihchich	• Feeds from a still waterbody. • Empties into a waterway. • Connects a waterway to a waterbody.
Aa Upaach	• Part of a waterbody. • *Narrow part.*
Aa Upaachich	• Part of a waterbody. • Type of narrows (aa upaach). • *Smaller than a narrows (aa upaach).*
Aamaataamapiich	• Feeds from a waterway. • Empties into a waterway. • Connected to a waterway. • Same as Aamaataashtikwaayaach. • Term used by trapline VC-13.
Aamaataashtikwaayaach	• Feeds from a waterway. • Empties into a waterway. • Connected to a waterway. • Same as Aamaataamapiich. • Term used by trapline VC-14.
Aanayaach	• Connected to a water body. • Has Material earth • Has Speaker middle aged
Aanayapskaach	• Connected to a water body. • Has Material rock • Used by middle aged
Aapiitukamaach	• Feeds from waterbodies. • Empties into waterbodies.

	• Connected to a Saakihiikin. • Type of lake (Saakihiikin). • *Parallel to another lake.*
Anatwaayach	• Part of a large waterway (siipii or shiipiish). • Downstream of a rapids (Paaushtikui). • Upstream of a rapids (Paaushtikui). • Connected to two rapids (Paaushtikui).
Awaashaashich	• Type of bay (waashaau). • Part of James Bay. • *Smaller than (waashaau).*
Iihthuwikimaauh	• Has 2 lakes as parts. • *The 2 lakes are not connected*
Kapataakan	• Avoids rapids.
Minaakuwamskau	• Contained by some waterway. • Type of island in a waterway (Minishtikuchuun) • Has Material sand
Minaapiskaau	• Contained by some still waterbody. • Type of rock island (Minaapiskw) • Has Material rock
Minaapiskw	• Contained by some still waterbody. • Type of island in a still waterbody (Minishtik) • Has Material rock
Minaauhkw	• Contained by some waterway. • Type of island in a waterway (Minishtikuchuun). • Has Material sand
Minishtik	• Contained by some still waterbody.
Minaauhkw	•
Minishtikuchuun	• Contained by some waterway.
Minishtikush	• Contained by some still waterbody. • Type of island in a still waterbody (Minishtik). • *Smaller than a Minishtik*.
Minishtikuuschuukaau	• Contained by some waterway. • Type of island in a waterway (Minishtikuchuun). • Has Material mud
Mischaakusaakihiikin	• Feeds from waterbodies.

	• Empties into waterbodies. • Type of lake (Saakihiikin). • Contained by an area of muskeg (Mischaakw).
Mischaakushtikw	• Feeds from waterbodies. • Empties into waterbodies. • Contained by an area of muskeg (Mischaakw).
Mischaakw	
Muschiwinipaakw	
Naasipaatimihch	• Connected to a water body.
Naaskimikaau	• Connected to a water body. • Has Speaker elders
Paaushtikui	• Part of a large river (siipii or shiipiish). • Downstream of an Anatwaayach. • Upstream of an Anatwaayach.
Paaushtuguiiat	• A Type of rapids (paaushtikui). • *Bigger than Paaushtikui.*
Pikutaauhkw	• Feeds from a spring. • Doesn't empty into any waterbody. • Type of lake (Saakihiikin).
Saakihiikin	• Feeds from waterbodies. • Empties into waterbodies.
Saakihiikinish	• Feeds from waterbodies. • Empties into waterbodies. • Type of lake (Saakihiikin). • *Smaller than Saakihiikin.*
Shakaapishiish	• Feeds from waterbodies. • Empties into waterbodies. • *Smaller than shikaapishii*
Shiipaashtikw	• Feeds from waterways. • Empties into waterways. • Connected to a waterway. • Part of a waterway. • *Feeds from and Empties into the same waterway.*
Shiipiish	• Feeds from waterbodies. • Empties into waterbodies.

	• *Smaller than siipii*
Shikaapishii	• Feeds from waterbodies. • Empties into waterbodies. • *Smaller than shiipiish*
Siipii	• Feeds from waterbodies. • Empties into waterbodies.
Sischutaauhkaach	• Contained by some waterway. • Type of island in a waterway (Minishtikuchuun). • Has Material mud
Upikimaau	• *Has 2 lakes (Saakihiikin) as parts.* • *Has a narrows (aa upaach) as a part.*
Waashaau	• Part of James Bay
Waawaachikimaau	• Feeds from waterbodies. • Empties into waterbodies. • Type of lake (Saakihiikin). • *Very windy*
Wiinipaakw	• Feeds from waterbodies
Yaatiwaakimii	• Part of a lake (Saakihiikin). • Feeds from waterbodies.

Appendix C: Logical Ontology

Cree Class	Properties
Aa Aschipuutaakinuwich	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Aa Saachiiuch	• FeedsFrom some (**mischaakushtikw** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **saakihiikin**) • ConnectedTo some (**saakihiikin** or **aa_aschipuutaakinuwich**) • ConnectedTo some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)

	• EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Aa Uchihchich	• FeedsFrom some (**aa_aschipuutaakinuwich** or **saakihiikin**) • EmptiesInto some (**mischaakushtikw** or **shiipaashtikw** or **shiipiish** or **shikaapishii** or **siipii**) • ConnectedTo some (**saakihiikin** or **aa_aschipuutaakinuwich**) • ConnectedTo some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Aa Upaach	• PartOf some (**saakihiikin** or **siipii** or **shiipiish** or **wiinipaakw**) • *Narrow part.*
Aa Upaachich	• PartOf some (**saakihiikin** or **siipii** or **shiipiish** or

	wiinipaakw) • Subclass (**aa upaach**). • *Smaller than **aa upaach**.*
Aamaataamapiich	• FeedsFrom some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • FeedsFrom only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • ConnectedTo some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • ConnectedTo only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • hasTrapline some **VC-13** • hasTrapline only **VC-13** • SameConcept **Aamaataashtikwaayaach**
Aamaataashtikwaayaach	• FeedsFrom some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • FeedsFrom only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • ConnectedTo some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • ConnectedTo only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • hasTrapline some **VC-14** • hasTrapline only **VC-14**

	• SameConcept **Aamaataamapiich**.
Aanayaach	• ConnectedTo some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • hasMaterial some **Earth** • hasMaterial only **Earth** • hasSpeaker some **MiddleAged**
Aanayapskaach	• ConnectedTo some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • hasMaterial some **Rock** • hasMaterial only **Rock** • hasSpeaker some **MiddleAged**
Aapiitukamaach	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or

	mischaakusaakihiikin or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • ConnectedTo some **saakihiikin**. • Subclass **saakihiikin**. • *Parallel to another lake.*
Anatwaayach	• PartOf some (**siipii** or **shiipiish**) • DownstreamOf some **paaushtikui** • UpstreamOf some **paaushtikui** • ConnectedTo some **paaushtikui** • *Connected to two rapids (Paaushtikui).*
Awaashaashich	• Subclass **waashaau**. • Part of James Bay. • *Smaller than (waashaau).*
Iihthuwikimaauh	• HasPart some **saakihiikin** • HasPart min 2 • *The 2 lakes are not connected*
Kapataakan	• PortagesAround only **paaushtikui**
Minaakuwamskau	• ContainedBy some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • Subclass **minishtikuchuun** • hasMaterial some **Sand** • hasMaterial only **Sand**
Minaapiskaau	• ContainedBy some (**saakihiikin** or **waashaau** or **aa_aschipuutaakinuwich**) • Subclass **minaapiskw** • hasMaterial some **Rock** • hasMaterial only **Rock**
Minaapiskw	• ContainedBy some (**saakihiikin** or **waashaau** or **aa_aschipuutaakinuwich**) • Subclass **minishtik** • hasMaterial some **Rock** • hasMaterial only **Rock**
Minaauhkw	• ContainedBy some (**siipii** or **shiipiish** or

	• **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • Subclass **minishtikuchuun** • hasMaterial some **Sand** • hasMaterial only **Sand**
Minishtik	• ContainedBy some (**saakihiikin** or **waashaau** or **aa_aschipuutaakinuwich**)
Minishtikuchuun	• ContainedBy some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**)
Minishtikush	• ContainedBy some (**saakihiikin** or **waashaau** or **aa_aschipuutaakinuwich**) • Subclass **minishtik**. • *Smaller than a Minishtik*.
Minishtikuuschuukaau	• ContainedBy some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • Subclass **minishtikuchuun** • hasMaterial some **Mud** • hasMaterial only **Mud**
Mischaakusaakihiikin	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)Subclass **saakihiikin**.

	• ContainedBy some **mischaakw**
Mischaakushtikw	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)Subclass **saakihiikin**. • ContainedBy some **mischaakw**
Mischaakw	
Muschiwinipaakw	
Naasipaatimihch	• ConnectedTo some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Naaskimikaau	• ConnectedTo some (**aa_aschipuutaakinuwich** or

	aa_mushaapaayaach or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Paaushtikui	• PartOf some (**shiipiish** or **siipii**) • DownstreamOf some **anatwaayach** • UpstreamOf some **anatwaayach** • ConnectedTo some **anatwaayach** • ConnectedTo min 2
Paaushtuguiiat	• Subclass **paaushtikui**. • PartOf some (**shiipiish** or **siipii**) • DownstreamOf some **anatwaayach** • UpstreamOf some **anatwaayach** • ConnectedTo some **anatwaayach** • ConnectedTo min 2 • *Bigger than Paaushtikui.*
Pikutaauhkw	• FeedsFrom only **muschiwinipaakw** • FeedsFrom some **muschiwinipaakw** • EmptiesInto max 0 • Subclass **saakihiikin**. • FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or

	saakihiikin or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Saakihiikin	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Saakihiikinish	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • Subclass **saakihiikin.** • *Smaller than Saakihiikin.*

Shakaapishiish	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • *Smaller than shikaapishii*
Shiipaashtikw	• FeedsFrom only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • FeedsFrom some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto only (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • EmptiesInto some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • ConnectedTo some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**). • PartOf some (**siipii** or **shiipiish** or **shakaapishiish** or

	shikaapishii or **shiipaashtikw** or **mischaakushtikw**).. • *Feeds from and Empties into the same waterway.*
Shiipiish	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • *Smaller than siipii*
Shikaapishii	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or

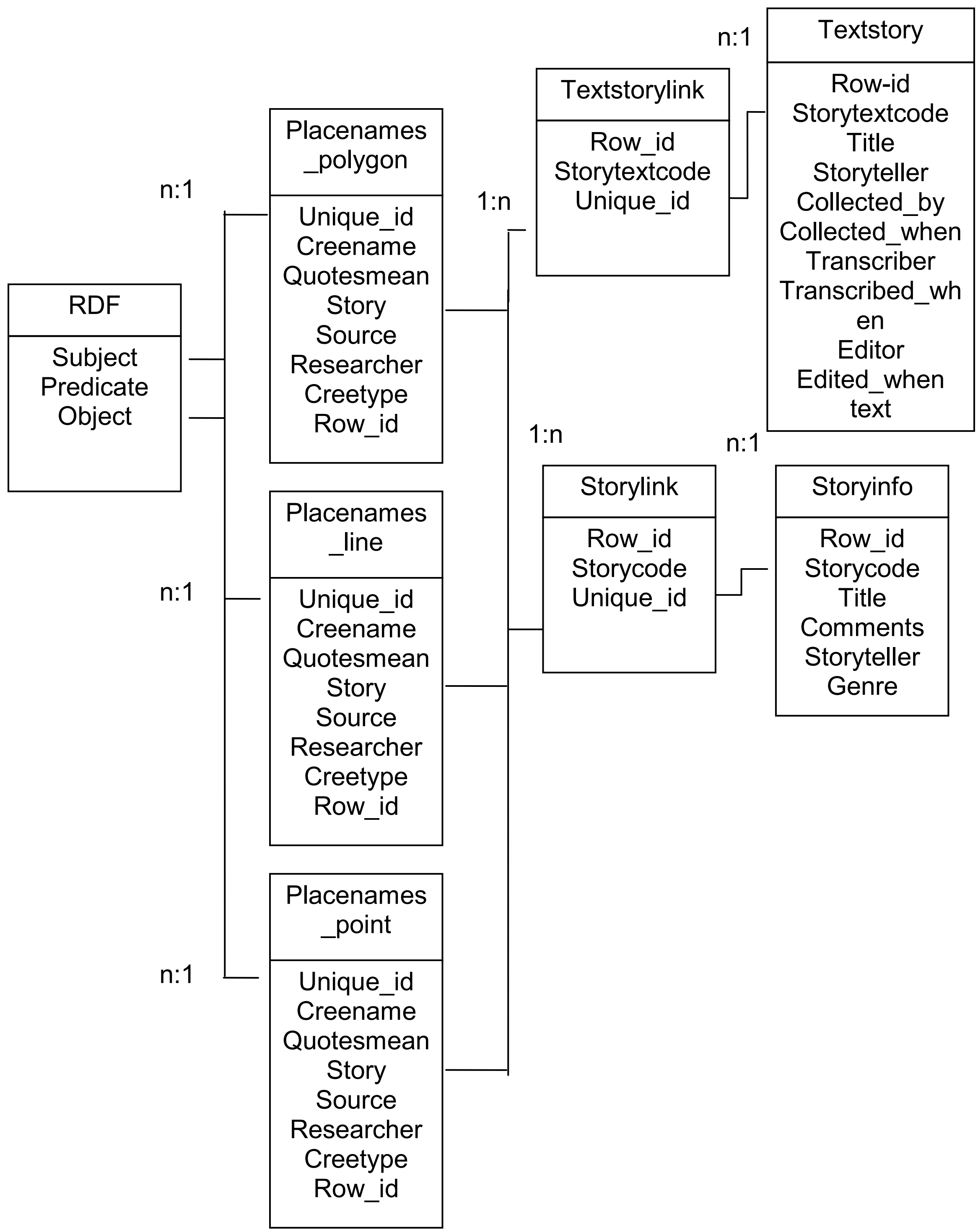
	aa_uchihchich or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • *Smaller than shiipiish*
Siipii	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto some (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or

	shiipiish or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Sischutaauhkaach	• ContainedBy some (**siipii** or **shiipiish** or **shakaapishiish** or **shikaapishii** or **shiipaashtikw** or **mischaakushtikw**) • Subclass **minishtikuchuun**. • hasMaterial some **Mud** • hasMaterial only **Mud**
Upikimaau	• HasPart some **saakihiikin** • HasPart some **aa_upaach** • HasPart min 3 • *Has 2 lakes (Saakihiikin) as parts.* • *Has one narrows (aa upaach) as a part.*
Waashaau	• PartOf only **wiinipaakw** • PartOf some **wiinipaakw**
Waawaachikimaau	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • EmptiesInto only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • Subclass **saakihiikin** • *Very windy*
Wiinipaakw	• FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or

	aamaataashtikwaayaach or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**)
Yaatiwaakimii MaterialValuePartition Earth AgeSpeakerValuePartition HasTraplineValuePartition	• PartOf some **saakihiikin** • FeedsFrom only (**aa_aschipuutaakinuwich** or **aa_mushaapaayaach** or **aa_saachiiuch** or **aa_uchihchich** or **aa_upaach** or **aamaataamapiich** or **aamaataashtikwaayaach** or **anatwaayach** or **wiyiwaau** or **mischaakusaakihiikin** or **mischaakushtikw** or **saakihiikin** or **shakaapishiish** or **shiipaashtik**w or **shiipiish** or **shikaapishii** or **siipii** or **waashaau** or **yaatiwaakimii**) • Subclass **Earth** • Subclass **Rock** • Subclass **Sand** • Subclass **Mud** • Subclass **Elder** • Subclass **Middle Aged** • Subclass VC-09 • Subclass VC-10 • Subclass VC-11 • Subclass VC-12 • Subclass VC-13 • Subclass VC-14 • Subclass VC-16 • Subclass VC-17 • Subclass VC-18 • Subclass VC-19 • Subclass VC-20 • Subclass VC-21 • Subclass VC-22 • Subclass VC-23 • Subclass VC-24 • Subclass VC-25

	• Subclass VC-26 • Subclass VC-27 • Subclass VC-28 • Subclass VC-29

Appendix D: Database Schema



Appendix E: Interview Guide for Ontology Elicitation

Geographic Information Systems and Traditional Knowledge

Wemindji, Quebec

Interview guide for ontology elicitation

The information sheet will be given to the research participant and read to them. I will then explain that I would like to create a GIS based on how the Wemindji people think of their territory. I will explain that I am interested in the landscape features which are different than English ones, such as *anatwaayach*, a river widening.

Profile Hunter or Elder

1. Have you spent time in the *Maatuskaau* or *Paakumshumwaau* areas? (This will usually be clear without asking).
2. When did you spend time there?
3. Did you tend to spend time inland or on the coast?
4. What trapline are you most familiar with?

Landscape Feature Categories (category x refers to a category on the list created during archival research).

1. How would you define category x?
2. Can you draw an example of category x on whichever map you're most comfortable with?
3. (repeat for as many categories as participant is comfortable with).

Final Questions

1. Do you have anything else you'd like to add?
2. Can you think of anyone else you think I should talk to about these things, or who would like to talk to me about these things?

Appendix F: Interview Guide for Ontology Verification

Geographic Information Systems and Traditional Knowledge

Wemindji, Quebec

Interview guide for ontology verification

I will explain that I would like to ask the research participant questions about the definitions of Cree words, as well as which Cree words they would use to describe certain places.

Profile Hunter or Elder

1. What trapline are you most familiar with?
2. Where on the trapline are you familiar with?

Landscape Feature Categories (category x refers to a class in the conceptual ontology, place y refers to a named place I have data on within the area they are familiar with.).

1. How would you define category x?
2. Would you use category x to describe place y?
3. (repeat for as many categories as participant is comfortable with).

Final Questions

1. Do you have anything else you'd like to add?
2. Can you think of anyone else you think I should talk to about these things, or who would like to talk to me about these things?

Appendix G: Interview Guide for Evaluating Ontology Realizations

Geographic Information Systems and Traditional Knowledge

Wemindji and Montreal, Quebec

Interview guide for testing ontology realizations

I will explain that I am creating an interactive Web map of Cree placenames and stories, and that I would like them to try it and give feedback. After loading interface 2 (control of the attribute output when a user queries the data) or 3 (control of the attribute output when a user queries the data AND control of the response of an interactive map to user input) on my laptop, I will zoom to an area they are familiar with and show them how to query the map. I will explain the meaning of the attribute fields. After showing them how to listen to the stories, I will ask them the following questions:

1. What do you think of the related stories column? Is it helpful for finding interesting stories?
2. What do you think about how the map shows part/whole relationships? Is it helpful for finding places?
3. What do you think about the Cree feature types? Are they interesting?

Time permitting, I will then switch the research participant to interface 1 (use of the conceptual ontology as the feature type catalog of the gazetteer) and ask them which they prefer, interface 1 or 2 or 3 (whichever of the latter two they used).

Final Questions

1. Do you have anything else you would like to add?
2. Can you think of anyone else you think I should talk to about these things, or who would like to talk to me about these things?

Appendix H: Information Sheet Given to Research Participants

Geographic Information Systems and Traditional Knowledge

Wemindji, Quebec

Information Sheet

Waachiya! [a Cree greeting meaning Hello] My name is Christopher Wellen, and I am a Masters student at McGill University in Montreal.

A Geographic Information System (GIS) uses a computer to link all sorts of information to locations. This information can then be stored, retrieved, and analyzed.

As part of a larger effort to investigate a culturally appropriate protected area in the Wemindji territory, I am working with Wemindji to explore how a GIS can be used for a number of applications, including:

- Creating and sustaining dialogue between Cree people and Southern researchers

- Disseminating results of research within Wemindji

- Disseminating traditional knowledge within Wemindji

There has been lots of research about how GIS can be used by local communities, including indigenous ones, but there hasn't been much research about how GIS can be re-created so it works better with traditional knowledge.

I would like to talk to you about how traditional knowledge – the placenames, stories, travel routes, values, and many other things Wemindji people know about their land – could be represented in a GIS.

If you choose to talk to me you are free to stop the interview at any time. You can choose for your name to be included in my report, or you can choose not to be named at all. You may have a copy of the report when I am done if you wish. If you have any questions about what I am doing, please ask them.

Christopher Wellen
Christopher.wellen@mail.mcgill.ca
McGill University, Department of Geography
1275 Jean-Talon E #201
Montreal, Qc
H2R 1W4
Tel: 514-276-5138 (Montreal)

Xxx road
Wemindji, Qc
Tel: xxx-xxx-xxxx (Wemindji)

Supervisor:
Renee Sieber, McGill University
Department of Geography
renee.sieber@mcgill.ca
Tel: (514)398-4941 or 4583

Appendix I: Ethics Forms

McGill

Research Ethics Board Office
McGill University
845 Sherbrooke Street West
James Administration Bldg., rm 419
Montreal, QC H3A 2T5

Tel: (514) 398-6831
Fax: (514) 398-4644
Ethics website: www.mcgill.ca/research/compliance/human/

Research Ethics Board I
Certificate of Ethical Acceptability of Research Involving Humans

REB File #: 229-0506

Project Title: Wemindji Cree Spatial Ontology

Principal Investigator: Christopher Wellen **Department:** Geography

Status: Master's student **Supervisor:** Prof. R. Sieber

Granting Agency and Title (if applicable): SSHRC/CURE; SSHRC/Aboriginal research (PI-C. Scott); SSHRC/Northern research development program - Creating a culturally appropriate terrestrial and marine protected area in Paakumshumwaau, QC

This project was reviewed on May 30, 2006 by

Expedited Review ✓
Full Review ____

Elaine Weiner, Ph.D.
Acting Chair, REB I

Approval Period: June 2, 2006 **to** June 1, 2007

This project was reviewed and approved in accordance with the requirements of the McGill University Policy on the Ethical Conduct of Research Involving Human Subjects and with the Tri-Council Policy Statement: Ethical Conduct For Research Involving Humans

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*All research involving human subjects requires review on an annual basis. A Request for Renewal form should be submitted at least one month before the above expiry date.

*If a project has been completed or terminated and ethics approval is no longer required, a Final Report form must be submitted.

*Should any modification or other unanticipated development occur before the next required review, the REB must be informed and any modification can't be initiated until approval is received.

cc: Prof. R. Sieber

McGill University

ETHICS REVIEW
RENEWAL REQUEST/FINAL REPORT

Continuing review of human subjects research requires, at a minimum, the submission of an annual status report to the REB. This form must be completed to request renewal of ethics approval. If a renewal is not received before the expiry date, the project is considered no longer approved and no further research activity may be conducted. When a project has been completed, this form can also be used as a Final Report, which is required to properly close a file. To avoid expired approvals and, in the case of funded projects, the freezing of funds, this form should be returned 3-4 weeks before the current approval expires.

REB File #: 229 - 0506
Project Title: Wemindji Cree Spatial Ontology
Principal Investigator: Christopher Wellen
Department/Phone/Email: 514-905-9476
Faculty Supervisor (for student PI): Dr. Renee Sieber

1. Were there any significant changes made to this research project that have any ethical implications? _X_ Yes ____ No
   If yes, describe these changes and append any relevant documents that have been revised.

The survey concerning children's access to the internet was dropped.

2. Are there any ethical concerns that arose during the course of this research? ___ Yes __X_ No. If yes, please describe.

3. Have any subjects experienced any adverse events in connection with this research project? ___ Yes _X_ No
   If yes, please describe.

4. __X__ This is a request for renewal of ethics approval.

5. ____ This project is no longer active and ethics approval is no longer required.

6. List all current funding sources for this project and the corresponding project titles **if not exactly the same as the project** title above. Indicate the Principal Investigator of the award if not yourself.

SSHRC/CURA – Creating a culturally-appropriate terrestrial and marine protected area in Paakumshumwaau, Quebec. PI: Colin Scott
FOAPAL: 207981-00094-2000

SSHRC/Aboriginal Research - Creating a culturally-appropriate terrestrial and marine protected area in Paakumshumwaau, Quebec. PI: Colin Scott
FOAPAL: 207889-00094-2000

SSHRC/Northern Research Development Program - Creating a culturally-appropriate terrestrial and marine protected area in Paakumshumwaau, Quebec. PI: Colin Scott
FOAPAL: 206693-00094-2000

Principal Investigator Signature: [signature] Date: May 15, 2007

Faculty Supervisor Signature: [signature] Date: MAY 14, 2007
(for student PI)

Submit to Lynda McNeil, Research Ethics Officer, James Administration Bldg., rm 419, fax: 398-4644 tel:398-6831

(version October 2002)

For Administrative Use	**REB:** ___AGR ___EDU ✓ REB-I ___REB-II

____ The closing report of this terminated project has been reviewed and accepted

✓ The continuing review for this project has been reviewed and approved

✓ Expedited Review ____ Full Review

Signature of REB Chair or designate: L McNeil Date: May 29, 2007

Approval Period: June 2, 2007 to June 1, 2008

McGill University

ETHICS REVIEW
RENEWAL REQUEST/FINAL REPORT

Continuing review of human subject research requires, at a minimum, the submission of an annual status report to the REB. This form must be completed to request renewal of ethics approval. If a renewal is not received before the expiry date, the project is considered no longer approved and no further research activity may be conducted. When a project has been completed, this form can also be used as a Final Report, which is required to properly close a file. To avoid expired approvals and, in the case of funded projects, the freezing of funds, this form should be returned 3-4 weeks before the current approval expires.

REB File #: 229-0506
Project Title: Wemindji Cree Spatial Ontology
Principal Investigator: Christopher Wellen
Department/Phone/Email: Christopher.wellen@mail.mcgill.ca
Faculty Supervisor (for student PI): Renee Sieber

1. Were there any significant changes made to this research project that have any ethical implications? ___Yes __X__No
   If yes, describe these changes and append any relevant documents that have been revised.

2. Are there any ethical concerns that arose during the course of this research? ___ Yes _X_ No. If yes, please describe.

3. Have any subjects experienced any adverse events in connection with this research project? ___ Yes _X_ No
   If yes, please describe.

4. ____ This is a request for renewal of ethics approval.

5. _X_ This project is no longer active and ethics approval is no longer required.

6. List all current funding sources for this project and the corresponding project titles **if not exactly the same** as the project title above. Indicate the Principal Investigator of the award if not yourself.

Principal Investigator Signature: [signature] Date: March 31, 2008

Faculty Supervisor Signature: [signature] Date: March 31, 2008
(for student PI)

For Administrative Use **REB:** ✓ REB-I ___REB-II ___REB-III

✓ The closing report of this terminated project has been reviewed and accepted

____ The continuing review for this project has been reviewed and approved

____ Expedited Review ____ Full Review

Signature of REB Chair or designate: [signature] Date: April 8, 2008

Approval Period: ________________ to ________________

******NOTE NEW MAILING ADDRESS******
Submit to Lynda McNeil, Research Ethics Officer, 1555 Peel Street, 11th floor, fax: 398-4644 tel:398-6831

(version 12/07)