SCIENCE EDUCATION FOR ENVIRONMENTAL SUSTAINABILITY:

A CASE STUDY OF THE PALOUSE WATERSHED

By

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To the faculty of Washington State University:

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Abstract

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This study uses case study and qualitative content analysis methodologies to answer the question: What is the relationship between Washington State's k-12 science education standards and the environmental sustainability needs of the Palouse River Watershed? After defining the Palouse Watershed's attributes, the author presents a land use history of the Palouse from prehistory to the present. Investigation of Palouse land, air, and water issues revealed that the Palouse Watershed is one of the most damaged ecosystems in the United States. Current efforts at restoring environmental quality in the Palouse were considered along with unaddressed environmental needs. Twenty-seven restorative and educative strategies were elucidated and later employed in a qualitative content analysis of Washington State's 58 k-12 science education standards. Content analysis revealed that only two of 58 science standards have content that is connected with preparing students to address the actual environmental sustainability needs of the Palouse Watershed.

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CHAPTER ONE

INTRODUCTION

The central problem addressed in this study is that science education in Washington State's schools is driven by the science portion of the Washington Assessment of Student Learning, or WASL. The problem with WASL-driven science instruction is that if the WASL and its associated k-12 science education standards fail to prepare students to live sustainably in the places they occupy, those same students leave the k-12 system unprepared to meet the complicated challenges of adult life, such as habitat loss, pollution, and population growth. Preparing Washington students to live sustainably should be an important priority since some ecosystems in our state are plagued by persistent problems such as topsoil loss, mass run-off of chemical fertilizers into watersheds, and the invasion and proliferation of non-native vegetation (Duffin, 2007).

Sustainability will be rigorously defined in Chapter Two. For the time being, I offer a definition from the Washington State Department of Ecology's (2007) *A Field Guide to Sustainability*:

> Sustainability is a holistic approach to living and problem-solving that addresses social equity, environmental health, and economic prosperity. To be sustainable, the economy must support a high quality of life for all people in a way that protects our health, our limited natural resources, and our environment over the long term (p. 1).

Purpose

The purpose of this inquiry is threefold: 1) to present a case study of the environmental sustainability needs of the Palouse Watershed portion of the Palouse Bioregion, 2) to examine Washington State's k-12 science education standards for content related to the sustainability needs of the Palouse, and 3) to offer analysis on the effectiveness of the Washington State science education standards at meeting the environmental sustainability needs of the Palouse. It is important to acknowledge at the outset that this report is primarily focused on the environmental aspects of sustainability. Economic and social equity aspects of sustainability are important parts of a comprehensive vision for sustainability, nevertheless, I have chosen to focus on environmental sustainability because, as a biologist, I am best prepared to offer a solid analysis working from within my own area of expertise. Since this report focuses primarily on the biological aspects of sustainability in the Palouse it follows that it is not a complete picture of the sustainability needs of the Palouse Watershed and Bioregion.

This report is framed around the concepts of bioregion and watershed. The bioregion concept, popularized by Peter Berg and Raymond Dasmann in the 1970s, is integral to this inquiry. A bioregion is "an area constituting a natural ecological community with characteristic flora, fauna, and environmental conditions [which is] bounded by natural rather than artificial borders" (Kleinedler, 2005, p. 385). This report is primarily concerned with the 3,280 square mile subset of the Palouse Bioregion known as the Palouse River Watershed. I have chosen to focus my examination on the Palouse Watershed because, as Saul

(1996) says, “Rivers and streams indicate the health of the land. If erosion, or pollution, or development causes problems in the landscape, rivers and streams reflect these problems with poor water quality and reduced ecological functions” (p. 2). A watershed is defined as “a body of land bounded above by a ridge or water divide and below by a level at which the water drains from the basin” (Smith & Smith, 2001, p. 645). In terms of science education, this investigation focuses on the December 14, 2008 draft science education standards which were obtained from the Office of the Superintendent of Public Instruction’s website:

http://www.k12.wa.us/CurriculumInstruct/Science/StandardsRevision.aspx

Research Questions

The primary question of this dissertation is: What is the relationship between the environmental sustainability needs of the Palouse Watershed and Washington State’s k-12 science education standards? Several corollary questions follow from this central question:

- What is sustainability?
- What is science education for environmental sustainability?
- What are the environmental sustainability needs of the Palouse Watershed?
- Which Washington State science education standards have content that is connected with the environmental sustainability needs of the Palouse?

- How effective are Washington State's k-12 science education standards at preparing students to address the environmental sustainability needs of the Palouse?
- What are the implications of this study for educational policy and practice in Washington State?

Theoretical Framework and Positionality

I openly acknowledge that my work as a researcher of education is flavored by my own education and experience. I am a classically-trained biologist that is firmly rooted in the scientific method yet I acknowledge that the positivistic approach I learned as an undergraduate is but one of many ways available to me as a scholar trying to make sense of the world. I am biased by the belief that education should empower students to live sustainably in the places they occupy (Greenwood, 2003; Sobel, 2004). The theoretical underpinnings of my conceptual framework are based in the literature of sustainability and in my own experiential understanding of education for environmental sustainability.

I first became intellectually aware of this approach to education through my enrollment in a pre-service teacher education course in family, school, and community collaboration at Washington State University in 2002. Education for sustainability, also called place-based education, connected with my own lived experience as a young person growing up in upstate New York in the 1960s and 70s. My experiences in 4-H Club (a US agricultural education program), Boy Scouts of America, and as a student at Wood Road Intermediate School were deeply rooted in the place where I lived: Ballston Spa, New York.

Epistemologically, I am connected with multiple traditions. I believe that Darwin's (1995) positivist theory of natural selection accurately describes the evolutionary processes I have witnessed in my work as a biologist. I affirm the praxis-oriented critical pedagogy of Freire (1970/1990), who asserted that experience is situational and is tied to specific geographic places. I connect epistemologically with Urrieta (2003), who writes about Latino/a identity to help his students work towards reinhabitation of self and community. Similarly, I am rooted to Haymes (1995), who used critical geography to help students of color decolonize themselves from their own geographic oppression. I share a need with Brandt (2004), Barnhardt (2008), and Sorensen (2008) to recognize the importance of indigenous knowledge in k-20 education. My epistemology, like education for sustainability itself, is rooted in diverse traditions that speak to the need to educate from a perspective that is responsive to the needs of particular places.

Methodological Framework

I have chosen to employ a mixed-method approach in this work because answering my research questions requires the use of multiple methodologies (Creswell & Plano Clark, 2007). I employ case study methodology in the preparation of a descriptive case study focused on identifying the environmental sustainability needs of the Palouse Watershed portion of the Palouse Bioregion (Yin, 1994). I then employ content analysis of Washington State's k-12 science education standards to contextualize the science learning outcomes within the environmental sustainability needs of the Palouse Watershed. I chose to focus the sustainability content analysis on Washington's science education standards because a survey of 1,323 Washington teachers reported that education for sustainability is most often taught in science courses (Office of the Superintendent of Public Instruction, 2008a). It is important to acknowledge at the outset, however, that I envision education for sustainability as a discourse and practice that needs to be inclusive of all disciplines, not just science (Orr, 1992).

Content analysis in the tradition of Lasswell, (1935), Berelson (1952), Krippendorff (2004) and Neuendorf (2002) has a long history rooted in the elucidation of inferences from the systematic analysis of diverse types of messages, including written text, oral communications, movies and television programs. Content analysis of Washington's science education standards can provide multiple types of data, including, frequency of sustainability terms and sorting of frequency data by grade band, core content statement, content standard and performance expectations. This analysis of empirical materials offers me the possibility of connecting directly with the object of my investigation (Washington's science education standards) in a way that might not be achieved indirectly though qualitative interviews and other methodologies (Krippendorff, 2004).

Significance

This inquiry is significant for several reasons. First, it is intended to inform educational policy and practice at the state and local level in Washington State. Employees of Washington's Office of the Superintendant of Public Instruction have been working to create a teaching endorsement in sustainability education. This new endorsement demonstrates that sustainability is a topic of concern and relevance for at least some segment of OSPI. It is my hope that a detailed analysis of the sustainability content of the science education standards in relation to the sustainability needs of the Palouse Watershed will augment and inform sustainability discussions occurring at the state level. Furthermore, as an educator committed to place, it is my desire to contextualize the results of this work within the needs and resources of my own local place – the Palouse Watershed. I provide a case study of the environmental sustainability needs of the Palouse Watershed for the purpose of comparing Washington State's science learning targets with the actual needs of this place. Knowing how well Washington State's science education standards prepare students for living sustainably is critical knowledge for those that want to understand the intersection between education and sustainable living in the Palouse. This work is also important because it can serve as a model for educators wanting to understand the relationship between education and the environmental sustainability needs of places far removed from the Palouse.

CHAPTER TWO

LITERATURE REVIEW

This literature review serves the dual purpose of introducing and defining sustainability and education that is connected to the pursuit of sustainable living. Sustainability has been defined in a multitude of ways, often variously in connection with economic development, social justice and equity. Because sustainability definitions are so variable, it is important to rigorously define sustainability before connecting sustainability with science education. After defining sustainability, I present a review of literature grounded in *education for sustainability* (EFS). I query the issues and challenges associated with EFS literature and practice, and propose an operational definition for sustainability.

Sustainability

The research problems that are addressed in this investigation are approached from the perspective of sustainability. In this section, I discuss the history of the sustainability movement by looking at the work of three international groups / commissions convened to explore and define sustainability: the Brundtland Commission, the Earth Summits, and the Earth Charter. The act of defining sustainability is problematized and the section closes with an examination of three natural limitations of the sustainability concept.

Defining Sustainability

Several high-profile international organizations have gathered to discuss and define sustainability in the last twenty years. The most often cited definition of sustainability comes from the 1987 report from the World Commission on Environment and Development, also known as the Brundtland Commission (Our Common Future, 1987). The Brundtland commission sought to define environmental sustainability and development as a single, indivisible issue and thus authored the following definition, “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Our Common Future, 1987, p. 43). The Brundtland Commission recognized that many crises facing the planet are complex and “interlocking” and in so doing set the stage for the 1992 Earth Summit.

The Earth Summit

The 1992 Earth Summit, held in Rio de Janeiro, Brazil, convened when over 170 heads-of-state met to discuss environmental protection and socio-economic development. At the conclusion of the summit, participants signed the *Convention on Climate Change* and *Convention on Biological Diversity*, endorsed the *Rio Declaration*, and adopted *Agenda 21*, a 900-page plan for achieving sustainable development in the 21st century. The *Rio Declaration* contained 27 principles designed to guide sustainable development world-wide, whereas, *Agenda 21* laid out a detailed blueprint for balancing environmental protection and development globally, nationally, and locally. The Earth Summit also produced the United Nations Commission on Sustainable Development (CSD) which functions to monitor and report on the implementation of sustainability efforts by member nations and organizations. A five year review of the 1992

Earth Summit, dubbed *Earth Summit +5*, met in New York in 1997 when the United Nations General Assembly convened a special session to evaluate problems and progress associated with the *Rio Declaration*. Five years later, *Earth Summit +10* convened in Johannesburg, South Africa with the goal of broadening the sustainability debate and encouraging partnerships between government, business, and non-government organizations or NGOs. Reports at both five and ten year intervals showed very little progress by member nations and organizations in adopting the principles of sustainability embodied in the *Rio Declaration* and *Agenda 21*.

A Critique on the Brundtland Commission Report and Agenda 21

I take issue with the goals of the Brundtland Commission and the *Rio Declaration/Agenda 21*. First, the couplet sustainable development is an "oxymoron – a self-contained non sequitur between noun and modifier" (Disinger, 1990, p. 3). Furthermore, pairing sustainability with development creates a "conceptual muddle" where the fox [development] is companion to its prey [the environment] (Jickling, 1994). To be blunt, this pairing fails to recognize the long-term gutting of the environment by governments, corporations, and individual developers more intent on development and profitability than sustainable practices.

My second problem with sustainable development is that Brundtland and *Rio* / *Agenda 21* call for more discipline-specific environmental education as a means of efficaciously achieving environmental sustainability. As Greenwood (2004) showed, environmental education as a school discipline "is easily ignored and can be stripped of its revolutionary political content as it becomes constituted as disciplinary practice" (p. 95). Furthermore, as was mentioned previously, reports from *Earth Summit +5* and *+10* showed very little progress using *Agenda 21's* strategies for sustainable development, one of which was an increased focus on environmental education.

The Earth Charter

In 1994, former Soviet leader, Mikhail Gorbachev, and Secretary-General of the Rio Summit, Maurice Strong, convened an independent commission to author a document that embodied a global consensus statement on the meaning of sustainability. That consensus statement came to be known in 2000 as the *Earth Charter*. In contrast to Brundtland and *Agenda 21's* focus on sustainable development, the Earth Charter calls for humanity to join together to bring forth a sustainable global society founded on several themes: respect and care for the community of life**,** ecological integrity, social and economic justice, democracy, nonviolence, and peace. (The Earth Charter, 2008). The Earth Charter points to the evolution of the sustainability concept, particularly with respect to the inclusion of social and economic justice components. This is important to note since many of the leaders associated with the Earth Charter had been involved with the Brundtland Commission and Earth Summits. The Earth Charter is composed of 16 principles that convey a comprehensive vision for sustainability:

I. Respect and care for the community of life

1. Respect Earth and life in all its diversity.
2. Care for the community of life with understanding, compassion,

and love.

3. Build democratic societies that are just, participatory, sustainable, and peaceful.
4. Secure Earth's bounty and beauty for present and future generations.

II. Ecological integrity

5. Protect and restore the integrity of Earth's ecological systems, with special concern for biological diversity and the natural processes that sustain life.
6. Prevent harm as the best method of environmental protection and, when knowledge is limited, apply a precautionary approach.
7. Adopt patterns of production, consumption, and reproduction that safeguard Earth's regenerative capacities, human rights, and community well-being.
8. Advance the study of ecological sustainability and promote the open exchange and wide application of the knowledge acquired.

III. Social and economic justice

9. Eradicate poverty as an ethical, social, and environmental imperative.
10. Ensure that economic activities and institutions at all levels promote human development in an equitable and sustainable manner.
11. Affirm gender equality and equity as prerequisites to sustainable

development and ensure universal access to education, health care, and economic opportunity.

12. Uphold the right of all, without discrimination, to a natural and social environment supportive of human dignity, bodily health, and spiritual well-being, with special attention to the rights of indigenous peoples and minorities.

IV. Democracy, nonviolence, and peace

13. Strengthen democratic institutions at all levels, and provide transparency and accountability in governance, inclusive participation in decision making, and access to justice.
14. Integrate into formal education and life-long learning the knowledge, values, and skills needed for a sustainable way of life.
15. Treat all living beings with respect and consideration.
16. Promote a culture of tolerance, nonviolence, and peace (p. 1-3).

The Earth Charter stands apart from earlier efforts at defining and working towards sustainability because it “is founded on the principle that caring for the earth and caring for people are two dimensions of the same task” (Greenwood, 2004, p. 96). I believe this charter possesses the power to challenge the dominant paradigm of economic development as the yardstick for individual, community, national, and global progress. Next, I continue the discussion of sustainability by looking at natural limitations of the sustainability concept.

Natural Constraints of the Sustainability Concept

In this section, I consider sustainability from the perspective of three concepts: community succession, evolution via natural selection, and bio-geologic events. I connect the discussion to Palouse wheat farming practices to show how sustainability, from a natural, bio-geological perspective, is a little like aiming at a moving target. This section closes with a call for including these constraints on sustainability in considerations of local sustainability.

I approach the study of sustainability as a biologist, with the recognition that perpetual growth of any kind only occurs when organisms or systems are out of balance (Campbell, Reece & Mitchell, 1999). For example, cancer occurs in the human body when mechanisms regulating cell division fail to properly function. Uncontrolled cellular proliferation under such circumstances often results in the death of the organism. On a system level, when nitrogen-based fertilizers wash from streams into standing bodies of water an algal bloom can result because nitrogen is often to the only resource limiting algal population growth. As algae live and die by the billions, decomposing bacteria thrive in similar numbers which reduces the amount of dissolved oxygen in the water resulting in the collapse of the local food chain and a body of water that is essentially devoid of life (Leonard & Penick, 2003).

Should the concept of sustainability embody the notion that human pursuits, such as wheat farming on the Palouse, can be done in perpetuity? I believe that to commit to do so is to act against what is observed in biological systems. Biological succession is a process that communities of organisms undergo in response to environmental changes due to climate, fire, wind, and other factors (Smith & Smith, 2001). Succession tells us that microbial, plant, and animal communities are constantly changing in response to differing environmental stimuli. As was mentioned above, sustainability, in a sense then, is like focusing on a moving target. A brief look at Palouse agriculture illustrates this point.

The agricultural productivity that has been the bedrock of the Palouse economy for more than a century is the result of the deposition of wind-blown loess soils that stopped accumulating locally more than 10,000 years ago (Duffin, 2007). That fact alone is of obvious import to the implementation of long-term sustainable farm practices on the Palouse. Intensive wheat farming on the steep slopes of the Palouse has resulted in phenomenal loss of top soil, often exceeding 50 tons per acre per year (Duffin, 2007). In addition to top soil loss, according to Campbell, Reece and Mitchell (1999), "to grow a ton of wheat, the soil gives up 18.2 kg of nitrogen, 3.6 kg of phosphorus, and 4.1 kg of potassium" (p. 718). Palouse crop yields started to decline as early as the 1940s due in large part to the loss of the above three elements from local fields. In light of such information, I argue that human and natural processes, like succession, need to be taken into consideration when investigating sustainability in local places.

Another biological concept that is cogent to this discussion is evolution through natural selection. Since Darwin, we have understood that biological organisms and systems are in constant flux as they respond to external stimuli (Freeman & Herron, 2001). On the Galapagos Islands, Darwin and his successors observed that beak lengths of different generations of finches changed over time in response to the availability of different types of food sources. In dry years, finches with long beaks had a higher rate of reproductive success than finches with shorter beaks because the long-beaked birds could open a wider variety of food-stuffs. The lesson here, as with succession, is that generations of organisms are constantly changing in response to other organisms and their shared physical environment. I believe that that it is important to recognize the biological limitations of sustainability in order to create a more-highly developed and realistic view of sustainability. In local places, this means cultivating awareness for recognizing natural, as well as, human-caused agents of change when defining sustainability for unique biological and physical places such as the Palouse.

A third constraint on the concept of sustainability occurs in bio-geological events that have a history of repeating in the Palouse. I cite three examples: The Great Missoula Floods, ice age events, and volcanic events. The Great Missoula Floods roared through areas west of the Palouse as many as 50 times from 20, 000 – 12,000 years ago producing spectacular geological sites such as Dry Falls, WA, the Channeled Scablands east of Ephrata, WA, and hundreds of small lakes called “potholes” just south of Moses Lake, WA (Duffin, 2007). The Great Missoula Floods routinely washed the rich loess soils of the western expanses of the Palouse into the Columbia River. Other types of bio-geologic events have shaped the Palouse over the millennia and continue to shape this place. Ice ages tend to occur periodically at this latitude. The last one, at the end of the Pleistocene Era, melted from the Palouse less than 20,000 years ago; in geologic time that is less than the blink of the proverbial eye. Ice ages were responsible for mass extinctions where up to 90% of all forms of life perished in repeated intervals in Earth history (Smith & Smith, 2001). A formidable series of volcanoes to the west of the Palouse and the world's largest super-volcano to the east in Yellowstone National Park promise challenges to sustainability in the future; we just don't know how soon. One thing that seems certain is that global climate change is underway again and the question for the purpose of local sustainability is: How will climate change alter the productivity of Palouse farms; the bedrock of the local economy (Duffin, 2007). In the next section, I move from a consideration of the natural limitations of sustainability to the definition of sustainability that will be employed in the remainder of this inquiry.

An operational definition of sustainability

Several groups have worked since 1987 to understand and define sustainability. The Brundtland Commission and the Earth Summits tied sustainability to economic development, a mistake in my view because of the reasons cited previously. The Earth Charter (2008), on the other hand, provides a more complete definition of sustainability as it relates to social and economic justice. I embrace the Earth Charter's plan for achieving a sustainable global society through attention to respect and care for the community of life**,** ecological integrity, social and economic justice, as well as, democracy, nonviolence, and peace. I recognize that the Earth Charter is merely an idea rooted in group consensus. It is not a law and thus is not enforceable. In spite of this, I agree with Greenwood (2004) who asserts that the Earth Charter has great potential for “interrupting our discourse, and to challenge our norms and routines with a comprehensive, socio-ecological vision for society and education” (p. 100).

In reflecting upon the multiple views of sustainability offered by Brundtland, the Earth Summits and the Earth Charter, I embrace the sustainability definition offered by the Washington State Department of Ecology (2007) for this work because it expresses what I believe to be the best of each of its aforementioned predecessors with respect to long-term planning, ecosystem health, and issues of social justice and equity:

> Sustainability is a holistic approach to living and problem-solving that addresses social equity, environmental health, and economic prosperity. To be sustainable, the economy must support a high quality of life for all people in a way that protects our [collective] health, our [collective] limited natural resources, and our environment over the long term (p. 1).

The Washington State Department of Ecology’s (2007) *A Field Guide to Sustainability* expands upon the above definition in identifying the four key principles of sustainability that are:

1. Whole-system thinking
2. Long-term thinking
3. Recognizing limits
4. Improving livelihoods

Whole-system thinking refers to making sense of phenomena and experience through the merging of social, environmental, and economic forms of knowledge into a coherent and complex understanding. *Long-term thinking* focuses on understanding the results of decisions and actions over time. In the spirit of the Iroquois, *long-term thinking* compels one to consider consequences for seven generations hence. *Recognizing limits* acknowledges that all forms of life depend on healthy, functioning ecosystems while *improving livelihoods* is concerned with equitably raising the quality of life for current and future generations without compromising ecological health. When considered together, these four principles of sustainability point to the need for an educated populace that can think into the future about very tangled and complex issues that are only partially understood by experts.

As was mentioned in Chapter One, this report focuses primarily on the environmental aspects of sustainability. I acknowledge that economic and social equity aspects of sustainability are important parts of a comprehensive vision for sustainability, but they are, unfortunately, beyond the scope of this author's expertise and personal constraints. Adapting Washington State's Department of Ecology definition for this work results in the following definition:

> Environmental sustainability is a holistic approach to living and problem-solving that addresses environmental health. To be sustainable, we must protect our collective health, our collective limited natural resources, and our environment over the long term.

The implications for education for sustainability, the subject of this investigation, are huge because students in this milieu need more than the currently-advocated introduction to basic science literacy to understand how complex systems work individually and in combination with other systems.

Sustainability: In Conclusion

In this section, the history of the sustainability movement has been explored and the term sustainability has been defined with reference to the Earth Charter and other documents rooted in sustainability. Three natural constraints on local sustainability were examined: community succession, evolution through natural selection, and bio-geological events. Sustainability was defined with respect to the environmental focus of this report. In the next section, sustainability is examined from the perspective of education.

Education for Sustainability

Education for sustainability (EFS) is defined in this section. Then, the history of EFS is considered, along with examples of EFS practice. Educating for sustainability is differentiated from environmental education and the section closes with a consideration of several constraints on this form of educational practice.

Educating and empowering people to efficaciously address environmental challenges indefinitely is the challenge of educating for sustainability. By extension, educating for sustainability should equip students with the skills necessary to meet the four key principles of sustainability that are part of Washington State Department of Ecology's (2007) definition of sustainability:

1. Whole-system thinking
2. Long-term thinking

3. Recognizing limits
4. Improving livelihoods

Education centered in preparing people to live sustainability should then provide an abundance of opportunities for learners to explore complex issues that involve both whole systems and multiple systems. For example, there is a finite amount of water available in any watershed. In order to sustainably address watershed needs with respect to environmental health, learners need to understand aquifer use and recharge rates, point-source and non-point source pollution, land and water use history, and urban and rural development to name just a few types of learning needs. In order for water use to be sustainable in the long term, it would be essential to know how much water is available to a particular place, the sources of that water, precipitation patterns, population dynamics with respect to multiple species of life, as well as, the history and contemporary issues associated with water use and distribution.

In consideration of these issues, using the Washington State Department of Ecology's definition of sustainability as the foundation for defining education for the purpose of achieving sustainability, I offer the following as a definition of education for sustainability:

> Education for sustainability is a holistic approach to education and problem-solving that empowers students to efficaciously address environmental health for the long term needs of bioregions and watersheds through whole-system thinking, long-term thinking, recognizing limits, and improving livelihoods.

This definition requires complex multidisciplinary understanding on the part of the learner that goes beyond the common practice of educating via the traditional separate disciplines of biology, economics, social studies, and so on. Furthermore, this definition acknowledges the need to give learners the practical, problem-solving experiences necessary to address issues in the home places of the learner. In the next section, I consider some of the many names used in the literature to describe education rooted in local sustainability.

I have made the conscious choice to inscribe my approach to this work with the label *education for sustainability* (EFS) because I feel this terminology best describes the potential for healthy relationships between schools and the places that support them. A 2004 survey of Vermont educators who are practitioners of education centered in local needs revealed that more than 35 different terms were used to describe “curriculum that is grounded in local issues” (Jennings, Swidler, & Koliba, 2005, p. 55). Others have called this approach to teaching and learning community-based education (Knapp, 1996), critical pedagogy of place (Greenwood, 2003), education for eco-justice (Bowers, 2001), new localism (Cameron, 2008), place-based education (Smith, 2002b; Sobel, 2004), outdoor education (Lyman, 2004), and sustainability education (Higgs & McMillan, 2006; Sterling, 1996). For the sake of clarity, it is important to recognize that while there are significant philosophical and epistemological differences between critical pedagogues centered in place and educators for eco-justice, (Bowers, 2005; Greenwood, 2005a) the underlying theme of these variations on sustainability education is empowering students to live well in the places they occupy.

In its simplest form, education for sustainability is teaching and learning that empowers students to live sustainably in their communities and physical places (Sobel, 2004). According to Greenwood (2008), “All education prior to the invention of the common school was place-based” (p. 1). Types of early EFS exist today in the form of apprenticeships and internships.

In contemporary terms, the concept of education centered in the needs of place first appears in 1967 in a *Harvard Educational Review* article by Newman and Oliver. According to veteran environmental educator Clifford Knapp, the duo recommended that education should be approached “in community” from three entry points: the school itself, a studio-laboratory, and through community seminars (Knapp, 2008, p. 6). Greenwood (2003a, 2008) recently demonstrated that k-20 educators claiming place as a guiding construct hail from science education (Senechal, 2008; Woodhouse & Knapp, 2000), art education (Graham, 2007), social studies education (Bartsch, 2008), and indigenous education (Barnhardt, 2008; Sorenson, 2008).

Examples of Education for Sustainability

Education for sustainability is based in the idea of empowering students to address the unique needs of individual places so it takes many forms. In Maine, the loss of traditional economies based in timber, textiles, and military bases has resulted in the out-migration of many of Maine’s young people. Place-based educator Julie Bartsch (2008) works with The Rural School and Community Trust to connect students with the local by documenting and reporting area histories using cutting-edge technologies. Students learn marketable skills that can lead to meaningful local employment.

Science teacher Elaine Senechal (2008) anchors science teaching and learning in the context of her school's urban community with a sustainability focus on air and environmental quality. Utilizing state-of-the-art air-quality monitoring technology, Senechal and her students challenged bus idling practices resulting in new legislation improving local air quality. Senechal and her students went on to successfully fight the installation of a biohazard laboratory planned for location within their community.

In Alaska, Ray Barnhardt (2008) works with the Alaska Rural Systemic Initiative to integrate indigenous knowledge systems into the entire k-12 curriculum. Village and city elders work side-by-side with teachers and administrators to plan, teach, and reflect on robust locally-centered teaching and learning. The result is a pedagogy of place that shifts the focus from teaching about culture to teaching "through culture" (Barnhardt, 2007, p. 113). Students learn in an environment that openly acknowledges the complexity of living in two worlds: native and generic, media-produced Americana. The result is a paradigm shift that recognizes a complex learning system involving traditional ways of knowing in a complementary relationship with contemporary scientific practice.

John Cameron (2008) has been practicing what he calls "new localism" in Australia since 1983. A former professional environmentalist, Cameron was instrumental in the creation of Australia's Sense of Place Colloquium. Cameron's approach to place-based education combines of awareness of one's own locality with traditional Aboriginal teachings on ecology and stewardship. His systematized approach to place-based instruction initiates students into place with field-based experiences of the local, followed by environmental and social justice projects in the greater community and farther out in the Australian bush country.

Comparing EFS and Environmental Education

Education for sustainability is distinguished from environmental education in two important ways. First, EFS is not an academic discipline; it is an approach to teaching and learning that transverses and unites the disciplines through cross-disciplinary collaboration. Environmental education, on the other hand, is a discipline in-and-of itself, and, as such, is susceptible to disciplinary practice (Foucault, 1977). Greenwood (2004) argues that the Foucauldian self-disciplining of environmental education serves to "weaken the potentiality of environmental education's transformative discourse" through subtle-but-effective conformity to the norms and routines of school (p. 79). Conversely, EFS is an approach to teaching and learning that empowers teachers and students working from within multiple disciplines in collaboration with community to apply learning to the sustainability needs of local places.

A second way that EFS differs from environmental education involves worldview. The environmental focus of environmental education can be exclusionary. For example, in historic practice, environmental education has been implicated in situations that have protected places at the expense of indigenous people – often the people most connected to the land (Nabhan, 1997). EFS is grounded in the assumption that sustainability needs to be inclusive of the environmental and cultural needs of local places and peoples. Barnhardt (2008) and Brandt (2004) accomplish this in their academic work that is inclusive of positivist-oriented science and indigenous knowledge sources.

Issues and Challenges for EFS Practitioners

There are several challenges to the implementation of educational practices rooted in sustainability. Environmental educator Bob Stevenson (1987) calls these challenges constraining regularities. His thesis is that there is a fundamental disconnect in the way schools operate that creates a form of social inertia that interferes with the adoption of progressive educational practices like educating for sustainability. Drawing upon the work of Stevenson (1987), Greg Smith (2007) identifies constraining regularities that could be instrumental in inhibiting the practice of educating for sustainability:

- The prescription to present standardized forms of knowledge associated with state and national learning standards
- An over-reliance on teachers as primary information sources
- The use of assessment procedures based on ease-of-marking and justification
- School policies centered in student control of movement, expression, and learning style

These constraining regularities are worth exploring in further detail because they are grounded in the experiences and understanding of Greg Smith, a sustainability educator with over 30 years of experience mentoring and learning from others dedicated to EFS. Smith acknowledges the role that prescribed learning standards play in distracting educators from educating for sustainability. At the time of this writing, 47 of the 50 United States have state learning standards in accordance with the requirements of The No Child Left Behind Act of 2001 (NCLB). NCLB was signed into law by President George W. Bush in January, 2002. By the US government's own admission, NCLB marked the most sweeping reform in the thirty-six year history of the Elementary and Secondary Education Act. NCLB promises to close the achievement gap between materially-disadvantaged students and students with material abundance by 2014. This law mandates that students and schools meet adequate yearly progress goals in a package deal that is connected to levels of federal government funding for local education. Furthermore, schools that fail to meet adequate yearly progress goals for five years can be shut down or privatized, with replacement of the entire faculty and administration. For these reasons, under NCLB, if state standards fail to address sustainability then it becomes an uphill battle to encourage the practice of education for sustainability, and, moreover, students are more likely to leave the k-12 system unprepared to meet the challenges of adult life in the places they occupy. This issue is central to the research questions posed in this investigation since it is my intent to examine Washington State's science learning outcomes for content related to the environmental sustainability needs of the Palouse, and, to infer through content analysis (Krippendorff, 2004), the role of local sustainability in Washington State's science learning outcomes.

Smith's second constraining regularity concerns an over-reliance on teachers as primary information sources. Educating for sustainability is a complex process well-beyond the means of individual teachers working from within the isolation of their classrooms. This approach to teaching and learning virtually obligates teachers to make the walls of their classrooms "permeable" to community members with their various expertise's, as well as, to the needs of local places (Smith, 2007, p. 190). I know this personally from my Master's thesis research (Lyman, 2004). I collaborated with soil scientists, a botanist, and a local city planner in my work as a biology student-teacher working with students in a local wetland restoration. I did not possess the expertise needed to give my students a thorough understanding of the complexity of wetland ecosystems so I found those that could provide what I lacked. Smith (2007) recognizes that many teachers are uncomfortable sharing their limited control and authority with community members which ultimately can serve as a barrier to educating for sustainability.

The next constraining regularity involves the use of assessment procedures based on ease-of-marking and justification. Teaching and learning for sustainability is a complex process so assessing this type of learning is likewise complex and not effectively measured by mass-produced, multiple-choice assessments. Teaching and learning for environmental sustainability requires factual knowledge as a starting point to more sophisticated understanding across multiple interacting systems. In the literature connected with EFS, long-term, portfolio research projects are often shown as effective tools for measuring student learning (Smith, 2002a, 2004, 2007). These types of assessments are time-intensive at multiple levels (creating, staging, grading) which obviously could strain already-overworked educators.

School policies centered in student control of movement, expression, and learning style are Smith's final constraining regularity against EFS. I know from personal experience that educating for sustainability goes against the grain of schools as systems-of-control. Foucault (1997) went so far as to compare schools, in their practices, policies, and underlying philosophies, to prisons. As a science and math teacher working in Washington State from 2003-2007, I was routinely challenged by administrators, fellow teachers, and even building custodians for my practice of holding class outside of my classroom at least once per week (Greenwood, 2005). Several schools have made the decision to implement less-restrictive policies to allow for greater permeability between schools and the communities that support them. Portland, Oregon's Sunnyside Environmental School, Molokai's, HI's Kualapu'u school, and Salem, OR's Optimum Learning Environments Charter School all provide a supportive environment for teachers to collaborate within and without the walls of their schools and communities (Smith, 2007).

In considering the constraining regularities that work against educating for sustainability it is reasonable to ask: Why do teachers choose to take this approach? Greenwood (2005) asserts that teachers who embrace educating for sustainability work to a higher set of standards that is inclusive of the ecological and social justice needs of students and the communities that support them.

Sustainability and Education: In Conclusion

This literature review is intended to serve the dual purpose of introducing and defining sustainability and education that is connected to the pursuit of sustainable living. Sustainability was defined in light of several key sustainability documents and my own lived experience. Bio-geologic limitations of the sustainability concept were explored to show how the very idea of sustainability is in contradiction to the long-term history of physical and biological changes on Planet Earth. A review of literature grounded in education for sustainability was presented, along with issues and challenges associated with the practice of educating for sustainability. One of those issues, Smith's (2007) prescription to present standardized forms of knowledge associated with state and national learning standards, was found to be particularly relevant to the central research question posed in this inquiry. In the next chapter, I consider the design of this study and the methodologies that I have chosen to employ to answer my research questions.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

In this chapter, I elaborate on the research design and methodologies employed in pursuit of answers to my research questions. According to Krippendorff (2004), research design is “the network of steps a researcher takes to conduct a research project” (p. 81). Accordingly, my goal herein is to provide a comprehensive narrative account of the important steps in my methodological and theoretical frameworks, as well as, the particulars of the case study and content analysis designs that I propose to use to seek answers to my research questions.

I disclosed my research questions in Chapter One. Be reminded that the primary question of this dissertation is: What is the relationship between the sustainability needs of the Palouse Watershed and Washington State’s k-12 science education standards? Several corollary questions follow from this central question:

- What is sustainability?
- What is science education for environmental sustainability?
- What are the environmental sustainability needs of the Palouse Watershed?
- Which Washington State science standards have content that is connected with the environmental sustainability needs of the Palouse?

- How effective are Washington State’s k-12 science education standards at preparing students to address the environmental sustainability needs of the Palouse?
- What are the implications of this study for educational policy and practice in Washington State?

I answered the first two corollary questions in my literature review in Chapter Two. The remainder of my research questions will be addressed in Chapter Three and answered in the remainder of this dissertation.

Methodological Framework

As was mentioned in Chapter One, I have chosen to employ a mixed-method approach to provide answers to my research questions (Creswell & Plano Clark, 2007). There are many reasons why I believe that a mixed-method approach is justified. First and foremost, the primary question of this dissertation requires the use of multiple methodologies. I will employ case study methodology to describe the environmental sustainability needs of the Palouse Watershed. According to Yin (1994), the unique strength of case study methodology is its “ability to deal with a full variety of evidence - documents, artifacts, interviews, and observations” (p. 8). I hope to draw upon these strengths of case study methodology using documents, interviews, and physical observations to enumerate the environmental sustainability needs of the Palouse Watershed.

I propose answering the following research questions using content analysis methodology:

- Which Washington State science education standards have content that is connected with the environmental sustainability needs of the Palouse?
- How effective are Washington State's k-12 science education standards at preparing students to address the environmental sustainability needs of the Palouse?

I have chosen to employ qualitative content analysis in this study because qualitative techniques, grounded in narrative descriptions, allow me the opportunity to explore the sustainability content in Washington State's science education standards. Qualitative content analysis, referred to as message analysis by Neuendorf (2002), is a broad area of non-statistical content analysis situated in rhetorical analysis (McCroskey, 1993), narrative analysis (Propp, 1968), discourse analysis (Greenwood, 2004), critical analysis (Lyman, 1997) and thematic content analysis (Markel, 1998). I propose analyzing the manifest or surface content (Neuendorf, 2002) of the science education standards with particular a priori focus on how the science education standards align with the identified sustainability needs of the Palouse Watershed (Duffin, 2007).

This analysis of empirical materials offers me the possibility of connecting directly with the object of my investigation (Washington State's science education standards) in a way that might not be achieved indirectly though qualitative interviews and other methodologies (Krippendorff, 2004).

Theoretical Framework

I am biased as a researcher by the passionate belief that k-12 education should empower students to live well and sustainably in the places they occupy (Greenwood, 2003; Sobel, 2004). As I mentioned in Chapter One, I am a classically-trained biologist who is firmly rooted in the scientific method yet I acknowledge that the positivistic approach I learned as an undergraduate is but one of many ways available to me as a scholar trying to make sense of the world.

Epistemologically, I am connected with multiple traditions. I believe that Darwin's (1995) positivist theory of natural selection accurately describes the evolutionary processes I have witnessed in my work as a biologist. I affirm the praxis-oriented critical pedagogy of Paulo Freire (1970/1990), who asserted that experience is situational and is tied to specific geographic places. I connect epistemologically with cultural studies scholar Luis Urrieta, Jr. (2003), who writes about Latina/o identity to help his students work towards reinhabitation of self and community. My epistemology, like education for local sustainability itself, is rooted in diverse traditions that speak to the need to educate from a perspective that is responsive to the needs of particular places. In the next section, I provide a detailed overview of case study research and connect this methodology with my study.

Case Study Methodology

I chose to use case study methodology to describe the environmental sustainability needs of the Palouse after reading two fine books on case study methods: Merriam's (1998) *Qualitative Research and Case Study Applications in*

Education and Yin's (1994) *Case Study Research: Design and Methods* (2^{nd} ed.). According to Merriam (1998), a "qualitative case study is an intensive, holistic description and analysis of a single instance, phenomenon, or social unit (p.27). It is my intention to write a good case study of the environmental sustainability needs of my local place, the Palouse Watershed, and then to tie those needs to Washington State's science education standards. I wish to do this in order to understand the relationship between the needs of this place and the science learning outcomes that are mandated by Washington State for k-12 students. Be reminded that I chose to focus the sustainability content analysis on Washington's science education standards because a survey of 1,323 Washington teachers reported that education for sustainability is most often taught in science courses (Office of the Superintendent of Public Instruction, 2008). It is important to acknowledge at the outset, however, that I envision education for environmental sustainability as an overarching theme that needs to be included in all disciplines, not just science (Orr, 1992).

Yin (1994) describes three types of case studies: exploratory, descriptive, and explanatory. Exploratory case studies are often conducted by researchers as a process tool for elucidating appropriate research questions and strategies. Descriptive case studies, on the other hand, present a detailed account of the phenomena under scrutiny (Merriam, 1998). Historical case studies are often descriptive in that they chronicle sequences of events. Descriptive case studies often employ a descriptive theory as an analytical tool, as in Trochim's (1989) case study which employed pattern-matching as a means of comparing empirically-based patterns with predicted ones. Explanatory case studies are authored for the purpose of explaining phenomena. According to Yin (1994), these case studies should "pose competing explanations for the same set of events" and "indicate how such explanations may apply to other situations" (p. 5).

It is my intention to create a descriptive case study of the sustainability needs of the Palouse Watershed and then to use the case study to examine the relationship between Washington State's k-12 science education standards and the environmental sustainability needs of the Palouse. I elaborate on the particulars of my descriptive case study design after a consideration of the history, benefits, and limitations of case study methodology.

A Brief History of Case Study Research

In peer-reviewed literature, case studies first appear in medical education and sociology literature in the 1930s. William F. Whyte's (1943) seminal *Street Corner Society* is a single descriptive case study of urban youth that defined community sociology for decades. Whyte, a graduate of the University of Chicago's prestigious sociology program, was one of many Chicago School sociologists that popularized case study research. In the field of organizational dynamics, Philip Sleznik's (1949) *Tennessee Valley Authority and the Grass Roots* is recognized as a classic case study of public organizations and organizational behavior. In the 1960s, Strauss and Glaser (1967) built upon Chicago School case study methodology with their development of grounded theory wherein a researcher gathers data and then develops theory to explain the data. Educational researchers have used case study methodology to study many aspects of education, including, school culture, the training of teachers, and program evaluation (Merriam, 1998).

The Purposes of Case Study Research

Case study methodology can fulfill many research purposes. Yin (1994) identifies four:

1. To explain complex causal links in real-life situations
2. To describe the real-life context in which things occur
3. To describe the effect of interventions
4. To explore intervention situations that have no clear set of outcomes

In this study, I choose to employ case study methods to describe the real-life context of the sustainability needs of the Palouse Watershed. I also wish to describe the effect of interventions aimed at addressing the sustainability needs of the Palouse Watershed.

Limitations of Case Study Research

Critics of case study research enumerate several limitations of case study research. Yin (1994) suggests that “the greatest concern has been over the lack of rigor of case study research” because some case study researchers have been “sloppy” and allowed personal bias to factor into findings and conclusions (p. 9). Tellis (1997) points out that some critics of single-case studies operate from the premise that studies involving a single case are “incapable of providing a generalizing conclusion” (p. 3). Yin (1994) responds to such criticism by creating a highly-detailed and rigorous protocol for case study design that satisfies the three tenets of qualitative research (describing, understanding, and explaining) and allows the researcher to engage in analytic generalization of theories as opposed to statistical generalization based in numeric frequencies.

A third concern of critics of case studies is that “they take too long [to complete] and result in massive, unreadable documents” (Yin, 1994, p. 10). Yin (1994) responds by acknowledging that some case studies have been too long in the past and by pointing to confusion by some researchers over the distinction between case study research and similar methods of research rooted in ethnography and participant observation, which are considered in some circles to be too time intensive and produce overly-long reporting documents.

Critics of case study research and single-case studies in particular offer a challenge to case study researchers, such as me, to employ rigorous case study design so that our work can stand side-by-side with the work of our critics (Yin, 1994). It is my goal in this study to satisfy single-case study critics by using a rigorous case study design that draws upon procedures recommended by experts in the field of case study methodology. I outline the design of my case study in the next section.

Case Study Design

In this section, I outline the process followed as I planned, collected data, and wrote a descriptive case study of the environmental sustainability needs of the Palouse Watershed.

Case Study Protocol

Yin (1994) recommends that the first step in case study design is the development of a case study protocol. The protocol should provide an overview of the case study project, describe the procedures for obtaining data, enumerate the questions to be addressed by the case study, and, provide an outline of the case study report format. The protocol should also challenge the case study researcher to anticipate possible problems and issues that stand in the way of meeting the objectives of each case.

Overview of the c*ase study.*

The central objective of this case study is to describe the environmental sustainability needs of the Palouse. The sustainability definition used in this study is:

> Sustainability is a holistic approach to living and problem-solving that addresses environmental health. To be sustainable, we must protect our collective health, our collective limited natural resources, and our environment over the long term.

As was mentioned previously, this report focuses primarily on enumerating the environmental sustainability needs of the Palouse. Framing the sustainability needs of the Palouse through the three overlapping lenses of social equity, environmental health, and economic prosperity would provide a more thorough and comprehensive picture of local sustainability. Doing so however is problematic in terms of this author's areas of expertise and time constraints for the completion of the study. Another important challenge to a more-broad case study is centered in the fact that much of the existing research concerning sustainability originates from researchers that employ traditional, science-based definitions of sustainability that often focus solely on the environment.

A third constraint on employing a broad vision of sustainability is that the goal of sustainability can be seen as running counter to the social and economic realities of life on the Palouse. The communities of the Palouse Watershed, like the rest of the United States, are rooted in hundreds of years of modern liberalism's attachment to individual property ownership and economic survival of the fittest. In the view of this researcher, social and economic equity calls for the Palouse Watershed's physical and biological resources to be equitably distributed to all occupants – even non-human ones. Furthermore, the needs of future occupants also need to be considered for resource equity to exist in any model of sustainability. In this view, the act of writing a case study of the Palouse Watershed that is inclusive of social and economic equity is akin to writing a plan for turning this place into a utopian society.

The case study that follows in Chapters 4-6 is organized around three aspects of Palouse physicality: land, water, and air. The use of land, air, and water as organizational elements in sustainability studies is consistent with reporting procedures used by government agencies, scholars, and environmental groups such as the Palouse-Clearwater Environmental Institute.

Unit of analysis.

The unit of analysis in this case study is the Palouse Watershed. Be reminded that a watershed is defined as "a body of land bounded above by a ridge or water divide and below by a level at which the water drains from the basin" (Smith & Smith, 2001, p. 645). I chose the Palouse Watershed as the unit of analysis for this case study for two reasons. One, it makes sense to me as a biologist to study an ecologically-rooted concept like sustainability using natural rather than artificial borders. Second, other researchers have used the watershed as a unit of analysis in sustainability studies (Saul, 1996).

Obtaining data.

Yin (1994) lists five sources of data for case studies: documentation and archival records, interviews, direct observations, participant observation, and physical artifacts. I collected four types of data for this case study. I gathered peer-reviewed and non-peer-reviewed documents and archival data from sources including local libraries and via internet connection to government document databases and scholarly journals. I completed Washington State University's institutional review board protocol so that I could interview key participants in connection with the environmental sustainability needs of the Palouse. [See Appendix A for the case study interview guide.]. I interviewed 16 individuals that are connected with sustainability efforts on the Palouse, including, sustainability coordinators at Washington State University and the University of Idaho, Moscow's sustainability intern, individuals from the Palouse-Clearwater Environmental Institute and other pertinent faculty and staff from the University of Idaho and Washington State University. I also interviewed individuals that work in city, county, state, and federal government capacities. Last, since this is largely a report on the impact of agriculture in the Palouse, I spoke with local farmers about agriculture and sustainability.

In regards to the role of interview data in this study, it is important to acknowledge that this is not an ethnographic study. Interview data was used primarily to drive the selection of topics for inclusion in this study. Four data types were collected, including interview data, and each data type represented a significant contribution to the total data pool from which the case was drawn. Validity will be discussed later in this chapter. For the time being, however, it is important to note that my study has a good degree of construct validity because it draws from multiple sources of data.

Miles and Huberman (1984) remind qualitative researchers such as me to consider possible barriers to data acquisition. This researcher has lived in the Palouse Bioregion for 19 years. I have full access to university libraries and have worked in various capacities at both the University of Idaho and Washington State University since 1989. I have been a student of local sustainability for more than 15-years and am familiar with many of the groups and individuals that are interested in local sustainability. In light of this, I was able to access both the documents and human capital necessary to successfully complete a good case study of the sustainability needs of the Palouse Watershed.

Case study questions.

The central question that drives this case study is: What are the environmental sustainability needs of the Palouse Watershed? When broken down into the three organizational components (land, water, and air) there are three essential questions that this case study seeks to answer:

1. What are the Palouse Watershed’s land-centered environmental needs?

2. What are the Palouse Watershed's water-centered environmental needs?
3. What are the Palouse Watershed's air-centered environmental needs?

Yin (1994) recommends that researchers include a list of probable sources for answers to case study questions when considering case study design protocol. I sought answers to my case study's questions from documentary evidence, published research papers, and directly from biologists and other experts concerned with environmental sustainability in the Palouse Watershed.

Case study report format.

The case study that follows presents the environmental sustainability needs of the Palouse Watershed in three chapters organized according to land, water, and air aspects. Chapter Four introduces the reader to the Palouse Watershed area with a consideration of land use up to the year 2000. Chapter Five enumerates the contemporary environmental sustainability needs of the Palouse. Chapter Six describes current efforts at making the Palouse a sustainable watershed and offers analysis on needs that still need to be addressed.

Case Study Analysis

According to Tellis (1997), the analysis of case study data is "one of the least developed aspects of case study methodology," especially for qualitative case studies that lack statistical data (p.12). Miles and Huberman (1984) suggest the use of alternate analytical techniques in such circumstances, such as arrays to display data, tabulating the frequency of events, ordering information chronologically or otherwise, and through the creation of visual data displays. Yin (1994) recommends the use of pattern-matching, explanation building, or time-series analysis when those strategies match the objective of the case study.

Few of the analytic strategies recommended by Miles and Huberman (1984), Yin (1994), or Tellis (1997) apply to this case study. Since my case study is descriptive by definition, I have chosen to use land, water, and air, three factors routinely used in sustainability literature, as an analytic framework for describing the environmental sustainability needs of the Palouse Watershed. Yin (1994) acknowledges the acceptability of employing a descriptive framework for cases, such as this, that lack theoretical propositions.

It was my intention to employ qualitative analytical strategies suggested by Patton (2002) in the creation of the Palouse case study. Patton (2002) offers strategies for coding data, finding patterns, and labeling themes. Data in this study was initially separated into at least three types of coding categories:

1. Data concerning the Palouse Watershed's environmental land issues
2. Data concerning the Palouse Watershed's environmental water issues
3. Data concerning the Palouse Watershed's environmental air issues

It was my goal to identify patterns that emerged from diverse data sources and to employ mutually-exclusive theme labels. According to Patton (2002), pattern refers to a descriptive finding. For example, “almost all participants reported feeling fear when they rappelled down the cliff” is construed as a pattern while a theme takes a more categorical or topical form in the theme label *fear*.

Braun and Clarke (2006) see a theme as a label that “captures something important about the data in relation to the research questions” (p. 82). In the case of this study, I employed themes like Braun and Clarke, as data-driven extensions of my chosen coding categories. I acknowledge that there are no hard and fast rules about what proportion of a data set was required to display evidence of a certain theme in order for a theme to be a valid construct. I chose to follow Braun and Clarke’s (2006) advice to count thematic occurrences while being open to thematic elements that might be important but poorly represented in a particular data set.

I employed six phases of thematic analysis that are based upon those identified by Braun and Clarke (2002).

1. Data familiarization: I familiarized myself with the data by transcribing interviews and reading and re-reading document and archival data.
2. Generating initial codes: I coded the entire data set for placement within the three categories which are tied to the organizational schema used in the case study.
3. Searching for themes: I collated coded data into potential themes and created a thematic map that functioned as a working visual piece throughout the process of theme identification.
4. Reviewing themes: I checked to see if preliminary theme labels worked in relation to coded portions and the entire data set.

5. Defining and naming themes: I used ongoing analysis to refine the specifics of each theme's definition and place within the overall case study.
6. Producing the report: I wrote a narrative that weaves vivid and compelling passages from the data set to illuminate the case study's story.

Limitations of Thematic Analysis

Braun and Clarke (2006) enumerate two limitations of thematic analysis that are worthy of consideration. First, some thematic analysts produce works that are nothing more than strung-together excerpts of data. Thematic analysis requires the researcher to make meaning of data through narrative analysis. The proper use of excerpted data is to support the analysis, not to be the analysis. A second problem with thematic analysis occurs when themes are not internally coherent and consistent. This can also happen when the researcher fails to adequately quote passages from the data.

In this study, I circumvented the above issues by using Braun and Clarke's (2006) six phase approach thematic analysis which was discussed above. My hope is that using a recursive process to map out themes in relation to my research questions helped me to strike an appropriate balance between narration, data citation, and analytic conclusions.

Reliability

Reliability is the extent to which analysis yields the same results in repeated trials. Reliability differs from validity in that validity is concerned with truth. An analysis can be highly-reliable but still not provide results that are reflective of the underlying "truth" of the phenomena under scrutiny. According to Kaplan and Goldsen (1965), "the importance of reliability rests on the assurance it provides that data are obtained independent of the measuring event, instrument or person" (p. 83-84).

In this study, I have tried to achieve a high level of reliability by transparently identifying the steps taken in constructing this case study of the sustainability needs of the Palouse Watershed. It is my intent that a person with a similar background to mine could read the same data and arrive at the same conclusions.

Validity

As was mentioned above, validity is concerned with truth. There are many kinds of validity that are important in case study research. I have purposely matched my research questions to the operationalized definition of sustainability used in this work towards the goal of achieving *internal validity*. It is my intent that this study possesses another kind of validity - *social validity*, "that quality of research findings that leads us to accept them on account of their contribution to the public discussions of important social concerns" (Krippendorff, 2004, p. 314). It is also my goal that this study possess *construct validity*. Construct validity is "the extent to which a study shares measures with other studies" (Neuendorf, 2002, p. 116). Tellis (1997) reminds us that construct validity is problematic in many case studies because of investigator subjectivity. Yin (1994) proposed three remedies to counteract possible claims of subjectivity on the part of the investigator: using multiple forms of evidence, establishing a chain of evidence, and, writing a draft case study to be reviewed by key informants. I employed each of these recommendations in the quest for construct validity.

It was my intention to achieve *sampling validity* in the case study portion of this report. Sampling validity is validity concerned with sample sizes. I stopped looking for new data when interviews and published reports failed to provide new data.

The case study portion of this work is possibly limited by the absence of *external validity*. According to Tellis (1997), "external validity deals with knowing whether the results [of a case study] are generalizable beyond the immediate case" (p. 6). The concept of external validity is philosophically problematic for a study of watershed sustainability because no two watersheds are alike, thus, generalizing to other watersheds is not only impossible, it is faulty by design. In the next section, I consider the second methodology used in this dissertation study – content analysis.

Content Analysis

Content analysis is a dynamic research methodology that uses message content as data for inferential analysis. In this section I provide a brief overview of the history, background, limitations and benefits of this research practice. After the overview, I connect my description of content analysis with a goal of this study: the content analysis of Washington State's science education standards for content related to the environmental sustainability needs of the Palouse Watershed.

Content analysis is a term used to describe the analysis of message content. The practice of content analysis has a long history rooted in the elucidation of inferences from the systematic analysis of diverse types of messages, including written text, oral communications, movies, and television programs. Researchers that name content analysis as their methodology of choice come from a variety of backgrounds, including communications (Woelfel, 1997), journalism (Wells & King, 1994), history (Holsti, 1969), marketing (Fan & Cook, 1997), psychology (Pennebaker, 1997), and education (Beyer & Ogletree, 1998; Pickreign & Capps, 2000).

A brief history of content analysis.

The term *content analysis* does not appear in the literature until 1941 when Waples and Berelson (1941) reported a content analysis of political messages aimed at changing voter behavior. Krippendorff (2004) tells us that the systematic analysis of message content can be traced back to "the inquisitorial pursuits of the [Roman Catholic] Church in the 17^{th} century" (p. 3). The mass publication of books that began with Gutenberg's invention of the printing press in the 15^{th} century was challenged by the Roman Catholic Church which employed content analysts to examine texts for heretical content. This practice continues today through the Church's practice of the *imprimatur* – the Vatican seal guaranteeing a book to be free of doctrinal error.

In the late 1890s, the newspaper industry boomed, and, with it, the application of quantitative techniques used to measure newspaper content (Speed, 1893). The quantitative content analysis of newspaper messages provided a scientific-backbone which was used by content analysts and those that hired them to wage journalistic arguments. In the 1930s and 1940s content analysis continued to develop, along with social science research and statistical methodologies. During World War Two, content analysis was applied to propaganda from both sides of the struggle in an effort to evaluate the influence of pro-war communiqués on the masses (Krippendorff, 2004).

Purposes of content analysis.

Berelson (1952) enumerated five purposes for content analysis. It is important to consider these in order to place this study within a contextual frame.

1. To describe substance characteristics of message content, also called content characteristics.
2. To describe form characteristics of message content.
3. To make inferences to producers of content.
4. To make inferences to audiences of content.
5. To determine the effects of content on an audience

I attempted to engage three of Berelson's five purposes in pursuit of answers to my research questions. I wished to describe the substance characteristics of message content contained in Washington State's science education standards. The science education standards are 58 sets of learning outcomes that Washington students need to meet in order to demonstrate proficiency on the Washington Assessment of Student Learning or WASL. It was also my desire to use qualitative content analysis (described below) of the science education standards to identify content related to the environmental sustainability needs of the Palouse.

I desire to use content analysis techniques to make inferences to the producers of the content being analyzed, Washington State's Office of the Superintendent of Public Instruction, or OSPI, with regards to sustainability content in the science standards. As was mentioned in Chapter One, I wish to share inferences from this content analysis with Washington parents and their children, science teachers, elementary teachers, social justice educators, and sustainability educators of every stripe.

Conceptual limitations of content analysis.

Content analysis employs messages as a source of data for making inferences about message content. In most cases, the content that becomes grist for the analyst's mill was never intended for detailed scrutiny of manifest or latent content (Neuendorf, 2002). Because of this limitation, it is important to be clear about the epistemological assumptions of messages, in my case, text, before proceeding with methodological particulars. Krippendorff (2004) proposes six limitations of text that I acknowledge:

1. "There is nothing inherent in a text; the meanings of a text are always brought to it by someone" (p. 22).
2. Any text can have "multiple meanings" (p. 22).
3. Inter-subjective agreement on text messages between individuals and groups "rarely exists" (p. 23).

4. Texts often “speak to something other than manifest content of the message for they can involve feelings or cause behavioral changes” (p. 23).
5. “Texts have meanings relative to particular contexts, discourses, or purposes” (p. 24).
6. “Texts, messages, and symbols never speak for themselves” (p. 25).

Krippendorff’s (2004) list of the limitations of text is a potent reminder of the limitations on inferences drawn from the process of content analysis. I acknowledge that my analysis of the science education standards is certainly not the only story that could be inferred by close scrutiny of these learning outcomes. I know from professional experience working as a Washington science teacher as my curriculum faced periodic inspection at the hands of administrators. If I failed to align my curriculum with the science education standards, I would be called to account for my oversight. In this section, six limitations of content analysis have been explored. In the next section, I examine several reasons why content analysis is my method of choice for answering my research questions.

Why content analysis?

I have chosen to employ content analysis for the simple reason that this approach is a good fit for answering some of the research questions I have posed. There are other reasons as well. As was mentioned in Chapter One, content analysis also allows me direct access to the information I wish to examine without the data contamination that can occur in more obtrusive methodologies such as “controlled experiments, interviews, focus groups, surveys and projective tests" (Krippendorff, 2004, p. 40). I make this claim in light of Heisenberg's Uncertainty Principle, which asserts that the acts of measurement and observation tend to interfere with the phenomena being examined.

Another benefit of content analysis is that it is a process that uses unstructured data "which preserves the conceptions of the data's [original] sources" (Krippendorff, 2004, p. 41). Still-another advantage to using content analysis is that, unlike ethno-methodology and case study approaches, content analysis is a methodology that is designed to handle very large quantities of data. For example, Pierce (1930) analyzed 427 school textbooks, Foster (1938) examined 8,039 newspaper editorials, and Gerbner (1979) looked at 15,000 characters in 1,000 hours of televised fiction. In the next section, I distinguish between quantitative and qualitative approaches to content analysis.

Quantitative Versus Qualitative

The earliest content analyses were qualitative, thematically-based studies conducted by officials in the 15-16th century Roman Catholic Church for the purpose of assessing doctrinal purity in written texts. Since the 1930s, when content analysis moved into quantitative, statistically-based reporting, this methodology has been largely perceived as wholly-quantitative. Neuendorf (2002) goes so far as to label qualitative content analysis "message analysis" in contrast to statistically-based, quantitative analysis (p.5). Krippendorff (2004), on the other hand, questions the validity and usefulness of the distinction between quantitative and qualitative content analysis on the grounds that "all reading of texts is qualitative, even when certain characteristics of a text are later converted into numbers" (p. 16). I agree with Krippendorff. Even a brief reflection upon the limitations of text demonstrates that all forms of this methodology generate from human-constructed, descriptive understandings that are qualitative at the root. In the next section, I outline my qualitative study design.

Content Analysis Study Design

In this section, I communicate the plan for a content analysis of Washington State's k-12 science education standards. I consider the data population (the science education standards) in terms of various levels of unitization (sampling units, data collection units, and coding units) with respect to sustainability content. The goal of this content analysis is to identify and analyze Washington State's k-12 draft science education standards for content related to the environmental sustainability needs of the Palouse Watershed. Content factors for this study are enumerated in Chapter Seven.

Defining the Data Population

In content analysis, sampling refers to the messages sampled for analysis. Messages can originate in multiple forms such as film, art, verbal communications, and of course, text, the traditional data source in content analysis (Krippendorff, 2004). Recall that I chose to analyze the science education standards because these learning outcomes drive science instruction in Washington State through their connection with the science portion of the Washington Assessment of Student Learning. I sampled the entire set of 58 k-12 science education standards. In content analysis, this type of sample is termed a census sample since it includes all the message content in a particular data set (Neuendorf, 2002). By sampling the entire textual content of the science education standards, I am assured that my sample is adequate in every respect as I have sampled the most-appropriate text for this type of analysis (Neuendorf, 2002). It is my intent to employ individual science education standards as sampling units in this study (Holsti, 1969).

Qualitative Analysis

This study's content analysis builds sequentially upon the case study of the sustainability needs of the Palouse Watershed. The qualitative techniques employed in this analysis are grounded in thematic analysis (Patton, 2002) of the sustainability needs of the Palouse and my experiential understanding of education for environmental sustainability. I have been a student of and practitioner of science education in pursuit of local sustainability for more than six years and a university-trained biologist for more than 25 years. Thematic analysis was considered earlier in this chapter in the discussion of case study methodology.

In summary, the qualitative analysis of Washington State's k-12 science education standards is rooted in the identification of key learning activities that address the sustainability needs of the Palouse Watershed. All 58 of Washington State's science education standards were examined and compared with the identified sustainability needs of the Palouse Watershed.

Reliability

Reliability is the extent to which analysis yields the same results in repeated trials. Reliability differs from validity in that validity is concerned with truth. An analysis can be highly-reliable but still not provide results that are reflective of the underlying "truth" of the phenomena under scrutiny. According to Kaplan and Goldsen (1965), "the importance of reliability rests on the assurance it provides that data are obtained independent of the measuring event, instrument or person" (p. 83-84). In content analysis, reliability means that the reading of textual data, as well as of the research results, is repeatable by others (Krippendorff, 2004).

Validity

As was mentioned above, validity refers to truth captured through the research process. According to Riffe, Lacy, and Fico (1998), "the essence of validity in content analysis is . . . that research should speak as truthfully as possible to as many people as possible" (p. 150). There are many kinds of validity that are important in content analysis. I have purposely matched my research questions to the operationalized definition of sustainability towards the goal of achieving *internal validity*. It is my intent that this study possesses *social validity*, "that quality of research findings that leads us to accept them on account of their contribution to the public discussions of important social concerns" (Krippendorff, 2004, p. 314). This study is limited by the absence of at least one form of validity: *construct validity*. Construct validity is "the extent to which a study shares measures with other studies" (Neuendorf, 2002, p. 116). This study employs original, untested measures of sustainability content so I work de novo, literally anew, from the beginning.

Research Design and Methodology: In Conclusion

Answering the research questions posed in this report requires the use of multiple methodologies. In this chapter I have disclosed the theory behind case study methodology and content analysis. I have also sought to provide the reader with a transparent look at the detailed procedures that I employed to answer the questions posed in this dissertation. The next three chapters (Chapters 4-6) are a case study of the sustainability needs of the Palouse. Chapter Seven is a content analysis that uses the environmental sustainability needs of the Palouse as a frame for analyzing Washington State's k-12 science education standards. Chapter Seven also answers the primary question of this dissertation: What is the relationship between the sustainability needs of the Palouse Watershed and Washington State's k-12 science education standards. In Chapter Eight, I conclude with a discussion of the implications of this study for educational policy and practice.

CHAPTER FOUR

A(N) (UN)NATURAL HISTORY OF THE PALOUSE WATERSHED

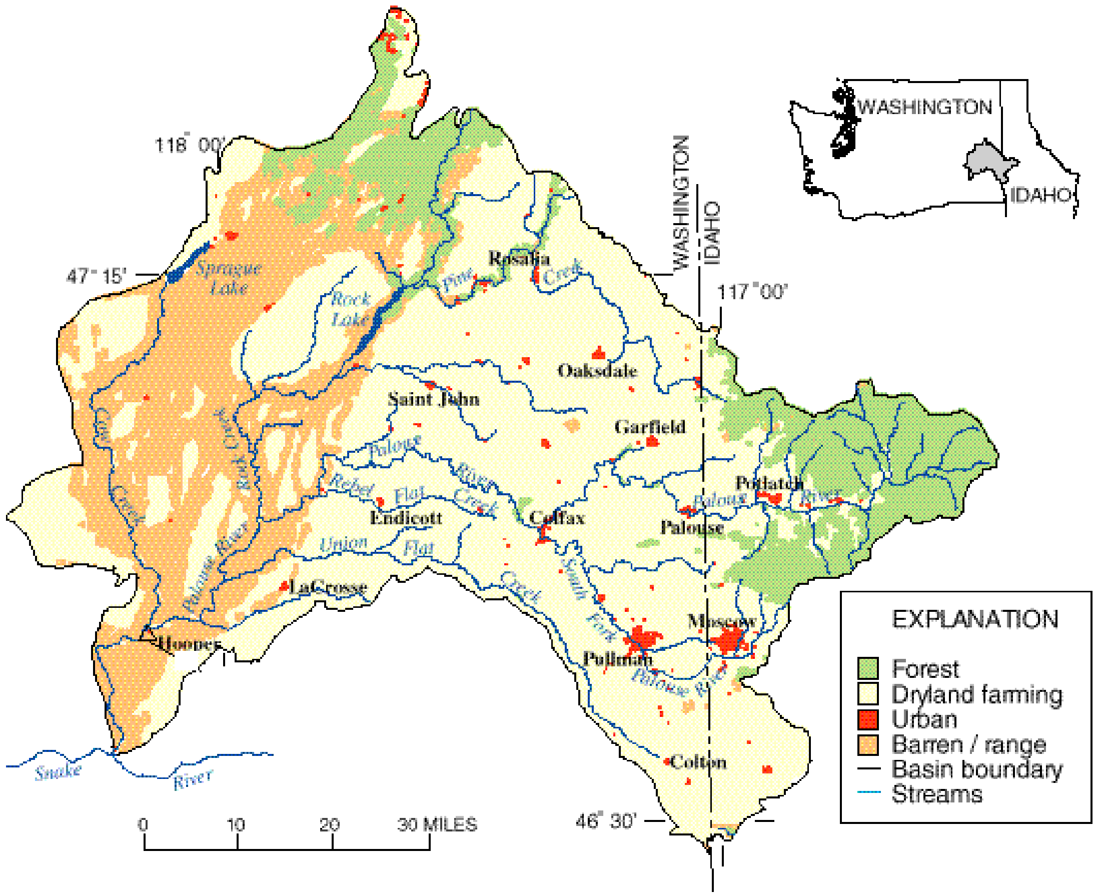
This chapter is the first chapter of a three chapter case study of the environmental needs of the Palouse Watershed portion of the Palouse Bioregion. The goal of this case study is to answer the question: What are the environmental sustainability needs of the Palouse Watershed? Multiple sources of data were used to answer this question. Written data was gathered from more than a twenty organizations working to address environmental issues in the Palouse Watershed. Sixteen Palousians that are involved in local sustainability efforts were interviewed using the interview guide provided in Appendix A. Interview transcripts revealed that no two participants perceive sustainability in the same way. Some see sustainability in purely environmental terms while others include economic and equity concerns in a larger, more inclusive conception of sustainability. While there was significant disagreement over the scope of sustainability, comments from three participants convinced me of the value of preparing a comprehensive case study organized around Palouse water, land, and air.

Be reminded that the focus of this study is environmental sustainability, and more specifically, fostering environmental sustainability in a way that protects our limited natural resources and our environment over the long term (Washington State Department of Ecology, 2007). It is important to consider environmental sustainability in the Palouse River Watershed since Noss, LaRoe, and Scott (1995) include the Palouse on a list of the 30 most endangered ecosystems in the United States. The Palouse Watershed is described first including location, geology, climate, flora and fauna, as well as, watershed attributes. Second, the history and impact of human habitation on the Palouse Watershed are examined with particular emphasis on practices that have resulted in environmental degradation from the years 1860 - 2000. This discussion continues in Chapter Five where the current condition of the Palouse Watershed will be explored in detail. The case study concludes in Chapter Six with a consideration of efforts underway to address the environmental sustainability needs of the Palouse River Watershed.

Physical Attributes of the Palouse

This chapter is the first part of a case study of the environmental needs of the Palouse Bioregion's Palouse Watershed [See figure 4.1, Palouse Watershed Map]. The Palouse Bioregion and Watershed are part of the greater 63,000 square mile Columbia River Plateau. Recall from Chapter One that a bioregion is "an area constituting a natural ecological community with characteristic flora, fauna, and environmental conditions [which is] bounded by natural rather than artificial borders" (Kleinedler, 2005, p. 385). The 6,178 square mile land area of the Palouse Bioregion is mostly composed of rolling hills, up to 100 meters in height, that are incised by the water courses of the Palouse River and Snake River Watersheds (Anspach, 2008). Palouse elevation ranges from 1,200 - 6,000 feet above sea level (366 – 1,830 meters). This report is primarily concerned with the 3,280 square mile subset of the Palouse Bioregion known as the Palouse River Watershed. I have chosen to focus my examination on the Palouse Watershed because, as Saul (1996) says, “Rivers and streams indicate the health of the land. If erosion, or pollution, or development causes problems in the landscape, rivers and streams reflect these problems with poor water quality and reduced ecological functions” (p. 2). Recall from Chapter One that a watershed is defined as “a body of land bounded above by a ridge or water divide and below by a level at which the water drains from the basin” (Smith & Smith, 2001, p. 645). Another way of thinking of the watershed concept is to consider the *bathtub analogy*. Every drop of water that lands inside the rim of the tub is in the watershed while every drop that lands outside is in another watershed.

Figure 4.1 Palouse Watershed Map



(Source: http://wr.civil.uidaho.edu/cwis/palouse/images/WRIA34.gif)

Palouse Geology

The geologic foundation of the Palouse hills consists of multiple layers of basalt rock that flowed up through fissure cracks in the earth's crust as hot lava during the Miocene and Pliocene Epochs 23 – 4.5 million years ago (Duffin, 2007). The Palouse hills were covered with fine, wind-blown, glacial till called loess beginning 2.4 million years ago continuing to about 10,000 years ago (Duffin, 2007). Loess is one of the soil components that historically-conferred legendary productivity to local soils (Williams, 1991). The hills that stood to the west and north of the Palouse were dramatically swept away 20,000 – 12,000 years ago by torrents of the Great Missoula Floods that occurred more than 50 times during warm periods in the Pleistocene ice age. The Palouse escaped being washed away in the Missoula Floods simply because it is higher in elevation than areas to the north and west.

The Palouse River Watershed is bordered on the west and south by the desert terrain of the Snake River and Columbia River Plateau of Eastern Washington and Northeastern Oregon. The watershed's eastern and northern borders abut the Clearwater Mountains and pine forests of North Central Idaho and Eastern Washington. The Palouse River Watershed is distinct from neighboring watersheds in at least two important respects: climate and vegetation.

Palouse Climate

The Palouse's location in the rain shadow of the Cascade Mountains results in a climate typified by cold, wet winters and hot, dry summers with regular periods of drought occurring from July – October. Palouse precipitation ranges from 10-30 inches per year with the bulk of precipitation falling from November – May (Anspach, 2008). The western expanses of the watershed typically receive less precipitation whereas more rain and snow occurs in the eastern areas of the Palouse which are adjacent to Idaho's Clearwater Mountains.

Wind has played a major role in shaping the Palouse River Watershed over the last two million years. The rolling hill typography of the Palouse is largely caused by prevailing winds from the southwest that deposited more loess on northeast-facing slopes creating steep northeast-facing slopes and gentle southwest-facing slopes. Geologic and climatic forces have worked to produce a Palouse composed of undulating dry prairie cut by the seasonally-abundant waters of the Palouse River water courses.

Palouse Flora and Fauna

The deposition of fine loess on the hills of the Palouse ended approximately 10,000 years ago with the retreat of the Pleistocene's last glaciers (Duffin, 2007). This fact is of huge import to later discussions of Palouse agriculture, soil loss, and soil regeneration. For the time being, however, it is important to point out that the beginnings of the meadow-steppe flora of the Palouse are rooted in the climatic warming that occurred at the end of the last ice age, a mere 12,000 years ago. In the years before European contact, the Palouse's meadow-steppe vegetation was characterized by Idaho fescue, blue bunch wheatgrass, common snowberry, serviceberry, wild rose, willow, red osier dogwood, alder, and hawthorn (Duffin, 2007). Ponderosa pine forests occupied the lower timberline on hills and small mountains while the transition zone between forest and meadow-steppe communities consisted of a complex inter-fingering between these two vegetation types (Duffin, 2007).

The Palouse Watershed has historically been home to a diverse array of birds. Palouse grassland communities have been occupied by American kestrel, ring-necked pheasant, upland sandpiper, western kingbird, horned lark, black-billed magpie, western meadowlark, and savannah sparrow (Palouse Prairie

Foundation, 2009). Riparian areas of the Palouse have been inhabited by Lewis' woodpecker, grey catbird, western bluebird, orange-crowned warbler, northern oriole, black-headed grosbeak, and lazuli bunting (Palouse Prairie Foundation, 2009). Typical Palouse carnivores and herbivores have included skunk, fox, raccoon, mule deer, white-tailed deer, bobcat, black-tailed jackrabbit, and Washington ground squirrel (Palouse Prairie Foundation, 2009). Native herpeto-fauna have historically included bullfrog, painted turtle, western fence lizard, and the Northern Pacific rattlesnake (Palouse Prairie Foundation, 2009). In the next section, the physical attributes of the Palouse Watershed are considered.

The Palouse River Watershed

The Palouse River Watershed drains a 3,280 square mile area in Eastern Washington and North Idaho. The Palouse River, the only river in the watershed, originates in the Clearwater Mountains northeast of the community of Moscow, Idaho and runs 124 miles in a westerly direction before draining into the Snake River at Lyon's Ferry, just outside the community of Starbuck, Washington (Washington Department of Ecology, 2007a). The Palouse River includes over 398 miles of streams and tributaries which, in sum, drain 2.1 million acres in Washington and Idaho (Washington Department of Ecology, 2007a).

In terms of political geography, the watershed occupies portions of Latah County in Idaho and four counties in Washington State: Whitman, Spokane, Lincoln, and Adams. Eighty-three percent of the Palouse Watershed occurs in Washington, primarily in Whitman County, and the remaining 17% occurs in Idaho. There are 46 communities within the boundaries of the Palouse

Watershed. Those in Idaho are Genesee, Moscow, Potlatch, and Viola. Palouse Watershed communities in Washington are: Albion, Amber, Belmont, Busby, Colfax, Colton, Diamond, Dusty, Eden, Elberton, Endicott, Ewan, Fairfield, Fallon, Farmington, Hooper, Johnson, LaCrosse, Lamont, Latah, Medical Lake, Malden, Mockonema, Oakesdale, Pampa, Pine City, Plaza, Pullman, Ringo, Rodna, Rosalia, Staley, Sprague, St. John, Sunset, Sutton, Thera, Thornton, Uniontown, Waverly, Willada, and Winona.

The main tributaries of the Palouse River include the North Fork of the Palouse, the South Fork of the Palouse, Rebel Flat Creek, Rock Creek, Pine Creek, Union Flat Creek, and Cow Creek. The tributaries of the Palouse River Watershed all flow freely, with no natural or human-constructed impoundments. The 185 feet drop at Palouse River Falls, located six miles before the confluence with the Snake River, serves as a natural barrier to fish migration, thus, the watershed is naturally-free of anadromous salmonids, also known as migratory salmon. [See photo four in Appendix B]. The Palouse Watershed has 42 year-around lakes that mostly occur in the Cow Creek and Rock Creek sub-basins.

Groundwater in the Palouse Watershed is pumped from two aquifers located deep within underlying basalt formations. In general, rural residents draw from the shallower Wanapum aquifer while city wells from the watershed's three cities, Colfax, Moscow, and Pullman, as well as, Washington State University and the University of Idaho, draw from the deeper Grande Ronde aquifer. Precise boundaries have yet to be delineated for the Wanapum and Grande Ronde (Palouse Basin Aquifer Committee, 2007). What is known is that the thickness of the Grande Ronde is approximately 2,300 feet west of Pullman, Washington while the aquifer thins to a thickness of less than one foot along basin boundaries between Pullman and Moscow, Idaho. The thickness of the Wanapum ranges from less than one foot to 250 feet (Palouse Basin Aquifer Committee, 2007). Both aquifers are part of the Columbia River Basalt Group which resulted from the deposition of lava flows thousands of feet thick that covered the region from 17 – 6 million years ago. The eastern end of the basin has thick sedimentary interbed deposits that thin west of Moscow and act as a barrier to water flow between the communities of Moscow, Idaho and Pullman, Washington.

The goal of this chapter thus far has been to describe the physical attributes of the Palouse Watershed. Palouse geography, geology, climate, flora and fauna have been considered, along with the physicality of the water contained in the Palouse Watershed. Next, I consider the historical influence of human habitation on the lands and waters of the Palouse River Watershed.

Land Use History of the Palouse Watershed

Descendants of the first human occupants of the Palouse call themselves *the people of the river* or Na-ha-um. Anthropologists estimate that the Na-ha-um lived locally for almost 12,000 years, making the Palouse one of the areas of longest continuous inhabitation in North America (Duffin, 2007). People of European descent mistakenly called the Na-ha-um the *Palus* after the Sahaptin name of a basalt outcrop located at the confluence of the Snake and Palouse Rivers. The earliest population estimates for the tribe date back to the early

1800s and put the number at between 300 – 2,300 people at any given time (Duffin, 2007).

The Na-ha-um lived in the Palouse's river canyons for much of each year, thriving off salmon, elk, and mule deer. In spring, the tribe traveled to upland prairies to harvest camas bulbs, a potato-like tuber that was a dietary staple high in starch and vitamin C. Two events in the 1700s posed major changes for the Na-ha-um people. As was the case with other indigenous people, the tribe was decimated by the spread of smallpox. There are no figures to represent the impact on the Na-ha-um but the Nez Perce to the immediate south saw their population decline from 6,000 to about 2,500 (Black, Strand, Morgan, Scott, Wright, & Watson, 2003). Another major change for the tribe was the introduction of the domesticated horse. Possessing and using horses allowed the Na-ha-um to expand their trading circles beyond the inland northwest but wreaked havoc on the land because the tribe's horses compacted local soils in habitat that had historically never experienced the crush of hooves, thus opening the Palouse to the invasion of non-native vegetation.

European-American Settlement and Palouse Land Use: A(n) (Un)Natural History

The settlement of the Palouse Watershed by European-Americans began in earnest in the early 1860s with the discovery of gold in the vicinity of Moscow Mountain (Black et al., 2003). Palouse agriculture started as early as 1862 when George Pangburn made the first official land claim in the area and began cattle ranching on a plot of land adjacent to Union Flat Creek near present-day Endicott, Washington (Duffin, 2007). Early efforts at cattle and sheep ranching on the Palouse proved profitable and encouraged a steady influx of emigrants in the 1860s. Grazing almost immediately led to soil compaction which inhibited the growth of native bunchgrasses. Profit-seeking ranchers responded by increasing grazing domains which exposed even more of the Palouse meadow-steppe to grazing pressures.

Farmers arrived on the heels of ranchers, erecting fences to exclude cattle and sheep entry, thus ending the brief period of open range ranching on the Palouse. Early Palouse farmers planted wheat and other cereal grains in flat areas between hills, reserving slopes and hill tops for grazing small herds of cattle and sheep raised for personal consumption. Early grain yields fluctuated, in no small part, due to the fact that low-lying flat areas stay wet later into the spring than hillside slopes and were more prone to experiencing frost damage than adjacent upland terrain. Many local farmers responded by taking a trial-and-error approach that involved cultivating flat areas, slopes, and hilltops. Many farmers observed phenomenal yields from hillside cultivation (Duffin, 2007). The result was that, “by the end of the 1870s, it was common practice to till slopes as steep as the implements of the day would allow” (Duffin, 2007, p. 40).

Rural isolation made Palouse farming marginally profitable until the arrival of the Oregon Railroad and Navigation Corporation’s railroad line in the early 1880s. The railroad changed Palouse farming from small-acreage, mostly subsistence farming to a “capitalistic, commercialized business” rooted in maximizing cultivation and yield (Duffin, 2007, p. 43). As will be shown later, the implications of this mindset for the Palouse Watershed have produced dire consequences for soil and water quality, as well as, biodiversity and overall ecosystem health. The short term consequence of the increased profitability of Palouse farming resulted in more land being put to the plow. By 1890, more than half the total land area of Whitman County, Washington was under cultivation (Duffin, 2007). By 1905, nearly all arable land in the same area was used for agricultural purposes. One hundred years later, approximately 90% of the total land area of the Palouse River Watershed is used for dry farming and livestock grazing (Black et al., 2003).

Wheat emerged as the dominant agricultural crop on the Palouse in the early 1900s. Farming was labor intensive with farmers relying upon human power and horse power to cultivate and harvest crops. According to Williams (1991), an organized harvesting / threshing team in the 1920s required 120 men and 320 mules and horses. Industrial agriculture arrived on the Palouse in 1930. By the end of the decade, over 90% of the Palouse wheat crop was harvested using petroleum-powered mechanical combines. The switch to motorized equipment reduced manpower needs on Palouse farms and virtually eliminated the need for pasture land. The end result was that even more Palouse land went under the plow. As combine technology continued to develop, steeper and steeper slopes were cultivated leaving less than 6% of the original bunchgrass plant cover in undisturbed condition by 1970, making the Palouse meadow-steppe one of the most endangered ecosystems in the United States (Noss et al., 1995).

Wheat farming on the Palouse hills was not without adverse environmental consequences. The first signs of soil erosion appeared around

1900, a single generation after the beginning of Palouse agriculture. Moderate to heavy rainfall filled roadside gullies with rich Palouse topsoil, completely covering fences in some spots (Duffin, 2007). One agricultural practice that was designed to decrease soil erosion, summer fallow, actually exacerbated the problem. By 1910, many soil scientists advised wheat farmers to let fields lie fallow, or bare, to increase soil moisture and decrease weed growth. In practice, summer fallow left soil vulnerable to the formation of deep lines called *rills* that functioned as spillways for vast amounts of topsoil. [See photo six in appendix B]. Summer fallow also resulted in the loss of humus, organic material high in nitrogen, leaving the soil hard to plow and less able to retain moisture in the long term (Duffin, 2007). The practice of summer fallow continued on many Palouse farms through the 1970s, in spite of more than 40 years of agricultural education to the contrary.

The problem of soil erosion on the Palouse started to get widespread attention in the 1930s. Scientists with the new US Soil Erosion Service (SES) warned that erosion was a threat to national economic security. SES promoted a new approach to agriculture called *conservation farming*. Initial efforts at conservation farming centered in crop rotation, planting cover crops such as alfalfa, the use of disc plows, the elimination of stubble-burning, and reducing areas under tillage in connection with financial subsidies to farmers. In the long run, early efforts at conservation farming failed to curtail erosion on the Palouse, in part, because participation was voluntary and only a small percentage of farmers opted to participate. Duffin (2007) asserts that participation in soil conservation practices remained low up through the 1930s because many Palouse farmers thought that erosion was not a significant problem since local topsoil was perceived to be almost limitless.

The first comprehensive study of erosion on the Palouse was conducted in 1939-1940 and showed that an average of 11.5 tons of topsoil was lost from every cultivated acre on the Palouse that year (Duffin, 2007). At the time, many farmers continued pre-conservation practices since the Soil Conservation Service (SCS), the renamed Soil Erosion Service, could provide no solid proof that erosion led to decreased crop yields. Moreover, crop production in the 1930s and 1940s increased in spite of tremendous losses of Palouse topsoil. Thus, it is no surprise that by 1945, 15-years into government-sponsored soil conservation, *Washington Farmer* reported that as few as one in ten Palouse farmers followed a program of soil maintenance (Washington Farmer, 1945).

Mid-twentieth century soil science researchers failed to demonstrate the relationship between erosion and diminishing crop yields simply because the initial loss of surface layers of Palouse soils had a minor impact on crop yields that could be confused with variability in weather, precipitation, and / or temperature (Duffin, 2007). Connecting wheat yield with soil erosion rates was further confounded by the use of agricultural chemicals such as anhydrous ammonia, which replenishes nitrogen in eroded soils resulting in increased yields. Furthermore, problematic clay-containing portions of Palouse soils generally are found deeper in the ground. When wheat roots fall in clayey regions of the soil, root nodules struggle to provide nourishment to plants because clay deposits have reduced water availability (Veseth, 1987).

As soil eroded from Palouse hills in great depths and in quantities up to 200 tons/acre, the loss of soil productivity that farmers had been warned about since the 1930s arrived (Duffin, 2007). Veseth (1985) reports that the loss of an inch of topsoil in the root zone decreases wheat yield 1.6 – 2 bushels/acre which correlates to a decrease of 4-8%. When considering the scale of soil erosion on the Palouse, such losses should have resulted in economic strain on Palouse farmers but they did not.

The use of chemical herbicides, fertilizers, and pesticides, combined with disease-resistant wheat strains beginning in the 1940s, allowed the tired and eroded Palouse soils to produce phenomenal yields in spite of continuing problems with erosion. Palouse wheat crops increased 85% per acre for the 1950s and 1960s while dry pea yield went up by 72% in the same frame (Duffin, 2007). Widespread use of agricultural chemicals was whole-heartedly embraced by Palouse farmers. It was not until the early 1960s, with the publication of Rachel Carson's *Silent Spring*, that some Palousians started to think critically about blanketing the Palouse hills annually with hundreds of tons of chemicals.

By the 1940s, 10% of the Palouse had lost all of its topsoil and 60% of the Palouse had lost 25-75% of its topsoil due to erosion (Jennings, 1990). Government policy in the face of World War Two served to further exacerbate the Palouse's erosion problems. The *Food for Freedom Act* encouraged farmers to put every available square foot of tillable land under production (Saul, 1996). This occurred just when many Palouse farmers were starting to retire steep slopes from cultivation. The end result was that reductions in Palouse erosion, accomplished through conservation farming, were reversed, leading to erosion rates similar to the 1930s (Saul, 1996). The other result of this legislation was that it encouraged farmers to fill and till wetlands with the end result being the loss of 97% of Palouse wetlands (Black et al., 2003). The influence of the Food for Freedom Act on Palouse land use continued into the 1970s when the US Department of Agriculture (1978) reported that the Palouse region continued to have one of the highest soil erosion rates in the whole of the United States (Black et al., 2003).

European American Influences on the Palouse Watershed 1860 -2000

Palouse land use since the arrival of European American mining and agriculture in the 1860s has changed the surface and groundwater characteristics of the Palouse Watershed in numerous ways. In terms of groundwater aquifer use, the water level of the shallow Wanapum aquifer dropped drastically in the 1950s and early 1960s but recovered in the 1970s and 1980s when the deeper Grande Ronde aquifer was tapped for use by the cities of Pullman and Moscow, and Washington State University. The Grande Ronde has been in decline since the decision to use the aquifer as Pullman and Washington State University’s sole water source. The Palouse Basin Aquifer Committee (2007) reported that “water levels in the Grande Ronde have historically declined at a rate of between one to two feet per year for the last 70 years” (p. 5). This is especially problematic since, according to Douglas, Osiensky, and Keller (2006), “basalt interiors typically form confining layers between interflow zones” that restrict aquifer recharge from surface waters (p. 504). Douglas et al. (2006) conducted a radioactive carbon-14 study to determine the age of Grande Ronde water and reported that water in the lower portion of the aquifer was between 13,000 – 26,400 years old while water in the upper strata was between 4,400 and 11,800 years old. Douglas et al. (2006) concluded that very little recharge occurs in the Grande Ronde while the Wanapum experiences a moderate level of recharge. In short, the Grande Ronde aquifer has been mined; residents of Pullman and Moscow have been drinking water stored away during the last ice age for forty years as water levels continue to decline. Discussion of the current state of the Palouse Watershed will continue in the next chapter. Next, I consider historical issues pertaining to surface water in the Palouse River Watershed.

Changes in the Palouse River Watershed surface waters since 1860.

Surface water characteristics of streams in the Palouse Watershed started to change soon after the advent of European American colonization. Gold mining activities in the vicinity of Moscow Mountain resulted in increased sediment loads into Paradise Creek in the 1860s. During the same decade, as agriculture intensified, first with ranching and then with grain cultivation, many farmers started to notice a sharp decline in trout and other cold-water fish species in local streams . This occurred because farmers removed trees, shrubs, and other plant growth from riparian zones to increase cultivation in flat areas adjacent to streams. Cold water fish died off because they were unable to tolerate the lack of stream-side shade. Warm water fish such as chubs, dace, and pike minnows replaced the native cutthroat and steelhead salmon that had been a staple of the Na-ha-um people (Duffin, 2007). Increased sediment load from soil eroding into streams was likely to have contributed to the demise of local cold water fish species, especially since the number of acres under cultivation increased sharply from 1870-1890.

Early European American farmers encountered a Palouse dotted with seasonal wetlands. Logging of many of the Palouse trees, mostly from ridgelines and in riparian zones, as well as the removal of riparian shrubbery, initiated a drying of the Palouse that resulted in drying up of many wetlands and decreased stream flows. Furthermore, many streams that had previously run throughout the year now ran only intermittently during the summer and fall months. George Klemgard, a Mormon pioneer that arrived in the Palouse in 1882, observed that Union Flat Creek was dryer for progressively longer periods of time throughout the 1880s and 1890s (Duffin, 2007). The North Fork of the Palouse had historically been used to transport fallen logs from the Clearwater Mountains downstream to the communities of Palouse and Colfax but by 1910 there was not enough flow except during spring floods. Without knowing it, Palouse farmers initiated drying conditions on the Palouse through the removal of riparian plant cover and upland trees.

In 1935, Victor and Rockie reported that decades of intensive use of moldboard plows in local agriculture left a “greasy semi-fluid mess” of silt and loam, two important soil components, running into Palouse streams (p. 18). This report is especially significant since Rockie had a long history of observing environmental change on the Palouse. Widespread use of fallowing, letting land lie fallow or bare, throughout the 1930s and 1940s, introduced millions of tons of soil into the watershed, which further eroded stream banks and worked to decimate aquatic populations in Palouse streams and further degrade streamside habitat. Duffin (2007) reports Soil Conservation Service biologist Verle Kaiser's (1946) observation that the stream beside one Palouse farm was "thick as gravy with 15% silk" and upland fields with erosion rills so eroded it looked like "a giant hand squeezing putty which was oozing out from between the fingers" (p. 115).

The use of chemical herbicides, fertilizers, and pesticides beginning in the 1940s allowed the tired and eroded Palouse soils to produce phenomenal yields in spite of continuing problems with erosion. One downside to blanketing Palouse hills annually with hundreds of tons of chemicals was that the chemicals eroded into Palouse streams alongside the topsoil. This is problematic because when nitrogen-based fertilizers, such as anhydrous ammonia, are introduced to aquatic environments, they feed algae population explosions called algal blooms which result in eutrophication, the process whereby oxygen is removed from a body of water, leading to zones where virtually all typical forms of aquatic life are absent. In the 1960s, biologists started to observe eutrophication in the Palouse River Watershed. Nitrogen levels have since been historically observed to peak when winter rains and melting snow wash agricultural chemicals from Palouse fields into the watershed (US Geological Survey, 2008).

In response to growing public pressure, the State of Washington passed the Washington State Environmental Policy Act in 1971. This act, known as SEPA, was based on the precept that each person has a fundamental and inalienable right to a healthful environment and a responsibility to contribute to the preservation and enhancement of that environment. SEPA requires state and local governments and businesses to submit to a review process for projects that have the potential to harm the environment. Duffin (2007) asserts that a lack of legislative enforcement at state and local levels made SEPA ineffectual to make any significant changes on the Palouse. Thus, it is not surprising that a 1974 joint report from Washington State University and the University of Idaho concluded that the Palouse River and its tributaries contain ever-increasing quantities of fecal coliform bacteria [bacteria that originate in sewage], low levels of dissolved oxygen, and tremendously high levels of sediment and nitrogen (Gladwell & Funk, 1974).

SEPA's review process provided an entry point for the US Department of Agriculture (USDA) to get involved. The USDA completed a study in 1978 which showed that 90% of the Palouse had an erosion problem and that 10% of the land was entirely devoid of topsoil and only continuing production through the use of vast amounts of chemicals (USDA, 1978). Furthermore, the study found a direct relationship between agricultural erosion and nitrate levels in streams (Duffin, 2007). Last, the USDA showed that the origins of most nitrogen-based pollutants were located to specific Palouse farms.

As the 1980s dawned, there was continuing dissatisfaction at the state level in Idaho over the lack of progress in improving water quality in the Idaho portion of the Palouse Watershed. A 1981 study by the state's Division of Environment reported elevated levels of stream sediments, phosphorus, nitrogen, and fecal coliform bacteria in the South Fork of the Palouse and Paradise Creek. Using a newly-devised ranking system employing zero as an optimum score and 100 as the worst possible score, both streams were assigned a score of 99.

Growing dissatisfaction over soil erosion and water quality at the federal level led to passage of the Farm Security Act (FSA) of 1985. The FSA required farmers to retire seriously eroded land in exchange for generous subsidies and price supports. There was a higher degree of enforcement than with previous measures which resulted in lowering sediment loads in Palouse streams and overall increases in water quality. This was accomplished through mulching of field stubble instead of field burning, the use of strip cropping following the contours of the land, the planting of cover crops such as alfalfa, and the planting of trees on steep slopes. Farmers were also encouraged to try a newly developed method of seeding called no-till that employed seed drills instead of soil-compacting combines for seeding acreage. A joint report issued by the USDA and US Geological Service 13 years after the passage of FSA showed that the Palouse River and its major tributaries carried half as much sediment from 1993 – 1996 as the streams had from 1962 – 1971 (Ebbert & Roe, 1998).

According to Duffin (2007), what began as a modest soil conservation law resulted in sweeping environmental reform on the Palouse and elsewhere.

In spite of recent gains, however, some parts of the Palouse Watershed continued in decline. A 1994 study by Washington State University showed that Paradise Creek was unfit for drinking and primary contact recreation because of sediment load and the presence of unacceptable quantities of phosphorus and fecal coliform bacteria (Doke & Hashmi, 1994).

In 1996, the *Freedom to Farm Act* was passed with overwhelming support by the republican-controlled US congress. This law took the teeth out of FSA because it no longer required farmers to implement conservation plans in order to receive government subsidies. The end result was that the moderate gains under FSA in environmental and water quality were being reversed by the end of the century. Thus, it is not surprising that Palouse soils and waters were in the top 25th percentile nationally for nitrogen compounds with several sampling stations also reporting alarming levels of environmental pathogens such as PCB, and several pesticides including DDT and diazinon (Census of Agriculture, 1997).

A(n) (Un)Natural History of the Palouse Watershed: In Conclusion

The Palouse Watershed is a place of uniqueness. It was defined historically by immense lava flows, the arrival and retreat of fantastic glaciers, the Great Missoula Floods, and persistent wind from the southeast. All of these forces worked together over millions of years to create a place unlike any other on earth – the Palouse. The Na-ha-um people lived on the Palouse for as long as 12,000 years without grossly affecting environmental quality. In contrast, 150 years of European American agriculture has altered this place seemingly beyond recognition. The Palouse hills are still here but the bulk of the topsoil that covered them has washed into streams and is piling up behind the many dams on the Snake and Columbia Rivers. Soil conserving measures were introduced to Palouse farmers starting in the 1930s. Strip cropping, tree planting, crop rotation, retirement of steep slopes, and later, the introduction of no-till direct seeding, were all effective measures for reducing erosion and maintaining water quality in the Palouse Watershed. Sadly, many Palouse farmers acted in favor of short-term financial returns instead of the long-term needs of this place. Conflicting advice from government entities served to further confound Palouse environmental quality as techniques such as fallowing were followed in spite of decades of evidence showing the negative effects of this practice upon Palouse lands and waters. In the century and a half history of European American agriculture the only time that environmental degradation was curbed on the Palouse was when farmers were required to utilize conservation measures in conjunction with the Farm Security Act of 1985. In the next chapter, I continue this discussion in connection with the current state of the land and waters of the Palouse Watershed.

CHAPTER FIVE

AN EXAMINATION OF THE ENVIRONMENTAL SUSTAINABILITY NEEDS OF THE PALOUSE WATERSHED

The Palouse Watershed portion of the Palouse Bioregion is a unique place that has been beset with environmental problems; largely because of farming practices going back as early as 1860. This watershed includes all the water within the Palouse River Basin, as well as, the land area drained, and, for the purposes of this report, the air above the Palouse land. This chapter answers the question: What are the environmental sustainability needs of the Palouse Watershed? Contemporary environmental issues in the Palouse Watershed are broken down into matters of land, air, and water to provide a comprehensive summary of the challenges facing an environmentally- sustainable Palouse. The issues that are considered below represent a summary of concerns enumerated by scientists, university administrators, environmental educators and activists, farmers, and government officials.

Land-based Environmental Issues in the Palouse River Watershed

Recall from Chapter Four that the land area of the Palouse River Watershed is approximately 3,280 square miles. In this section, I consider problematic aspects of watershed land use with a particular contemporary focus on soil and soil erosion, habitat, and biodiversity.

Palouse Soil

As has been discussed previously, soil erosion is problematic because it reduces the ability of land and water to support life. From an economic standpoint, the loss of topsoil results in reduced crop yields and reduced income for farmers and their communities. In terms of water quality, the erosion of soil into streams can result in contamination of surface and below-surface waters with agricultural chemicals and particulate matter that make life difficult to impossible for aquatic species. With more than 90% of the land area of the Palouse Watershed under cultivation, understanding the current level of soil erosion is an important part of this report's overall goal of understanding the sustainability needs of the Palouse Watershed.

The Palouse Watershed has experienced phenomenal levels of soil erosion beginning in the 1860s. Several practices evolved since then in response to this problem. Some practices, such as fallowing, proved problematic while other practices, such as, strip cropping, the planting of cover crops, retirement of steep slopes, and no-till seeding, have curtailed the loss of Palouse topsoil to varying levels. Ebbert and Roe (1996) used the Universal Soil Loss Equation (Wischmeier & Smith, 1978) to compare Palouse erosion control practices in use in 1979 and 1994 and concluded that the use of conservation measures, such as those listed above, resulted in the reduction of 1.7 million tons of Palouse topsoil loss per year in the watershed. This amounts to about a 10% reduction in annual topsoil loss which is equivalent to saving 1.4 tons of topsoil on each of the 1.2 million acres of Palouse cropland. It follows mathematically from this figure that each acre under cultivation in the Palouse still loses an average of 12.6 tons of topsoil per year. This rate of soil loss is problematic since research has shown that a normally-functioning soil system can sustain the loss of about five tons of topsoil loss per year per acre (Anspach, 2008). This leaves Palouse fields on average with an unsustainable loss of more than seven tons or 14,000 pounds of topsoil per year per acre. In many individual tracts of land, however, soil loss continues at the rate of 15 tons per year or 45,000 pounds of annual soil loss (Rudzitis, 2008). Clearly, the current rate of topsoil loss as a result of Palouse agriculture is a major threat to sustainability in the Palouse.

The long-term sustainability of soils in the Palouse Watershed is threatened by at least two additional factors connected to erosion: declining levels of organic matter in local soils and increasing levels of soil acidification (McCool, Huggins, Sexton, & Kennedy, 2001). Rasmussen, Collins, and Smiley (1989) conducted a long-term study of dry land farming in the vicinity of Pendleton, Oregon, an area with similar climate and typography, and determined that organic material in the soil decreased by 40-50% over the course of 100 years of farming. Organic material, often called humus, is an important surface layer component of soil that holds soil moisture and provides habitat for soil microbes, worms, and other forms of life. The loss of vast quantities of organic material results in a general drying of the soil which makes it further susceptible to the effects of wind and water erosion. Another problem with the loss of Palouse humus is that humus serves as habitat for the very soil organisms that create more humus through the decomposition of plant matter. In a scenario resembling an endless loop, the loss of humus thus leads to further loss of humus.

Soil acidification is another threat to sustainable agriculture in the Palouse Watershed. Soils formed under native Palouse Prairies are found to be neither acidic nor basic but close to a neutral pH of 7.0. Plants and soil organisms adapt to soil pH over a long span of time and possess varying levels of tolerance to changes in soil pH. Mahler, Halverson, and Koehler (1985) reported that Palouse soil pH declined from near neutral to an acidic pH of 6.0 by the early 1980s. This change represents a 10-fold increase in soil acidity since the acid base rating system is based on a log rhythm scale. The change in soil pH is directly attributed to the use of nitrogen-based fertilizers in Palouse agriculture. Furthermore, in comparison with conventional tillage, the practice of no-till seeding, the most promising technique for reducing Palouse erosion is linked to greater decreases in soil pH (Bezdicek, Hamel, Fauci, Roe, & Mathison, 1998).

Hornick and Parr (1987) describe sustainable soil productivity as the balance between degradation processes and reclamation processes. Such a balance has yet to be achieved on the Palouse. The loss of vast quantities of Palouse topsoil through erosion, as well as, the depletion of organic matter and fertilizer-induced soil acidity, demonstrate the unsustainability of current agricultural practices in the Palouse River Watershed. In the next section, I continue the discussion of land-based sustainability issues in the Palouse Watershed with an examination of urban and rural habitat.

A Palouse Wilderness?

Smith and Smith (2001) define habitat as the physical places where organisms live. In this section, I examine sustainability in connection with Palouse habitats with a special focus on green spaces and biodiversity of plant and animal species. The concept of wilderness green space in connection with the Palouse Watershed area is considered first.

The European-American conception of valuing wild places is often traced to the nineteenth century naturalist writer Henry David Thoreau. Thoreau wrote about his experiences at Walden Pond and boating the Concord and Merrimack Rivers and in so doing spawned the environmental movement in the United States. A little over 100 years later, under pressure from scientists and the public, President Lyndon Johnson signed the *Wilderness Act of* 1964 into law. The Wilderness Act created a legal definition of wilderness and created the US National Wilderness Preservation System with an initial designation of 9.1 million acres of wilderness. The act was written by Howard Zahniser of the Wilderness Society who defined wilderness as "an area where the earth and its community of life are untrammeled by man [and / or woman], where man [and / or woman] him[her]self is a visitor who does not remain." The idea behind wilderness designation is to provide space where intact ecosystems can change naturally over time without the influence of human manipulation. Wilderness also acts as a haven where rare species of life can live in situ, rather than being sequestered in human institutions such as zoos or botanical collections.

Wittbecker (1991) completed an ecological development plan for the Palouse Region in 1991 that was based on the relationship between human communities, agriculture, and wilderness habitat. He asserted that wilderness areas need to be set aside in each bioregion “because cities depend upon agriculture and agriculture depends on wilderness for recycling, pest control, soil-making, and water purification” (Wittbecker, 1991, p. 16). Setting aside wilderness area in the Palouse is especially important to local sustainability since the Palouse Watershed is one of the most endangered ecosystems in the United States (Noss et al., 1995; Black et al., 2003).

Wittbecker argues for large reserves because they maintain the integrity of wild gene pools. The abnormal evolutionary path of white-tailed deer in Seneca County, New York, affirms his logic. In 1941, the United States Army fenced off a 10,000 acre swath of land to store World War Two munitions. The 24-mile long fence restricted movement of animals and contained a very small herd of white-tailed deer. Interbreeding within the population resulted in the expression of a recessive genetic abnormality called leucism (Freeman & Herron, 2001). Leucism results in the loss of an organism’s ability to create pigment or color so the Seneca white-tailed deer population literally started turning white. Leucism was reversed among the deer population when the fence was later torn down, allowing Seneca white-tailed deer to breed among a larger population.

Using equations and concepts rooted in population biology, the study of populations of single species (Frankel, 1975; Soule & Wilcox, 1980), Wittbecker (1991) employs the coyote as the key species for calculating minimum wilderness area for the Palouse River Watershed. Usually, larger carnivores such as bears and lions are used as indicators of land carrying capacity. In the case of the Palouse, the coyote is used since it has filled the niches left since the disappearance of larger carnivores from all but the eastern reaches of the Palouse River Watershed. Wittbecker calculates the size of wilderness area necessary to maintain the ecological integrity of the larger Palouse Region to be 16% of the total land area. He employs a larger-than-watershed area that extends north of Spokane, Washington and south to include the Camas Prairie communities of Cottonwood and Grangeville, Idaho. Adapting Wittbecker's methods to the smaller Palouse Watershed results in a minimum wilderness land area need of 987 square miles. This wilderness should include a cross section of the watershed, including bunch grass prairie and other meadow-steppe vegetation, as well as forest.

As of this writing in 2009, there has been no successful attempt to set aside more than small patches of Palouse meadow-steppe as wilderness by any level of designation. The Nature Conservancy's Rose Creek Preserve, Kamiak Butte State Park, Steptoe Butte State Park, Idler's Rest, the Virgil Phillips Farm, and Smoot Hill stand out as examples of near-wilderness. These areas, however, are too small and too spread out and bisected by highways to serve as anything but patches of wilderness that are too small to function as wilderness without significant human intervention. I know this from personal experience. I have seen local biologists, extension agents, and other boosters of native prairie work tirelessly to prevent the spread of noxious weeds, replant bunchgrass hillsides laid bare by chemical overspray from adjoining farms, and monitor populations of endangered Giant Palouse Earthworms.

I argue that any serious attempt at environmental sustainability in the Palouse River Watershed needs to include a wilderness preserve for the genetic and ecological health of the region, as well as, for the aesthetic joy that wild places bring. The cost of creating such a reserve would be a huge but necessary investment in the overall health and sustainability of this place, especially since a Palouse wilderness could offer untrammeled habitat for species struggling to exist in the Palouse Watershed.

Threatened Species in the Palouse Watershed

There are two threatened species in the Palouse River Watershed. Before discussing these, it is important to point out that the Palouse, as a single biological entity, is one of the most endangered ecosystems on the planet (Black et al., 2003). More than 95% of pre-European native plant cover has been lost on the Palouse and tracts of remaining bunchgrass prairie occur sparsely in very few places (Black et al., 2003). The fact that there are only two species on the Palouse that fall under or near US Fish and Wildlife Service's legal distinction of endangered or threatened seems to me to be an indictment of this government agency's understanding of what it means to be endangered or threatened.

The Giant Palouse Earthworm, known scientifically as *Driloleirus americanus*, is an albino worm that grows to three feet in length and can burrow to a depth of 15 feet to escape lengthy Palouse summer droughts. The worm was listed as an endangered species in 2001 by the World Conservation Union.

As of early 2009, however, the US Fish and Wildlife Service has refused to list the worm as threatened or endangered in spite of a number of lawsuits brought forth by environmental organizations. One issue that confounds Endangered Species Act listing is that little is known about the population of Giant Palouse Earthworm populations. Thought to be extinct for more than 20 years, there have only been a handful of sightings in the last decade.

Spaulding's Catchfly, botanically-known as *Silene spaudlngii*, is a perennial plant in the carnation family that blooms mid-summer and survives dormant below ground for long periods of time. US Fish and Wildlife listed the plant as threatened in 2007 after determining that populations were in severe decline across portions of Idaho, Montana, and Washington because of loss of habitat, competition from non-native species, and human encroachment. US Fish and Wildlife's (2007) recovery plan for Spaulding's Catchfly acknowledges only 99 known populations of the plant with many groups of plants suffering from poor genetic fitness for reasons similar to the Seneca white-tailed deer case cited previously. US Fish and Wildlife (2007) scientists acknowledge in the plant's recovery plan that "Spaulding Catchfly cannot be recovered if its habitat is not conserved and restored" (p. x). The recovery of this single species is estimated to cost over $8,000,000, money which could be invested into a more holistic solution such as wilderness creation. In this author's view, work aimed at restoring one species at a time fails to acknowledge the complex interconnectedness of species and their environment. In the next section, the problem of invasive species is considered.

Invasive Species in the Palouse Watershed

Plant species that originate in other ecosystems have historically been transported to the Palouse by humans and other species such as migratory birds. The problem with the introduction of vegetation from other ecosystems is that such plants have evolved in response to a unique set of challenges, predators, and food supplies. When non-native plants are introduced to new places they tend to take over an ecosystem since they are not bound by biologic relationships tied up in the evolutionary history of that place.

The US Government labels such plants noxious weeds if they have the potential to adversely affect other plants, particularly food crops, as well as, humans and other species. The *Federal Noxious Weed Act of 1974* spells out specific responsibilities of landowners and governmental entities in connection with noxious weed control. There are more than 18 plants in the Palouse Watershed that meet the US Government's definition of noxious weed. White bryony, bull thistle, tansy ragwort, Canada thistle, diffuse knapweed, Russian knapweed, poison hemlock, leafy spurge, and Scotch thistle are recognized as the most pernicious on the list.

Noxious weeds are problematic in the Palouse Watershed for several reasons. The rampant spread of some noxious weeds, including knapweed, can adversely affect crop yield. Poison hemlock, on the other hand, can kill grazing animals such as cattle and horses. Other species, such as white bryony, can wipe out tree and shrub populations by attaching to leaves and blocking the receipt of light energy from the sun. This is especially problematic in riparian zones because it results in a loss of stream-side shade. Mono-cropping of wheat over a vast area of the watershed makes the land even more vulnerable to noxious weeds since such land use intentionally depletes plant diversity and thus the ability of multiple types of plants to hold their collective ground space. Duffin (2007) points out that the Palouse Watershed has experienced problems with noxious weeds since soon after farmers started to till the native bunchgrass prairies.

Several treatments are used in the attempt to control noxious weeds in the Palouse River Watershed. Cutting the roots of plants a few inches beneath the surface effectively eradicates individual plants of white bryony and some other noxious species. Other plants, such as knapweeds, are usually attacked with herbicides. As was mentioned previously, the use of herbicides is problematic because the chemicals wash off inclined Palouse fields into local streams. The use of bio-controls such as flea beetles to selectively eat tansy ragwort is a strategy that shows promise but more research needs to be completed to determine local appropriateness and effectiveness. Another bio-control that is being studied on the Palouse involves the use of goats and sheep to graze weed cover.

The problem of noxious weeds in the watershed continues in spite of promising efforts using bio-controls. Current and long-term problems with noxious weeds in the watershed serve as evidence of the disrupted and disconnected state of the Palouse Watershed, and, point to the need for a more sustainable approach to ecosystem management in the Palouse Watershed. In the next section, I continue the discussion of land-based issues on the Palouse with a look at urban green spaces.

Urban Green Spaces

Wittbecker (1991) and others (Louv, 2005; Wilson, 1984) argue for the importance of wild places in urban settings called *green spaces*. This movement is historically tied to the playground movement of the 1870s which produced many of the nation's largest urban parks, including New York City's Central Park. In the aftermath of World War Two, the movement lost momentum and was superseded by the construction of parks dedicated to turf-based sports such as baseball, soccer, and football. In contemporary terms, urban green spaces take many forms including green belt paths, natural parks, city parks, community gardens, arboretums, vacant lots, and even natural roofscapes featuring sod roofs, trees, bushes, and flowers. A special form of green space built on or adjacent to school properties is a feature of many schools that are active in the green schools movement.

Schools and communities choose to participate in creating and maintaining urban green spaces because these islands of nature possess many benefits for urban places. Ecological benefits of green spaces include increased habitat area for non-human forms of life, increased rainwater absorption, reduced soil erosion, and cleaner air through the absorption of pollutants by trees. Green spaces also reduce urban heat retention associated with the *urban heat island effect*. Socially, green spaces provide people with places for play and opportunities to connect with the natural environment. Such places also can serve as ecologically-sound routes to school, work, and play and serve as learning laboratories for young and old alike. Richard Louv (2005), author of *Last Child in the Woods* asserts that time in green spaces can help people to be more psychologically-sound and save children from *nature deficit disorder*, or NDD, a term coined by Louv to describe “the human costs of alienation from nature” (p. 34). According to Louv, the symptoms of NDD are diminished sensory perception and attention difficulties such as attention deficit disorder. The cure for NDD is to simply provide people with time in natural settings.

There are two urban communities with populations over 10,000 in the Palouse Watershed and both have an abundance of green spaces. The Palouse Path - Chipman Trail, a “rails to trails” project started in the 1990s, connects the communities of Pullman, Washington, Moscow, Idaho and Troy, Idaho. The path is contiguous with paved walking/biking paths that traverse both Moscow and Pullman. This trail system is used daily for transportation and recreation and serves as a safe, quiet, and natural pathway for many Palousians. Moscow is home to the University of Idaho’s 63-acre arboretum and botanical gardens. The city of Moscow is also home to more than a dozen parks, including East City Park, Berman Creekside Park, Dog Park, and the Lena Whitmore Nature Park. Idler’s Rest, a Nature Conservancy property, and the Virgil Phillips Farm County Park are located five miles to the north of Moscow. The city of Pullman has eleven parks, including Kruegel Park, Petry Natural Area, Sunnyside Park, and Lawson Gardens. Together, the communities of Moscow and Pullman offer an abundance of urban green space that serves the recreation and transportation needs of local people, as well as, providing a diversity of habitat types for people interested in connecting with nature.

Thus far, land-based environmental issues in the Palouse Watershed have been considered. Soil erosion, loss of humus, and soil acidification were shown to be contemporary problems that challenge sustainable agriculture and point to the degradation of Palouse lands and waters. Two threatened species, the Giant Palouse Earthworm and Spaulding's Catchfly, were looked at along with the reason for their decline – habitat degradation. Large and small green spaces were also considered since these places offer a greater chance for ecosystems to remain intact, and, provide habitat space for people to connect with nature and enjoy various forms of recreation in natural or near-natural settings. In the next section, the examination of the sustainability needs of the Palouse River Watershed continues with a look at water-based issues.

Water-based Environmental Issues in the Palouse Watershed

Rivers are intimately linked with the land that supports them. According to Valerie Rapp (1997), author of *What the River Reveals*, "A river [system] is connected to its watershed in four dimensions: longitudinal (upstream - downstream), lateral (floodplain - uplands), vertical (surface water - ground water), and through time since the other connections are dynamic" (p. 31). In this section, surface water and groundwater issues connected with sustainable living in the Palouse River Watershed are examined. It will be shown that both surface and ground waters are negatively influenced by human activities that take place on the land and spread to each of Rapp's four dimensions. In what follows, I provide an overview of the key issues facing the watershed. In the next section, I detail water quality issues in the Palouse Watershed.

Contemporary Water Quality Issues in the Palouse Watershed

At the time of this writing, the Palouse Conservation District's (2007) *Palouse Watershed Plan* is the most current and comprehensive document available on Palouse water quality. The watershed plan was created with input from scientists, land owners, city officials, county extension agents, the Whitman County Farm Bureau, and Washington State's Department of Ecology. The report identifies four areas of concern within the Palouse Watershed: poor water quality, insufficient water supply, loss of riparian habitat, and inadequate stream flows. Water quality is considered first.

Water quality in the Palouse Watershed is affected by harmful substances that are directly introduced to local waterways, as well as, by secondary effects from some of those same substances which can act to lower levels of dissolved oxygen and therefore the ability of waterways to support life. Several types of harmful substances are routinely introduced into the waters of the Palouse Watershed. Chief among these are agricultural chemicals such as pesticides and fertilizers. Fecal coliform bacteria and soil sediments are also found in high concentrations in many parts of the watershed.

Pesticides reduce water quality because they are injurious to animal and aquatic life in many ways. In regard to animals, pesticides cause adverse skin reactions such as swelling and blistering. Pesticides also injure mucous membranes located around eyes, the nose, and mouth. Nervous and circulatory system injuries are also associated with animal exposure to pesticides. In fish, pesticide exposure is correlated with weight loss, impaired immunity, sterility, and reduced egg production. Heptachlor epoxide, alpha –BHC, dieldrin, and PCB 1260, 4-4 – DDE, and DDT are pesticides that are found in fish swimming the waters of the Palouse Watershed (Johnson, Era-Miller, & Kinney, 2005). In a testament to Rapp's (1997) time dimension of watersheds, DDT, though banned for use in the United States in 1972, still washes from Palouse fields into the Palouse River system.

Chemical fertilizers have been used in the Palouse River Watershed since the 1940s. These compounds are high in nitrogen and phosphorus and are the causal agents of eutrophication, a process that results in lowering levels of dissolved oxygen beyond the threshold of many aquatic organisms. Hundreds of tons of ammonium nitrate, ammonia, and various phosphorus-based fertilizers are applied to Palouse fields each year (Duffin, 2007). When these compounds enter streams containing cyanobacteria they feed the production of toxins that cause diarrhea, cramps, vomiting, skin rashes, and flu-like symptoms in humans and other animals. Additional nutrients arrive in Palouse waters from water and waste treatment facilities that are operated by the many towns in the Palouse Watershed.

A third type of contaminant that is found in the waters of the Palouse Watershed is bacterial in origin. Fecal coliform bacteria enter Palouse waterways from animal droppings, manure-based runoff, leaky septic tanks, and in the form of effluent from ineffective waste treatment facilities. [See photo two in Appendix

B]. Elevated water-based levels of fecal coliform bacteria are associated with several human illnesses: ear infections, dysentery, typhoid fever, gastroenteritis, and hepatitis A. Many aquatic species from insects to fish also fail to tolerate fecal coliform bacteria.

Soil sediment acts as another detriment to water quality in the Palouse Watershed. Most of the sediment that washes into Palouse waterways arrives by way of erosion from farm fields. Sediment flow tends to be heaviest in the immediate aftermath of winter and spring rainfall. The arrival of mass quantities of soil into Palouse streams coincides with the annual hatch of many aquatic species including fish. Sediment acts like water-borne smog and impairs the respiratory systems of young fish and water-borne insects. As sediment travels downstream, much of it is deposited behind the walls of the many dams on the Snake and Columbia Rivers. Over the long term, sediment deposits greatly reduce the available storage capacity of dams.

Insufficient Water Supply

The 2007 *Palouse Watershed Plan* lists insufficient water supply as a second area of concern. I address the matter of inadequate stream flows, the forth concern raised in the watershed plan, with insufficient supply since these issues are closely related. Several streams in the watershed experience periods of low to zero flow. This occurs most often during annual summer droughts. The Palouse receives very little rainfall from June – October. In some parts of the watershed, particularly along the South fork of the Palouse River and Paradise Creek, surface flow is only maintained by water that is released from municipal water treatment facilities. This becomes problematic when treated water containing fecal coliform bacteria makes up the bulk of the flow in these streams. This situation was observed and later reported in Washington State Department of Ecology's (2005) publication entitled *North Fork Palouse River Fecal Coliform Total Maximum Daily Load.*

A second aspect of Palouse water supply concerns the drawdown of the underlying basalt aquifers. Both the Grande Ronde and the Wanapum aquifers have been in historic decline with the Grande Ronde experiencing a 1-2 foot decline each year for the last 70 years (Palouse Basin Aquifer Committee, 2007). Aquifer decline results in a lowering of the water table – which is essentially the surface of the underlying ground water. The water table in many areas of the Palouse continues to fall because extraction exceeds recharge. One consequence of this is that roots of water-loving plants like willow must plunge deeper in the soil strata to tap into water supplies. This forces willows to divert resources from energy-gathering in photosynthesis to energy use in the creation of longer tap roots. In an already water-strapped environment, the lowering of water tables may prove over time a barrier to the growth of willow and cottonwood trees that are needed to provide necessary shade for fish and other aquatic species in Palouse streams.

A third problem with the Palouse's water supply is that water table recharge has been reduced because less water infiltrates from the surface to the underlying water table. In urban areas, this happens because paved areas are impervious to downward flow so water travels horizontally and collects until meeting unpaved surfaces. In rural areas, water table recharge is hampered because of soil compaction and changes in vegetative cover that leaves areas less permeable to the downward flow of water.

Current levels of groundwater use in the Palouse Watershed are unsustainable because aquifers continue to experience greater levels of extraction than recharge. As was mentioned previously, it is thought that the Grande Ronde, the main source of water for the universities and larger Palouse communities, is capable of very limited recharge because of both horizontal and vertical barriers to water flow. In 2007, the total combined pumpage by Pullman, Moscow, Colfax, Palouse, Washington State University, and the University of Idaho, the primary pumping entities in the watershed, was calculated to be 2.77 billion gallons (Palouse Basin Aquifer Committee, 2007). This figure represents a 2.2% decrease from the previous year and a 10.3% decrease from 1992, the first year the Palouse Watershed Management Plan was in effect (Palouse Basin Aquifer Committee, 2007). Decreases are attributed to water conservation education, improved irrigation and water-use technology, and seasonally-cool temperatures in several measurement intervals. The 2007 *Palouse Watershed Plan* requires Moscow, Pullman, Colfax, Palouse, Washington State University, and the University of Idaho to limit annual future pumping increases to no more than 1% above 1986-1990 levels. This cap serves to limit increases but still allows Palouse communities and universities to continue the unsustainable drawdown on the local aquifers.

To make matters worse, the cities of Moscow and Pullman have been under pressure by several business entities, including the Hawkins Development Company and Wal-Mart, to allow the building of super-sized shopping facilities that would draw even more water from local aquifers.

The last area of concern mentioned by the Palouse Conservation District's (2007) *Palouse Watershed Plan* is the loss of riparian and aquatic habitat. Most of the watershed's riparian habitat and wetlands have been lost because they stood in the way of increasing agricultural productivity. The loss of riparian habitat is associated with warmer stream temperatures that can be barriers to coldwater fish species and other forms of life. The loss of riparian habitat is indirectly responsible for increased streamside erosion and increased peak flows leading to flooding. Erosion occurs because of the absence of root systems that hold stream banks together. Erosion causes stream banks to lose shape, allowing water to escape to the floodplain before water levels actually reach flood stage. The loss of riparian habitat is cited as problematic in the *Palouse Watershed Plan* and other documents but no qualitative or quantitative data is available to further describe the amount or degree of loss. In Chapter Six, I discuss several restoration projects underway to improve riparian habitat in the watershed.

The Clean Water Act of 1972: Solution or Problem

The problems that plague Palouse streams continue in spite of more than 30 years of required monitoring under the *Clean Water Act* or *CWA*. Congress passed the CWA in 1972 in response to ongoing pressure from citizen activists concerned with poor water quality in many of the United State's bodies of water. The goal of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Federal Water Pollution Control Amendments, 1972, p. 1). Unfortunately, the CWA takes a narrow view of biological integrity and merely requires water to be free of chemical and biological contaminants, not that water bodies actually be able to support aquatic life (Rapp, 1997). Furthermore, agricultural runoff continues to be exempt from control under the CWA's non-point source provision. Under the most current version of the CWA (1987), the Palouse Watershed has been monitored and managed for contaminants and temperature but seemingly to no avail. In further testament to Rapp's (1997) aforementioned time dimension of rivers, toxic sediment laced with banned chemicals such as DDT continues to wash from fields into Palouse streams. I agree with Rapp (1997) who asserts that the CWA fails to address the complex relationships in aquatic ecosystems and between bodies of water and upstream land use practices. The CWA mandates the production of lengthy and costly investigations and reports that point to symptoms without actually addressing the underlying, systemic brokenness of streams and other bodies of water. The ramifications for the Palouse Watershed are huge. Clearly, current government control under the Clean Water Act has not led to sustainably clean waters. The CWA is not working so other strategies must be explored to address sustainability with respect to the waters of the Palouse River Watershed. It is this author's belief that k-12 education, applied to the needs of this place, might serve as a more effective means for restoring biological integrity to the Palouse River Watershed.

Water-based Environmental Issues in the Palouse Watershed: In Conclusion

In this section, I have detailed the four areas of concern enumerated in the 2007 *Palouse Watershed Plan*: poor water quality, insufficient water supply, loss of riparian habitat, and inadequate stream flows. Each of these environmental issues was shown to be directly connected with unsustainable human practices mostly centered in local agriculture which decrease the overall health of the ecosystems in the Palouse River Watershed. The Clean Water Act of 1972 was considered and found to be severely lacking in ability to restore Palouse streams to healthy, biodiverse places.

Air-based Environmental Issues in the Palouse Watershed

Palouse land and water-based environmental issues have been considered thus far in this chapter. It has been shown that both Palouse land and water are currently being unsustainably degraded by human activities. In this section, environmental issues connected with the air above the Palouse Watershed, an area known as the Palouse Airshed, are considered. It is important to consider air in this report because air is the medium that all respiring organisms use to obtain oxygen for respiratory, life-sustaining processes. Air pollutants are considered first; then, air pollution in connection with climate change and global warming is examined in respect to the Palouse Watershed and Airshed.

The Clean Air Act

The potential for environmental degradation is not limited to land and water. Air-borne pollution is found in the atmosphere at various levels above the ground and surface waters of the Palouse Watershed, an area known as the Palouse Airshed. Idaho's Department of Environmental Quality (2009) defines an air pollutant as "any substance in the air that can cause harm to humans or the environment" (p.1). Breathing in air pollutants can adversely affect humans and other animals causing lung damage, birth defects, nerve damage, reduced immunity, and increased potential for several forms of cancer (Idaho Department of Environmental Quality, 2009). The *Air Pollution Control Act* was signed into law in 1955 to address the adverse affects of chemicals and particulate matter in the air. The US Environmental Protection Agency (EPA) serves as the enforcement arm of the current air pollution law which is known as the *Clean Air Act of 1990* or *CAA.* The Clean Air Act sets air quality and emission limitations, addresses ozone protection, and calls for restoration plans for nonattainment areas with poor air quality. The CAA lists seven air pollutants as especially problematic: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, lead, and particulate matter of two size classes – small particulate matter 2.5 microns or less in size, and, coarse particulate matter that is 10 microns or larger. In the next section, air pollution is considered in connection with the Palouse Watershed.

Air Pollution in the Palouse Watershed

The Clean Air Act mandates air quality reporting at the state level so considering air quality in the Palouse Watershed involves working with separate agencies in Idaho and Washington. Idaho's Department of Environmental Quality and Washington's Department of Ecology both cite small particulate matter 2.5 microns or less in size, also referred to as *PM 2.5*, as the region's sole air pollutant of concern. PM 2.5 sources include smoke from wood stoves and field burning and emissions from motor vehicles. EPA requires PM 2.5 levels to be below 35 micrograms per cubic meter. When this concentration is exceeded, monitoring stations are required to report air quality using EPA's *Air Quality Index Values* or *AQI.* The AQI is a six-tiered system that combines measures for the seven pollutant types mentioned above into a single air quality value from 0-500. AQI values from 0-50 are considered good while values from 51-100 are labeled as moderate because a very small percentage of the population is potentially at risk. AQI values from 101-150 are unhealthy for sensitive groups including the very young, very old, and those with compromised respiratory function. Air quality values above 151 are considered unhealthy for the general population and are accompanied by government-issued health alerts.

There are five air quality monitoring stations in the Palouse Watershed. Moscow, Idaho has the only Idaho-based station in the Palouse while Washington State has stations in Pullman, LaCrosse, Rosalia, and Ritzville. Air quality data from each of these stations is reported by both the US EPA and each state's environmental agency. Reports generated from state agencies for 2008 show that PM 2.5 levels never approached the critical daily average of 35 micrograms per cubic meter concentration. In 2008, the highest daily average in the Palouse Watershed was recorded in July in LaCrosse, Washington.

LaCrosse’s 17.6 microgram per cubic meter reading is a little more than half of the critical threshold. It is interesting to note that the EPA reports the Pullman station having one day of moderate air quality with an AQI of 54 in 2008. I was unable to uncover the reason for this discrepancy.

State and federal reports on air quality in the Palouse Watershed might lead a person to believe that local air quality is very good. As a 20-year resident of the Palouse, I have reasons to doubt the veracity of local air quality monitoring. As a parent of a child with asthma, I have observed my son’s wheezing during spring and summer harvests. I regularly sent notes to school requesting that my son be excused from physical education class during harvests. I have also witnessed high school students struggle with harvest-related breathing difficulties when I worked as school teacher in Pullman. I believe that such breathing difficulties are due to breathing in particulate matter introduced into the air during harvesting.

Non-motor vehicle airborne particulate matter is generally composed of three loess components: sand, silt, and clay. Sand particles are 50 micrometers and larger in size and are too large to stay airborne for very long. Silt particles vary in size from 2 – 50 micrometers while clay particles are smaller than 2 micrometers. Accordingly, PM 2.5 monitoring should detect elevated levels of silt and clay in the atmosphere during harvest. An examination of 2008 data for each of the watershed’s monitoring stations reveals slightly elevated levels of PM 2.5 debris during harvest months, but, as was previously indicated, reports of particulate matter never approached levels of concern to the EPA and appropriate state agencies. This researcher cannot account for the apparent discrepancy. Perhaps the number and placement of air monitoring stations needs to be reconsidered because all five monitoring stations in the watershed are located in townships and are some distance from Palouse fields and rural households. Thus, it is conceivable that air quality reporting in these communities might be skewed by location.

There are two additional elements that impact air quality in the Palouse Watershed: field burning and motor vehicle emissions. The practice of burning crop stubble occurs after harvest in many places in the Palouse Watershed. Crop burning is problematic since it puts smoke and particulate matter into the air. In Idaho, burning is controlled by the state's Department of Environmental Quality while Department of Ecology oversees such practices in Washington State. Field burning continues in the Palouse in spite of multiple lawsuits and research that correlates respiratory illnesses with the practice (Jimenez, 2002). One of the reasons why burning continues is that those for and against the practice cite scholarly research affirming their particular view making it appear that the negative impacts of field burning are not conclusively known.

Motor vehicles emit particulate matter that falls under EPA's PM 2.5 controls. To date there are no studies that describe the level of automobile-related particulate matter that enters the Palouse Airshed. Current efforts at examining motor vehicle contributions to air pollution focus instead on greenhouse gas emissions and their role in global warming, the topic considered in the next section. In summary, the Palouse Watershed is an area where government monitoring and reports fail to correlate with the experiences of people living within the watershed that suffer ill health due to what may be particulate matter-induced respiratory problems.

Greenhouse Gas Emissions in the Palouse Watershed

Greenhouse gasses are a special category of air pollutants. These are gasses that absorb infrared radiant heat energy which raises air temperature in the atmosphere, a phenomenon known as the greenhouse effect since it mimics what happens in actual greenhouses. In what seems the ultimate paradox, the Earth would be uninhabitably cold without these gasses yet too high a concentration results in climate change and even global warming.

It is important to consider greenhouse gasses and global warming in any treatise on sustainability since human-caused global climate change is an outward sign of serious environmental imbalance. Furthermore, elevated temperatures are expected to pose dire future environmental consequences for the Palouse Watershed. Scientists with Washington State's Department of Ecology report that the state is currently warming at the rate of 0.5^{o}F every ten years (Washington Department of Ecology, 2009). This amounts to a threefold rate of increase over the period from 1900-2000. The warming of the Palouse is expected to raise the winter snow line approximately 300 feet for every degree of temperature increase. This means that more winter precipitation will fall as rain resulting in increased winter soil erosion, earlier peak flows, higher water temperatures, and less summer channel flow with more streams running only intermittently (Stiffler & McClure, 2003). The places likely to change the most are upland forests that are intolerant of warmer temperatures and lengthier periods of drought (Stiffler & McClure, 2003). Upland forests In the Palouse Watershed are located at the headwaters of the Palouse River, an area with already-compromised riparian zones (Palouse Basin Aquifer Committee, 2007). In short, global warming complicates and intensifies the environmental problems that the Palouse Watershed is already experiencing. Because of this, efforts at addressing environmental sustainability need to include measures to reduce the introduction of greenhouse gasses into the atmosphere.

There are four principal greenhouse gasses: water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and ozone (O_3). These gasses can arise through natural processes, such as through the decay of plant matter and by human activity including the burning of hydrocarbon fuels. Water vapor, a naturally occurring gas, is by far the greatest contributor to the greenhouse effect. In terms of human influence, carbon dioxide is of principal interest. Carbon dioxide levels have been shown, through ice core analysis, to have risen from a pre-industrial 1790 level of 280 parts per million to a 2007 level of 387 parts per million, an increase of 104 parts per million (Intergovernmental Panel on Climate Change, 2007). According to Stiffler and McClure (2003), the current level of atmospheric carbon dioxide is the highest in at least 420,000 years. The main sources of CO_2 are fossil fuel burning and deforestation. Over 90% of anthropogenic carbon dioxide released into the atmosphere comes from the burning of three sources: liquid fuels including gasoline and diesel (36%), solid fuels including coal (35%), and vaporous fuels including natural gas (20%) (Raupach, 2007). The US EPA ranks greenhouse gas contributors in the following order from largest to smallest: industrial, transportation, residential, commercial, and agricultural. Like the EPA, diverse organizations and governments have begun to recognize that greenhouse gasses are produced in virtually every sector of society. Many such institutions have conducted greenhouse gas inventories and set goals to voluntarily control emissions. The University of Idaho, Washington State University, and the City of Moscow are the only organizations that have conducted greenhouse gas inventories in the Palouse Watershed as of March 2009. Each of these entities has posted baseline emissions and committed to reducing emissions to sustainable levels. Unfortunately, at the time of this publication, plans for achieving sustainable emissions have yet to be reported. In Chapter Six, I outline preliminary steps taken by each of these entities as they work to create plans to achieve climate neutrality or no-net-negative influence.

Air-based Environmental Issues in the Palouse Watershed: In Conclusion

In this section, environmental issues connected with the Palouse Airshed were considered. Seven types of air pollutants were examined along with their corresponding effects on animal health. Air quality reports were shown to be in contradiction to research that asserts that harvest activities cause respiratory illness on the part of many Palousians. Air pollution in connection with climate change and global warming was discussed in respect to the Palouse Watershed and Airshed. Warming of the Palouse was shown to exacerbate watershed problems with erosion, water quality, and riparian areas.

The Environmental sustainability Needs of the Palouse: In Conclusion

The goal of this chapter has been to answer the question: What are the environmental sustainability needs of the Palouse Watershed? Environmental issues affecting the Palouse Watershed's land, water, and air were explored and it was determined that there are many human-caused challenges to achieving environmental sustainability in this watershed. Furthermore, it was shown that the environmental challenges facing the Palouse are a complex lot of interconnecting issues that transverse air, land, and water boundaries and speak to a wide-ranging level of ecosystem degradation.

CHAPTER SIX

CONTEMPLATING A SUSTAINABLE PALOUSE WATERSHED

This chapter concludes the three chapter case study of the environmental sustainability needs of the Palouse Watershed of Eastern Washington and North Idaho. In Chapter Four, the Palouse Watershed was described with respect to location, geology, flora and fauna, and climate. Palouse land use from 1860-2000 was discussed with an emphasis on human practices that have resulted in environmental degradation. Chapter Five addressed the question: What are the environmental sustainability needs of the Palouse River Watershed? Contemporary environmental issues were broken down into matters of land, water, and air to provide a comprehensive summary of the challenges facing an environmentally-sustainable Palouse. Efforts aimed at restoring environmental quality are considered in this chapter, along with factors that possibly delimit the success of such efforts. It is important to consider restoration efforts because they are the foundation from which an environmentally-sustainable Palouse can be created. Furthermore, understanding the actual steps that improve local environmental quality can serve to inform the types of skills and experiences necessary in educating and empowering students to achieve environmental sustainability in the Palouse River Watershed. Accordingly, this chapter closes with a consideration of the implications of this case study for science education.

Palouse Environmental Issues Addressed Through Legal Enforcement

In the United States, remedying environmental problems is primarily approached through the legal system. When citizen activists and scientists demanded cleaner waters in the 1960s and 1970s the end result was the creation and passage of the Clean Water Act. This law has been the primary vehicle to address water quality issues ever since. Several of the environmental issues that challenge sustainability in the Palouse Watershed fall under the control of four federal laws: the Clean Water Act, the Clean Air Act, the Endangered Species Act, and the Federal Noxious Weed Act. Looking at the Palouse's environmental problems through the legal framework set up to monitor and address such problems makes sense because these laws are what drives environmental restoration efforts in the US. Enforcement of the Clean Water Act and the Clean Air Act is the responsibility of the US Environmental Protection Agency or EPA while enforcement of the Endangered Species Acts falls to the US Fish and Wildlife Service. The Noxious Weed Act is enforced by four agencies attached to the Department of Agriculture: The Bureau of Reclamation, Fish and Wildlife, the National Park Service, and the Forest Service. Both the Clean Air Act and the Clean Water Act allow EPA to delegate monitoring and enforcement to states and local agencies. For example, the Clean Water Act requires states to monitor streams for several variables: introduced pollutants, sediment, bacteria, and temperature. Streams that fail to meet state water quality standards are required to be listed as impaired bodies of water on the state's 303(d) list, so-called in reference to the location of this provision within the Clean

Water Act. The Clean Water Act requires that states bring all 303(d) listed streams into compliance with *Total Maximum Daily Load*, or *TMDL*, for each area of infraction. TMDL refers to the acceptable amount of contaminant or temperature function as spelled out by state environmental quality limits. TMDL reports focus on accomplishing step-wise target reductions using *best management practices*, or *BMPs*. Specific BMPs will be discussed thoroughly later in this chapter. For the time being, it is important to note that BMPs are the actual restorative steps taken to address environmental problems recognized under the CWA. In the case of water issues, TMDL reports and their associated BMPs drive much of the work being done in attempts to restore the Palouse Watershed to environmental quality. In the next four sections, environmental issues affecting the Palouse are considered with respect to the laws that are intended to correct those same issues.

Environmental Issues Addressed by the Clean Water Act

The environmental problems affecting the Palouse Watershed are regulated through the *Clean Water Act of 1987*. As was mentioned above, when streams fail to meet state water quality standards they are listed on EPA's 303(d) list of impaired waters. Seven of the streams that lie within the Palouse Watershed are on the most recent 303(d) list (Washington Department of Ecology, 2007a). Those streams are listed in Table 6.1, *303(d) Listed Palouse Watershed Streams* found below. Table 6.1 show that there are six types of CWA non-attainment within the watershed: dissolved oxygen, fecal coliform bacteria, pH, temperature, and the presence of the following agricultural chemicals in Palouse streams: heptachlor epoxide, PCBs, 4,4'-DDE, dieldrin, and alpha-BHC .

Table 6.1 303(d) Listed Palouse Watershed Streams

Stream	303(d) List non-Attainment Issues
Palouse River including the North Fork of the Palouse River	Dissolved oxygen, fecal coliform bacteria, pH, temperature, and the following agricultural chemicals: heptachlor epoxide, PCBs, 4,4'-DDE, dieldrin, and alpha-BHC
South Fork Palouse River	Dissolved oxygen, fecal coliform bacteria, pH, and temperature
Missouri Flat Creek	Fecal coliform bacteria
Paradise Creek	Fecal coliform bacteria and ammonia
Rebel Flat Creek	Dissolved oxygen and fecal coliform bacteria
Cow Creek	Dissolved oxygen, fecal coliform bacteria, and temperature
Pleasant Valley Creek	Fecal coliform bacteria and pH

(Source: *2007 Palouse Watershed plan,* Washington Department of Ecology, Olympia, Washington).

The six types of non-attainment cited above are related to few causal elements. Fecal coliform bacteria enter the Palouse Watershed in two ways: as ineffectively-treated sewage effluent introduced downstream from water treatment facilities, and, when fecal matter from animals is introduced directly into streams at unprotected stream crossings or when runoff washes animal fecal material from land to stream. [See photo two in Appendix B]. Streams are put on the 303(d) list for temperature when stream temperatures are observed to be too high for native cold water aquatic species such as trout. As was mentioned earlier in this case study, stream temperatures increase when shade trees and shrubs are removed from riparian, stream-side areas, making these places intolerant to native species. [See photo three in Appendix B]. The remainder of the 303(d) issues in the watershed are all connected with the introduction of agricultural chemicals into Palouse streams during erosional events. For example, the presence of nitrogen-based fertilizers in streams selectively feeds exploding algae populations which results in lowered dissolved oxygen levels. The presence of agricultural chemicals in levels exceeding total maximum daily load allowances is considered problematic because of the toxic health effects, including cancer, associated with even minute quantities of PCBs and dieldrin. Since these chemicals enter the watershed via erosion, erosion needs to be considered as a co-problem of chemical runoff, in addition to, as a problem in and of itself. Problematic changes of pH within the watershed are also related to erosion and the application of agricultural chemicals since some nitrogen-based fertilizers change the pH of soil that later washes into Palouse streams resulting in lowered pH readings downstream from runoff sites.

The Clean Water Act and restoration in the Palouse Watershed.

The Clean Water Act requires that Washington and Idaho bring their respective 303(d) listed streams into compliance with *Total Maximum Daily Load*, or *TMDL*, for each area of infraction in the Palouse Watershed. Recall that TMDL refers to the acceptable amount of contaminant or temperature function as spelled out by state environmental quality limits. TMDL reports were commissioned and completed for each stream on the 2007 303(d) list. Restoration activities for each 303(d) parameter are considered below. Strategies for addressing North Fork and main stem fecal coliform TMDLs include (Washington Department of Ecology, 2006):

- Widespread water quality sampling
- Monitoring of bacteria in wastewater effluent from Palouse and Garfield treatment facilities
- Monitoring Garfield and Palouse sewer lines for leaks and blockages
- Conducting a survey of all drain pipes that empty into the North Fork and main stem
- Provide financial assistance to owners of known problematic rural septic systems
- Provide financial and labor assistance to landowners for the purpose of creating structures to restrict livestock access to streams
- Restoration of riparian areas adjacent to Garfield’s Silver Creek with native vegetation
- Issuance of water quality permits to all water-discharging businesses

- Regularly sweep Palouse streets and clean catch basins
- Pursue funding of a long-term monitoring station at the North Fork's confluence with the South Fork
- Educating livestock owners about proper water-related ranching practices
- Educating rural residents about septic system maintenance
- Educating Palouse residents about proper pet waste disposal
- Educating landowners about the value of healthy riparian zones

Strategies for reducing agricultural chemical loads including dieldrin and PCB in Palouse streams include (Washington Department of Ecology, 2007b):

- Issue municipal storm water permits to Pullman and Washington State University entities
- Require erosion and sediment control plans for land altering activities and building permits in Pullman
- Increase annual storm drain maintenance
- Complete the removal of all PCB sources on the Washington State University campus
- Complete computerized mapping of all existing storm water lines on the Washington State University campus
- Provide Department of Ecology oversight on all construction projects larger than one acre
- Investigate the abandoned landfill and incinerator on the South Fork
- Continue periodic sampling of Palouse River fish for dieldrin and PCBs

- Assess levels of dieldrin and PCBs in treated water
- Conduct a study of the relationship between conservation farming practices to reduce sediment and chemical load washing into Palouse streams

Activities aimed at addressing pH, dissolved oxygen, and stream temperature are grouped together since these 303(d) concerns have similar root causes centered in soil erosion and the loss of riparian ground cover. Scientists with Washington Department of Ecology (2007) assert that the first priority in addressing pH, dissolved oxygen, and temperature is to conduct studies that look at understanding the complex relationship between these three variables. Other efforts at addressing pH, dissolved oxygen, and temperature are:

- Educating Palouse farmers about the advantages of conservation tillage practices including no-till, minimum tillage, strip-cropping, and riparian buffer zones
- Providing financial assistance to help farmers adopt conservation tillage practices
- Complete riparian restoration along the North Fork, South Fork, Cow Creek, and Pleasant Valley Creek including native tree and shrub planting, stream bank re-sloping, the establishment of riparian buffer zones between streams and tilled soil, and the installation of coir logs and erosion control fabric adjacent to streams
- Working with land owners to develop conservation plans for adopting best management practices

- Providing financial and labor assistance to landowners for the purpose of creating structures to restrict livestock access to streams

The activities listed in the preceding pages are the Clean Water Act's solutions for restoring the Palouse River Watershed and its associated streams to environmental integrity. This approach to environmental management will be problematized later in this chapter after considering the respective roles of the Clean Air Act, the Endangered Species Act, and the Noxious Weed Act to address the remainder of the environmental issues that have been shown to be factors in contemplating environmental sustainability in the Palouse Watershed. In the next section, the Clean Air Act is considered in connection with its role in addressing environmental quality in the Palouse Airshed.

Environmental Issues Addressed by the Clean Air Act

The *Clean Air Act* or *CAA* authorizes EPA to set air quality standards with respect to air-based pollutants that affect human health. The CAA lists seven air pollutants as especially problematic: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, lead, and particulate matter of two size classes – small particulate matter 2.5 microns or less in size, and, coarse particulate matter that is 10 microns or larger. As was mentioned previously, the Clean Air Act mandates air quality reporting at the state level so considering air quality in the Palouse Watershed involves working with separate agencies in Idaho and Washington.

Idaho's Department of Environmental Quality and Washington's Department of Ecology both cite small particulate matter 2.5 microns or less in size, also referred to as *PM 2.5*, as the region's sole air pollutant of concern. PM 2.5 sources include harvest dust, smoke from wood stoves and field burning, as well as, emissions from motor vehicles. EPA requires PM 2.5 levels to be below 35 micrograms per cubic meter. In the year 2008, there was at most a single instance of less-than-good air quality in the Palouse Airshed when Pullman reported an Air Quality Index score of 54, just four points above the minimum reporting score. According to EPA rules, the entire area of the Palouse Airshed is listed as a 2008 attainment area for meeting CAA guidelines. If air quality had been poor by EPA's standards a few strategies might have been employed to improve local air quality. The most common step is for local entities to issue voluntary and/or mandatory burn bans. There were no burn bans issued in the Palouse Watershed during 2008.

The Clean Air Act at this point in time connects with the problem of global climate change only through setting emission and fuel standards for motor vehicles and aircraft. In this respect, the Clean Air Act is reflective of lax policy on the part of US legislative entities to aggressively mandate vehicles and mechanical equipment that are more responsive to the problem of global warming.

For all intents and purposes, by CAA and EPA standards, the Palouse Airshed was not in need of educational or restorative actions in 2008. I consider this matter again latter in this chapter when analyzing the relationship between environmental sustainability in the Palouse Watershed and the laws intended to insure environmental quality. Next, I consider the relationship between the Endangered Species Act and Palouse Watershed biodiversity.

Environmental Issues Addressed by the Endangered Species Act

The Palouse Watershed is one of the most endangered ecosystems on the planet (Black et al., 2003). More than 95% of pre-European native plant cover has been lost on the Palouse and tracts of remaining bunchgrass prairie occur sparsely in very few places (Black et al., 2003). It is surprising then that there is only one species on the Palouse that falls under US Fish and Wildlife Service's legal distinction of threatened. As was mentioned before, this seems to me to be an indictment of this government agency's understanding of what it means to be endangered or threatened.

Spaulding's Catchfly, botanically-known as *Silene spaudlngii*, is a perennial plant in the carnation family that blooms mid-summer and survives dormant below ground for long periods of time. US Fish and Wildlife listed the plant as threatened in 2007 after determining that populations were in severe decline across portions of Idaho, Montana, and Washington because of loss of habitat, competition from non-native species, and human encroachment. US Fish and Wildlife (2007) scientists acknowledge in the plant's recovery plan that "Spaulding Catchfly cannot be recovered if its habitat is not conserved and restored" (p. x). The recovery plan for Spaulding's Catchfly lists several important restoration activities (United States Fish and Wildlife Service, 2007):

- Seed banking of Spaulding's Catchfly plant seeds
- Plant population surveys and monitoring

- Fire management in Catchfly's habitat
- Livestock grazing management in sensitive areas
- Designation of special habitat areas
- Control of invasive species in native Catchfly habitat

Environmental Issues Addressed by the Federal Noxious Weed Act

The US Government labels plants noxious weeds if they have the potential to adversely affect other plants, particularly food crops, as well as, humans and other species. There are more than 18 plants in the Palouse Watershed that meet the US Government's definition of noxious weed. White bryony, bull thistle, tansy ragwort, Canada thistle, diffuse knapweed, Russian knapweed, poison hemlock, leafy spurge, and Scotch thistle are recognized as the most pernicious on the list. The Federal Noxious Weed Act makes weed control the responsibility of landowners.

Noxious weeds are problematic in the Palouse Watershed for several reasons. The rampant spread of some noxious weeds, including knapweed, can adversely affect crop yield. Poison hemlock, on the other hand, can kill grazing animals such as cattle and horses. Other species, such as white bryony, can wipe out tree and shrub populations by attaching to leaves and blocking the receipt of light energy from the sun. This is especially problematic in riparian zones because it results in a loss of stream-side shade. Mono-cropping of wheat over a vast area of the watershed makes the land even more vulnerable to noxious weeds since such land use intentionally depletes plant diversity and thus the ability of multiple types of plants to hold their collective ground space.

Several strategies are employed in the Palouse Watershed to manage the problem of invasive plant species:

- Educating people how to identify and reduce invasive plant populations
- Using bio-controls including beetles and larinus weevils to control populations of Tansy Ragwort and Spotted Knapweed
- Providing wash stations to clean agricultural vehicles and logging equipment leaving areas infested with noxious weeds
- Re-seeding cut banks and roadsides disturbed by road maintenance activities
- Using fines to enforce removal of especially problematic species including Canadian thistle

Legal means of addressing Palouse environmental issues have been explored in this part of Chapter Six with an emphasis on strategies to restore compromised environmental quality. Limitations of the legal approach to addressing environmental issues in the Palouse are considered next.

Federal Law and Gaps in Palouse Sustainability

There are several Palouse environmental issues that are not addressed or are only partially addressed through the application of the Clean Water Act, Clean Air Act, the Endangered Species Act, and the Federal Noxious Weed Act. This especially problematic since the primary method for addressing environmental issues in the United States at this time is law enforcement. Erosion and subsequent stream sedimentation, soil acidification, diminishing ground water supplies, greenhouse gas emissions, the matter of a Palouse wilderness, and the fate of the Giant Palouse Earthworm are all serious sustainability issues that need more attention than what is provided by the above laws.

The Continuing Problem of Palouse Erosion

Soil erosion has been observed to be a problem in the Palouse Watershed since at least the 1930s (Duffin, 2007). A variety of strategies have been advocated by agricultural educators over the years to combat this problem – some, like fallowing, have only served to increase local erosion rates. Other strategies, including no-till direct seeding, strip-cropping, terraces, retirement of steep slopes, and the establishment of riparian buffer zones have offered Palouse farmers several viable means for significantly reducing erosion. Early adopters of these strategies, such as John Aeschliman of Colfax, have reduced erosion to near-sustainable levels while applying less agricultural chemicals resulting in healthier soils with more humus, moisture, soil microbes, and more overall biodiversity of soil organisms. Farmers like Aeschliman, however, are few and far between on the Palouse. Duffin's (2007) natural history of the Palouse asserts that short-term profitability, not the health of the land, is the primary motivating force among most Palouse farm operations. One gap in the Clean Water Act known as the non-point source provision plays a major role in perpetuating Palouse erosion and erosion-associated problems such as soil acidity, chemical runoff, and stream sedimentation.

The Clean Water Act applies to pollutants that originate from water treatment facilities, universities, and manufacturing companies. Pollutants that originate from cultivated land, urban and rural lawns, and logging operations are labeled non-point source pollutants and are exempt from CWA enforcement. This means that individual property owners are not held responsible for the environmental damage caused by their non-point source pollutants. Under the current CWA, reducing non-point source erosion is a totally voluntary option that many farmers choose to ignore (Duffin, 2007). The non-point source provision serves to confound CWA-driven restoration activities since improvements on private land can only be completed with the cooperation of landowners. Financial incentives and education through agricultural extension agents have been the primary tools used to achieve farmer buy-in with regards to the value of conservation practices and restoration work. Some, including Duffin (2007), have studied extension education and found this approach to be largely ineffective in changing farmer behavior on the Palouse.

Another factor that confounds addressing erosion in a meaningful way concerns the makeup of groups that assemble to address water quality issues associated with the Clean Water Act. In agricultural areas such as the Palouse, geographic areas are divided into conservation districts. Whitman County, Washington, for example, is divided into four conservation districts. One job of conservation district members is to generate implementation plans for meeting TMDLs for 303(d) listed streams. In the Palouse Conservation District all of the elected members of the district are Palouse farmers living within the district. When this district issued the *North Fork Palouse River Water Quality Improvement Plan* in 2002, the members of the North Fork Palouse River

Watershed Committee expressed their “desire to see improvements realized in the watershed through voluntary efforts, not mandated changes” (Palouse Conservation District, 2002, p. i).This scenario seems very limiting in terms of providing effective oversight leading to improved water quality in the Palouse Conservation District. This is especially curious since the Palouse River is one of the most polluted streams in the United States.

Other Unaddressed Problems in the Palouse Watershed

The problem of diminishing ground water supplies is another sustainability issue left poorly addressed by federal environmental laws. As was mentioned previously, both aquifers in the Palouse Watershed are in long-term historic decline. The Grande Ronde continues to decline 12-24 inches each year in spite of more than 10 years of water conservation and improved water-saving technology such as low flow toilets and showerheads. The Palouse-Clearwater Environmental Institute, or PCEI, is one local organization that has worked for more than 10 years to educate Palousians about water use and water saving technology. PCEI works through schools, fairs, and several community groups to help Palousians reduce water use and understand aquifer supply limitations.

Another Palouse environmental issue left primarily unaddressed by federal law concerns greenhouse gas emissions. As was mentioned previously, the Clean Air Act sets emission limits associated with motor vehicles and fuels but to date the law fails to substantively address capping emissions in response to global warming. The University of Idaho, Washington State University, and the

City of Moscow have all identified baseline greenhouse gas emissions and have started to identify capital improvements that involve reduced emissions.

Another matter important to local sustainability that is left unaddressed by federal law is Palouse ecosystem protection under the Wilderness Act. The Wilderness Act specifies how land designated as wilderness is to be maintained but it does not call for setting aside tracts of wild land for the purpose of ecosystem integrity. As was mentioned previously, the Palouse ecosystem is among the most endangered of ecosystems in the United States (Black et al., 2003). Wittbecker (1991) calls for 16% of a land area type to be set aside for the purpose of maintaining ecosystem health and genetic integrity of key species. In the case of the Palouse, less than 1% of the watershed has been set aside and all these lands are spread out over a large area.

The last unaddressed Palouse sustainability issue to be discussed concerns the Giant Palouse Earthworm. This organism is known to exist in an extremely small population but it has nevertheless escaped protection under the Endangered Species Act. With more than 90% of the Palouse under cultivation and less than 1”% of the whole watershed dedicated to ecosystem integrity there is very little hope for continuation of this unique species without the special protection of the endangered species act.

Palouse Sustainability and Federal Environmental Law: In Conclusion

Environmental issues facing the Palouse Watershed have been considered in this chapter in connection with the federal laws meant to provide for environmental integrity. Strategies for improving environmental quality have been enumerated for the purpose of understanding the actual steps involved in restoring land, water, and air quality in the Palouse Watershed. Problematic elements in federal environmental laws were considered and gaps in effectiveness were uncovered for the purpose of understanding limitations of law for making the Palouse environmentally sustainable. In the next section, the last section of this chapter, the strategies previously enumerated for improving environmental quality in the Palouse are considered in terms of the skills necessary to empower students to address the sustainability needs of the Palouse Watershed.

Contemplating Educating for Sustainability in the Palouse Watershed

The goal of this case study is to describe the needs of an environmentally-sustainable Palouse Watershed. My ultimate purpose in exploring the Palouse's environmental issues is to understand the needs of this place so I can know what science education needs to offer students to empower them to make the Palouse environmentally-sustainable. At the very core, this view of science education is rooted in the assumption that education should teach a person how to live well in the places they occupy. Accordingly, this case study of the Palouse Watershed is meant to serve as a foundational document for a curriculum that can effectively offer Palousians skills for living well and sustainably.

Problems associated with Palouse land, water, and air have been explored in this case study. In the last part of this chapter, I consider the restorative and educational strategies mentioned in connection with the Palouse Watershed. Those strategies are:

- Water quality testing within the watershed for dissolved oxygen, sediment, temperature, pH, bacteria, and 303(d) listed chemical pollutants
- Monitoring of sewer lines for leaks and blockages
- Conducting surveys of all drain pipes that empty into local streams
- Working with landowners for the purpose of creating structures to restrict livestock access to streams
- Planning and implementing riparian restoration including native tree and shrub planting, stream bank re-sloping, the establishment of riparian buffer zones between streams and tilled soil, and the installation of coir logs and erosion control fabric adjacent to streams
- Monitoring water quality at water-discharging businesses
- Educating livestock owners about proper water-related ranching practices
- Educating residents about septic system maintenance
- Educating residents about proper pet waste disposal
- Educating landowners about the value of healthy riparian zones
- Educating the public including Palouse farmers about the advantages of conservation tillage practices including no-till, minimum tillage, strip-cropping, and riparian buffer zones
- Educating the public about livestock grazing management in sensitive areas
- Educating people how to identify and reduce invasive plant populations

- Learning how to create erosion and sediment control plans for land altering activities and building permit requirements
- Completion of computerized mapping of all existing storm water lines for a given area
- Conducting periodic sampling of Palouse River fish for dieldrin and PCBs
- Working with land owners to develop conservation plans using best management practices
- Conducting seed banking of Spaulding's Catchfly plant seeds and other endangered species
- Using bio-controls to control invasive plant species
- Conducting native plant seeding at cut banks and roadside areas disturbed by road maintenance activities

There are at least seven additional educative and restorative activities that could serve as learning objectives to empower students to effectively address environmental issues within the watershed. The following is a list of possibilities:

- Monitoring and reporting of EPA's air quality variables
- Conducting personal, family, and community carbon footprint analyses
- Educating the public about greenhouse gasses, global warming, and carbon footprints
- Educating the public about aquifer issues and water consumption reduction
- Conducting personal water consumption analyses

- Planning and creating human-constructed wetlands
- Conducting plant and animal population surveys of key species

The sum total of the above activities could serve, at least in part, as the hands-on field component of a science curriculum for environmental sustainability in the Palouse Watershed. Science is also about conceptual understanding of complex ideas and processes so it is important to acknowledge that the above activities could represent hands-on activities to reinforce such concepts as systems, ecosystems, and biodiversity. The above lists reappears in the next chapter as the content factors by which the Washington State k-12 science education standards are analyzed for content related to the sustainability needs of the Palouse.

The Palouse Watershed Case Study: In Conclusion

The goal of this case study has been to answer the question: What are the environmental sustainability needs of the Palouse Watershed? Be reminded that the focus of this study is environmental sustainability, and more specifically, fostering environmental sustainability in a way that protects our limited natural resources and our environment over the long term (Washington State Department of Ecology, 2007a). The Palouse Watershed was described in chapter four including location, geology, climate, flora and fauna, as well as, watershed attributes. Then, the history and impact of human habitation on the Palouse Watershed was examined with particular emphasis on practices that have resulted in environmental degradation from the years 1860 - 2000. In Chapter Five, the current condition of the Palouse Watershed was explored in detail. In this chapter, I have looked at efforts underway to address the environmental sustainability needs of the Palouse Watershed, as well as, factors that serve to limit the effectiveness of efforts to restore environmental quality in the Palouse. The overriding message of this case study is that Palouse lands, waters, and air have been degraded by human activities, primarily associated with intensive cultivation of wheat and other cereal grains. Four laws which serve as primary means of environmental accountability were explored and found to be problematic in terms of addressing systematic environmental issues, especially soil erosion. It is this author's view that individual property rights serve as a barrier to implementing systemic changes that could work to improve the whole of the ecosystem and watershed. In the current milieu, environmental problems are treated as isolated issues. Under the Clean Water Act, the Palouse Watershed is treated as a healthy system with multiple symptoms of ill health rather than as a system that is not well and plagued with multiple symptoms of system dysfunction.

This case study was concluded with a comprehensive listing of the educative and restorative activities that are aimed at restoring the Palouse Watershed to environmental quality. These same activities will serve as content factors in Chapter Seven's content analysis of Washington State's k-12 science education standards for content related to the environmental sustainability needs of the Palouse.

CHAPTER SEVEN

A PALOUSE-BASED ENVIRONMENTAL SUSTAINABILITY CONTENT ANALYSIS OF WASHINGTON STATE'S K-12 SCIENCE STANDARDS

The goal of this chapter is to report a content analysis of Washington State's k-12 draft science education standards for content related to the environmental sustainability issues of the Palouse Watershed. Content analysis is a research methodology that employs message content as data for inferential analysis. In this chapter, the message content under analysis is the complete set of 58 core content standards that make up Washington State's k-12 draft science education standards. It is important to analyze these standards because they drive science education in Washington State through their connection with state and federally-mandated high stakes tests. The goal of this chapter is to answer two questions:

1. Which Washington State science education standards have content that is connected with the environmental sustainability needs of the Palouse?
2. How effective are Washington State's k-12 science education standards at preparing students to address the environmental sustainability needs of the Palouse?

Defining Content Factors

An important first step in any qualitative content analysis is the elucidation of variables. Qualitative variables in content analysis are called content factors.

In this study, the restorative and educative activities connected with Palouse Watershed sustainability are employed as content factors. Recall from chapter six that there are twenty-seven restorative and educative activities that are appropriate to education that addresses the environmental issues facing the Palouse Watershed. There is significant overlap between many of the twenty-seven restorative and educative activities that can be addressed by thematic grouping. Repeated examination of the above list suggests three types of Palouse sustainability content factors: environmental sustainability investigation and implementation, public sustainability education, and personal sustainability assessment projects. Each of these are defined separately below.

Environmental Sustainability Investigation and Implementation

It should not be surprising that a lot of what goes into restoration and sustainability work is simply work. Several restoration activities on the Palouse are quite labor intensive and involve such things as:

- Riparian restoration including planting native plants, re-sloping slumping stream banks, and installing fences, erosion control fabric, and coir logs
- Conducting scientific surveys of drain pipes, storm water lines, and plant and animal populations
- Planting native plants in disturbed roadside areas
- Conducting and reporting water quality testing for 303(d) listed pollutants, monitoring sewer lines and business emissions, and testing fish for environmental pollutants

- Conducting air quality monitoring for EPA reporting
- Conduct seed-banking of seeds of endangered plants
- Identifying, monitoring, and managing invasive plant species
- Planning, constructing, and maintaining human-constructed wetlands

Public Sustainability Education

Educational outreach to the public in general, and, specifically landowners, is a strategy used to address environmental issues in the Palouse Watershed. Conservation districts, the Palouse-Clearwater Environmental Institute, the Palouse Basin Aquifer Committee, Washington State Department of Ecology, Idaho's Department of Environmental Quality, and the Natural Resource Conservation Service are some of the groups that offer environmental education in connection with Palouse issues. There are several types of public education that are addressing or can address Palouse environmental issues:

- Septic system maintenance
- Pet waste disposal
- Conservation tillage and creating conservation plans
- Invasive plant identification and management
- Riparian area management
- Global warming, greenhouse gasses, and carbon footprint

Personal Sustainability Assessment Projects

There are at least four types of personal assessment projects that can help individuals understand the connection between personal consumption and sustainability:

- Water use
- Carbon footprint
- Waste, recycling, and composting
- Personal land-use plans focusing on erosion and sediment control

Environmental sustainability investigation and implementation, public sustainability education, and personal sustainability assessment projects are the three content variables that are used in the content analysis of the Washington k-12 science education standards. Before proceeding with the content analysis it is important to consider the organization of the science standards.

Washington State's k-12 Science Standards

Washington State's science education standards were released December 14, 2008. There are 58 standards organized by grade band. The grade bands are k-1, 2-3, 4-5, 6-8, and 9-12. Each individual science education standard has three signifiers that point to the organizational structure of the standards. *Domain* refers to four broad categories that are tied to 1) physical science, 2) earth and space science, 3) life science, and, 4) cross cutting concepts and abilities that traverse the aforementioned science content areas. The next level of organization in the science standards is centered in nine *big ideas* that recursively appear through the ascending grade bands. Big ideas are drawn from what have historically been labeled essential academic learning requirements or EALRs. They are:

1. Forces and motion
2. Matter: Properties and change

3. Energy transfer and conservation
4. Earth in space
5. Earth systems, structure, and processes
6. Earth history
7. Structure and function of living systems
8. Ecosystems
9. Biological evolution

The 58 standards begin with core content statements. These are paragraph-length declarations of the related learning that students should have mastered in previous grade bands, what students are expected to learn through the particular standard, and why such learning is important. Core content statements are operationalized into two or more content standards and performance expectations that students are expected to master before the end of the appointed grade band. For the sake of clarity, I provide the full text of the k-1 system standard that is focused on part-whole relationships in Figure 7.1. In the next section, the content analysis is presented.

Figure 7.1 k-1 standard for part-whole relationships

K-1 SYS **Grade band 2-3**
Big Idea: *Systems*
Domain*: Cross-Cutting Concepts and Abilities*

Core Content Statement
Students learn that both inanimate objects and living organisms are made of parts, and they are expected to name the parts that make up several whole objects and organisms. They learn that some objects can be easily taken apart and put back together again, while other objects and organisms cannot be taken apart and reassembled without damaging them. Removing one or more parts will usually change how the object or organism functions. Fluency with the part-whole relationship is essential for all of the sciences and an important building block for more sophisticated understanding of how systems operate in natural and designed environments.

Content Standards		**Performance Standards**
Students know that:		Students are expected to:
K-1 SYSA	Living and nonliving things are made of parts. The parts have names that are different from the name of the whole object or organism	Given an illustration of a whole object or organism, identify at least five different parts. Compare a part of an object with the whole object, correctly using the words —whole‖ and —part.‖ Explain at least one way that a whole object is different from its parts.
K-1 SYSB	Some objects can easily be taken apart and put back together again while other objects cannot be taken apart without damaging them (e.g., books, pencils, plants, and animals).	Identify which objects may be taken apart and put back together without damaging them (e.g., a jigsaw puzzle) .*a Identify which objects cannot be taken apart without damaging them (e.g., books, pencils, plants, and animals), Predict what might happen when you take away parts of an object (e.g., propeller from a toy plane, flower from a plant).

(Source: www.k12.wa.us/CurriculumInstruct/Science/StandardsRevision.aspx)

A Content Analysis of Washington State's K-12 Science Standards

for Content Related to the Environmental Sustainability

Needs of the Palouse Watershed

The case study revealed 27 educative and restorative activities that address key environmental sustainability issues in the Palouse Watershed. Those activities encompass the skills and abilities that students need to be able to accomplish if they are to be empowered to address the sustainability needs of this place. The qualitative content analysis of Washington State's k-12 science standards that follows is in essence a report of the presence of the 27 educative and restorative activities in the text of the state standards. Each of the aforementioned 27 activities is by nature activity-based. Thus, it follows that this analysis is biased because it requires that learning standards be applied through actual sustainability activity in order for such standards to be considered inclusive of the sustainability needs of the Palouse. State standards that did not require students to apply their learning to local places were dismissed, even when they required students to demonstrate essential knowledge about ecosystems and biodiversity; topics integral to sustainability. I decided that sustainability content needed to be applied to actual situations and places after reading Warburton (2003) who asserts that "If action is to follow awareness, students must not only become aware of issues but also gain skills of analysis and investigation" (p. 50).

Each of the science standards were read three times over the course of three days. Standards that included activities aligned with the needs of the Palouse Watershed were counted and labeled as Palouse sustainability standards. Of the 58 k-12 science education standards analyzed - only two connect directly with the 27 restorative and educative activities connected with the environmental sustainability needs of the Palouse River Watershed. Both standards fall under the *sustainability investigation and implementation* group. These standards are included below with sustainability content in boldface for ease of identification.

Figure 7.2 Changes in Ecosystems Standard for Grades 2-3

Big Idea: Ecosystems (LS2) **Grades 2-3**
Core Content: *Changes in Ecosystems*
Core Content Statement

In prior grades, students learned that all plants and animals live in and depend on habitats. In grades 2-3, students learn that ecosystems include both plant and animal populations as well as nonliving resources. Plants and animals depend both on each other and on the nonliving resources in their ecosystem to survive. Ecosystems can change through both natural causes and human activities. These changes might be good or bad for the plants and animals that live in the ecosystem, or have no effect. Humans can protect the health of ecosystems in a number of ways.

Content Standards *Students know that:*		**Performance Expectations** *Students are expected to:*
2-3 LS2A	*Ecosystems* support all life on the planet, including human life, by providing food, fresh water, and breathable *air*.	Identify at least four ways that *ecosystems* support life (e.g., by providing fresh water, generating oxygen, removing toxic pollutants, and providing sources of useful materials).
2-3 LS2B	All *ecosystems* change over time as a result of natural causes (e.g., storms, floods, volcanic eruptions, fire). Some of these changes are beneficial for the plants and animals, some are harmful, and some have no *Effect*.	*Describe* three or more of the changes that occur in an *ecosystem* or *model* of a natural *ecosystem* (e.g., aquarium, terrarium) over time, as well as how these changes may affect the plants and animals living there.
2-3 LS2C	Some changes in *ecosystems* occur slowly, and others occur rapidly. Changes can affect life forms, including humans.	*Explain* the consequences of rapid *ecosystem* change (e.g., flooding, *wind* storms, snowfall, volcanic eruptions). *Explain* the consequences of gradual *ecosystem* change (e.g., gradual increase or decrease in daily temperatures, reduction or increase in yearly rainfall).
2-3 LS2D	Humans impact *ecosystems* in both positive and negative ways. Humans can help improve the health of *ecosystems* so that they provide *habitats* for plants and animals and resources for humans over the long term. For example, if people use fewer resources and recycle waste, there will be fewer negative impacts on natural *systems*.	*Describe* a change that humans are making in a particular *ecosystem*, and *predict* how that change could harm or improve conditions for a given type of plant or animal. **Propose a plan to protect or improve an *ecosystem*.**

Figure 7.3 Flow of Energy Through Ecosystems Standard for Grades 6-8

Big Idea: Ecosystems (LS2) **Grades 6-8**
Core Content: *Flow of Energy Through Ecosystems*
Core Content Statement

In prior grades, students learned how ecosystems change and how these changes affect the capacity of an ecosystem to support populations. In grades 6-8, students learn to apply key concepts about ecosystems to understand the interactions among organisms and the nonliving environment. Essential concepts include the process of photosynthesis used by plants to transform the energy of sunlight into food energy and possible causes of environmental change. Students also learn to investigate environmental issues and to use science to evaluate different solutions to the problem. Knowledge of how energy flows through ecosystems is a critical aspect of students' understanding of how energy sustains life on the planet, including human life.

	Content Standards *Students know that:*	**Performance Expectations** *Students are expected to:*
6-8 LS2A	An *ecosystem* consists of all the *populations* living within a specific area and the nonliving *factors* they interact with. One geographical area may contain many *ecosystems*.	*Explain that* an *ecosystem* is a defined area that contains *populations* of *organisms* and nonliving *factors*. Give examples of *ecosystems* (e.g., Olympic National Forest, Puget Sound, one square foot of lawn) and *describe* their boundaries and contents.
6-8 LS2B	Energy flows through an *ecosystem* from *producers* to *consumers* to *decomposers*. These *relationships* can be shown for specific *populations* on a *food web*.	Analyze the flow of energy in a local *ecosystem*, and draw a labeled *food web* showing the *relationships* among all of the *ecosystem*'s plant and animal *populations*.
6-8 LS2C	The major source of energy for *ecosystems* on Earth's surface is sunlight. *Producers* (plants) transform the energy of sunlight into the chemical energy of food through *photosynthesis*. This food energy is used by plants, animals, and all other *organisms* to carry on life processes. Nearly all *organisms* on the surface of Earth depend on this energy source.	*Explain how* energy from the Sun is transformed through *photosynthesis* to produce chemical energy in food. *Explain that* plants are the only organisms that make their own food. Animals cannot survive without plants because animals, including humans, get food by eating plants or other animals that eat plants.
6-8 LS2D	*Ecosystems* are continuously changing. Causes of these changes include nonliving *factors* such as the amount of light, range of temperatures, and availability of water, as well as living factors such as the disappearance of different *species* through disease, predation, and overuse of resources or the introduction of new *species*.	*Predict* what may happen to an *ecosystem* if nonliving *factors* change (e.g., the amount of light, range of temperatures, or availability of water), or if one or more *populations* are removed from or added to the *ecosystem*.
6-8 LS2E	Investigations of *environmental* issues should uncover *factors* causing the problem and relevant scientific *concepts* and findings that may inform an analysis of different ways to address the issue.	***Investigate* a local *environmental* issue by defining the problem, researching possible causative *factors*, understanding the underlying *science*, and evaluating the benefits and risks of alternative *solutions*.** Identify resource uses that reduce the capacity of *ecosystems* to support various *populations* (e.g., use of pesticides, construction).

Science Standards with Palouse Sustainability Content

Grade band 2-3's core content standard for *changes in ecosystems* meets the requirement for content for sustainability investigation and implementation. The second performance expectation for life science standard two D or *LS2D* reads "students are expected to . . . propose a plan to protect or improve an ecosystem" (Office of the Superintendent of Public Instruction, 2008, p. 35). Planning to protect ecosystems is the very essence of working towards sustainability according to the definition of sustainability used in this study.

Grade band 6-8's core content standard for *energy flow through ecosystems* is also counted as containing sustainability content that is connected to the needs of the Palouse. The first performance expectation for life science standard two E or *LS2E* reads "students are expected to . . . investigate a local environmental issue by defining the problem, researching possible causative factors, understanding the underlying science, and evaluating the benefits and risks of alternative solutions" (Office of the Superintendent of Public Instruction, 2008, p. 63). As with the example cited above, this performance expectation gets at several of the key aspects of addressing Palouse sustainability needs. For example, in order to meet this expectation, students must identify a local environmental issue, look at causes, the underlying science concepts, and an evaluation of possible solutions. These are all essential components in investigating and implementing sustainability work.

It may seem surprising that only two of 58 standards address the sustainability needs of the Palouse River Watershed. It is important to bear in mind that the content factors used in this analysis are all based in specific physical activities connected with ongoing and/or possible restorative and educative work in the Palouse. Only two standards met this environment-specific definition. There are many standards that involve sustainability concepts that fell outside the parameters of this analysis. These are considered in the next section.

A Consideration of Standards that are Sustainability-Related

The content factors used in this analysis are centered in scientifically-based activities anchored themselves in complex scientific concepts. It is important to acknowledge that more than 25 of the Washington State science standards address concepts related to sustainability without actually connecting with sustainability work. One of the nine big ideas employed in Washington State's science standards is ecosystems. Five such standards were rejected for possessing Palouse-connected sustainability content because they did not require students to use learning for ecosystem improvement or related educative pursuits. Important foundational concepts are explored in these five ecosystem standards including habitat, food webs, population dynamics, and the role of feedback in systems but students are never required to apply their learning to the needs of their local places. Similarly, the grade span 6-8 core content standard on *formation of earth materials* was rejected because the learning objectives centering in soils and erosion merely asked students to describe and explain abstract phenomena, not connect learning with local soil and erosion issues. The grade span 9-12 content standard on *energy in earth systems* was likewise rejected because the content standard involving global warming failed to require students to act locally on the knowledge that global warming is deleterious to Washington residents.

Washington State's Science Standards and Palouse Sustainability

One question remains to be answered in this chapter: How effective are Washington State's k-12 science standards at preparing students to address the environmental sustainability needs of the Palouse? In this chapter it has been shown that only two of 58 Washington science content standards are directly connected with teaching students actual skills needed for working towards an environmentally-sustainable Palouse. Those two skills involve investigating a local environmental issue and creating a plan to protect or improve an ecosystem. It was also shown that while many science standards involve sustainability concepts, only two prepare students to address real needs in this place.

In research one question often leads to another. In this case, I think it is important to consider the question: Which Palouse environmental issues are unaddressed by Washington's science standards? I briefly recap those issues in the upcoming conclusion so the reader can get an idea of the scope of the disconnect between the needs of this place and the education standards used to prepare local students for adulthood.

Palouse Sustainability and the Washington Science Standards: In Conclusion

The goal of this chapter has been to report a content analysis of Washington State's science standards for content related to the environmental sustainability issues of the Palouse Watershed. Content factors were developed from the environmental issues that challenge sustainability in the Palouse. Analysis of all 58 Washington k-12 science standards showed that only two standards met the terms of this analysis. The result is that many Palouse environmental issues remain unaddressed in Washington State's science standards:

- Palouse erosion
- Acidification of Palouse soils
- Loss of humus from Palouse soils
- Palouse water quality
- Palouse air quality
- Palouse riparian zone damage
- Invasive species
- Loss of native bunchgrass habitat
- Protection of local threatened species
- Global warming and Palouse climate change
- Grande Ronde aquifer depletion
- The need for a Palouse wilderness

It is the view of this author that Washington State's k-12 science education standards fail to prepare students to address the environmental needs associated with living sustainably in this place. Furthermore, students are not even adequately prepared to understand the concepts behind the environmental issues affecting the Palouse Watershed because the science standards fail to ask students to apply their learning to their own lived experiences in the places they occupy. Two questions were posed at the beginning of this chapter; one remains unanswered: How effective are Washington State's k-12 science standards at preparing students to address the environmental sustainability needs of the Palouse? My answer is *not very effective.*

CHAPTER EIGHT

CONCLUSIONS

The goal of this work has been to describe the relationship between the sustainability needs of the Palouse River Watershed and Washington State's k-12 science standards. Two overarching questions were explored:

1. What are the sustainability needs of the Palouse Watershed?
2. How effective are Washington State's k-12 science education standards at preparing students to address the environmental sustainability needs of the Palouse?

Findings

The sustainability needs of the Palouse Watershed were explored in the case study. It was shown that the Palouse Watershed is home to a unique ecosystem that has been environmentally-degraded by more than 100 years of ranching and intensive mono-cropping of wheat and other cereal grains. Various approaches to addressing erosion and horrific water quality were explored and found to be largely inadequate thus far to restore environmental quality to the Palouse Watershed. Current and possible restorative and educative efforts were identified and later used as content factors in the analysis of Washington State's k-12 science standards.

The content analysis in Chapter Seven revealed that only two of 58 k-12 science standards included content that directly addressed the 27 sustainability needs of the Palouse. More than 25 standards were observed to have content based in sustainability concepts including ecosystems, biodiversity, and erosion. Unfortunately, these standards never require students to apply their learning to addressing the needs of the Palouse Watershed. It is this author's conclusion that Washington State's December 14, 2008 k-12 science standards are wholly inadequate for empowering students with the necessary skills to work towards a sustainable Palouse Watershed.

Significance of findings

The case study demonstrated that the land, air, and water of the Palouse Watershed are in poor environmental condition and that current efforts at restoring the Palouse are hampered by multiple factors. Current approaches to watershed management wherein stakeholders are allowed to create lax management plans have only served to perpetuate water quality problems. The refusal of the EPA to more aggressively target non-point source pollutants further complicates the problem by limiting the effectiveness of the Clean Water Act to control known sources of water-borne pollutants.

The 27 restorative and educative activities that address sustainability issues in the Palouse are a starting point for addressing specific problems. On a deeper level, these activities are problematic because they follow from an approach to solving environmental problems that fails to recognize the complexity of relationships in ecosystems. In some ways, the 27 activities can be viewed as band-aids placed over gaping wounds. Band-aids work at the surface level of a wound but will still allow a person to bleed to death if there is an underlying severed artery. Some of the 27 activities tend to surface-level concerns without adequately addressing system-level problems such as the effects from using millions of tons of anhydrous ammonia fertilizer on inclined, erosion-prone Palouse fields.

The content analysis of Washington State's k-12 science standards demonstrated that the standards connect minimally with empowering students with the skills and experiences necessary to address the sustainability needs of the Palouse. This is especially significant for many reasons. First, the Palouse is one of the 30 most endangered ecosystems in the United States (Noss, LaRoe, & Scott, 1995). Second, at this time, education in Washington State is largely driven by the Washington Assessment of Student Learning (WASL) and its associated learning objectives. Empowering students with the skills to work for environmental sustainability is obviously not a priority of the WASL and state learning objectives so students leave school without necessary sustainability tools. The obvious implication is that locally-raised children will be just as incapable of improving Palouse environmental problems as their parents. Third, the environmental issues that plague the Palouse are not static but constantly changing. Global climate change is underway and poses new challenges to Palouse sustainability that will likely stymie Palousians that are unprepared by the current k-12 educational system.

In the next section, I consider the implications of my findings for education in Washington State.

What needs to happen?

The last question to be addressed by this study is: What are the implications of this study for educational policy and practice in Washington State? This question is answered at three different levels: state, district, and classroom.

Sustainability reform at the state-level.

The 10th amendment of the US constitution makes setting educational policy a matter to be decided by individual states. While The No Child Left Behind Act of 2001 poses many challenges to states, it is still up to each state to determine how to address such things as accountability, assessment, and sustainability. Currently, neither the State of Washington nor the US federal government has official policy for the purpose of educating for sustainability. Washington State's Office of the Superintendent of Public Instruction (OSPI) has initiated plans for creating sustainability standards but this is still in the planning stages. To my knowledge, only two states have made educating for sustainability a policy priority. These states are Alaska and Vermont. The state of Washington needs to join these states and step up to the challenge of educating for sustainability by supporting efforts to create sustainability learning standards that empower students with the skills and experiences necessary to address local issues. Upcoming sustainability standards from OSPI need to be a departure from current content standards which largely fail to require that students apply their learning to local issues and problems.

Sustainability is not just a matter for science educators. Preparing students to work for environmental and social sustainability should be an endeavor that is integrated in all courses so sustainability standards need to bring teachers and students together around local issues that transcend the typical content-area approach to education.

Preparing teachers to educate for sustainability should be a state priority. At the time of this writing, Washington State does not require that pre-service teachers show mastery of sustainability concepts or even basic environmental literacy. This is problematic since Desjean-Perrotta, Moseley, and Cantu (2008) revealed that most pre-service teachers lack a well-developed understanding of the environment and basic environmental literacy. This is further problematic since environmental literacy is one of the strongest influences in many teachers' decision to educate from an environmental perspective (Ernst, 2007).

Teachers that are already in the classroom also need to be taught how to educate for sustainability. States need to support this need by funding effective professional development that prepares teachers with the skills to address local issues. In my three years of experience as a Washington teacher I attended eight in-service workshops; all but one focused on the WASL. The same level of commitment, if applied to sustainability, could radically increase the readiness of Washington teachers to educate for sustainability.

States need to fund education for sustainability at least as well as school athletic programs. Sustainability education obligates teachers to bring their classes to local places so transportation funding is a necessity. Interdisciplinary sustainability education also requires that teachers have adequate time to collaboratively plan instruction. States can help make this happen by funding collaborative planning time for sustainability educators. Ernst (2007) studied barriers to environmentally-based education practice and determined that lack of funding, transportation, and planning time are significant barriers to many teachers that would otherwise incorporate aspects of environmental education.

In summary, Washington State's Office of the Superintendent of Public Instruction needs to take the following steps to make educating for sustainability a reality in Washington State:

- OSPI needs to create flexible cross-disciplinary sustainability learning standards that prepare students to address sustainability issues in Washington ecosystems.
- OSPI needs to require pre-service teachers to demonstrate basic mastery of sustainability concepts and environmental literacy.
- OSPI needs to fund and lead sustainability professional development for all teachers and administrators.
- OSPI needs to fund education for sustainability so teachers can have access to transportation, equipment, and collaborative planning time.

Sustainability reform at district and building levels.

Educating for sustainability needs to be supported at the district and individual building levels in a multitude of ways. Administrators should take leadership roles in setting sustainability priorities for local places. A top-down approach such as this can increase teacher participation and unite schools around relevant themes that connect with local needs. Portland, Oregon's Sunnyside Environmental School is an example of a school where administrators have worked with teachers and residents to develop a watershed focus that addresses local needs while serving as a unifying theme that is part of the school's official mission statement.

Educating for sustainability works best when administrators understand and support the controlled chaos that can result when teachers take students out of the classroom. My experience in three Washington schools has led me to conclude that many principals need to be taught how to support place-based learning. This could occur in programs that offer administrative credentials and through district-level professional development workshops that take administrator learning out of the classroom and into local places.

Professional development priorities often originate at the state level but are operationalized at the district level. Because if this, it is important for districts to develop in-service training that is aligned with the sustainability needs of local places. This approach requires that administrators become conversant with local sustainability priorities and community organizations that can serve as educational partners in addressing local needs. Districts could further support sustainability goals by employing sustainability coordinators in much the same way as they currently employ athletic directors and assessment specialists.

Schools are typically thought of as places where students are the recipients of information that is taught by teachers. Educating for sustainability posits teachers and students as co-learners and co-investigators in situations that can result in newfound knowledge that is of importance to the local public. Nine of the 27 activities connected with Palouse sustainability were educative.

Palouse-area schools could participate in and even lead such education to further the cause of local sustainability. Schools need to become places where the public can go to learn how to live more sustainably.

In conclusion, sustainability education at district and building levels can be furthered through three key changes:

- Administrators should assume leadership roles in setting sustainability priorities for local places.
- Districts need to develop professional development programs that are tied to preparing teachers and administrators to empower students to address local needs.
- Schools need to become places where community members can come to learn how to live sustainably. Schools can also lead sustainability efforts through public outreach at businesses, fairs, farms, parks, and natural places.

Sustainability reform at the classroom level.

The most effective way to support sustainability reform at the classroom level is to insure that each teacher is environmentally-literate and knowledgeable about local sustainability needs. Since sustainability transcends the content areas it is imperative that teachers be supported in their need to work collaboratively in teams rather than in isolation. Teachers need to have adequate planning time to insure that coordinated units of cross-curricular instruction are adequately planned and executed.

Ernst (2007) reminds us that teacher motivation is a potent force in determining whether teachers will teach using the environment as an integrating context. According to Ernst (2007), teachers need a well-developed level of environmental sensitivity that can only come from time spent in natural settings. In this view, teachers need to have spent enough time in nature to feel motivated to want to teach others the value of protecting natural places.

In summary, there are several key ways that educating for sustainability can be supported at the level of the individual classroom:

- Teachers need to be environmentally-literate and knowledgeable about local sustainability needs.
- Teachers need to have adequate planning time to insure that coordinated units of cross-curricular instruction are adequately planned and executed.
- Teachers need a well-developed level of environmental sensitivity that can only come from time spent in natural settings.

In this section, three levels of educational reform have been explored for the purpose of aligning education with the sustainability needs of the Palouse. It was shown that several reform measures from the state level to the individual classroom could support the goal of educating students to address sustainability issues in the Palouse Watershed.

In Conclusion

The Palouse is a place that is truly unique among the world's ecosystems. While there is much that is wrong with the environmental condition of the Palouse

Watershed, there is also much that can be done to improve the ecological outlook of this place. I argue that education can and should play a significant role in empowering k-12 students to address the sustainability needs of the Palouse.

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APPENDIX A

Appendix A includes the interview guide for the case study of the sustainability needs of the Palouse Watershed.

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tment of Teaching and Learning
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December 2, 2008

Study:

Science Education and Environmental Sustainability: A Case Study of the Palouse

Interview guide for the case study of the sustainability needs of the Palouse Watershed.

1. How do you define sustainability?
2. What do you see as the environmental sustainability needs of the Palouse Watershed?
3. What groups and individuals are involved in looking at sustainability on the Palouse?
4. What efforts are underway to address sustainability on the Palouse?
5. What would your version of a timeline for achieving sustainability on the Palouse look like?
6. What do you see as unique issues and problems for achieving sustainability on the Palouse?
7. Are there key publications you would point me to for the purpose of creating a database of documents regarding sustainability in general and Palouse sustainability specifically?

8. What is the role of the bioregion and/or watershed in your conception of sustainability?

APPENDIX B

Appendix B includes photos from the author's personal files that illustrate environmental phenomena in the Palouse River Watershed.

Photo 1: Industrial garbage along Paradise Creek west of Moscow, ID

Photo 2: Manure piles release nitrogen and fecal coliform bacteria to Paradise Creek west of Moscow, ID

Photo 3: Shade-less riparian areas along Paradise Creek are responsible for increased stream temperatures, erosion, and the loss of stream bank stability

Photo 4: At 185 feet, Palouse River Falls acts as a barrier to upstream Salmon migration

Photo 5: Hillside slumping due to erosion east of Pullman, WA

Photo 6: Rill erosion east of Pullman, WA

Photo 7: Hillside erosion east of Pullman, WA