AN ABSTRACT OF THE THESIS OF

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Abstract approved:

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The rapid proliferation of exempt wells since the settlement of the West has left the State of Washington with little knowledge of the existing number of exempt wells within its boundaries. Exempt wells are primarily a rural phenomena that when abandoned leave aquifers vulnerable to contaminants and create a general safety hazard to those living, working, or playing in their vicinity. Two main questions are addressed within this study: (1) how do you identify exempt wells within Washington; and (2) what local policies, collaboration, and economic/demographic factors influence exempt well identification and proper decommissioning during the study period of 2001 through 2011.

The first question is addressed through constructing exempt well criteria that can predict exempt wells out of the total well population in five sample counties—Grays Harbor, Kitsap, Mason, Pierce, and Skagit. Pipe diameter, bore method, and designated beneficial use had the highest predictive power with a 91% success rate. From the total sample size for decommissioned and drilled, all sample counties combined had 80.8% of exempt wells decommissioned with 96.9% of exempt wells drilled during the 2001-2011 period. There is a lack of knowledge on how many exempt wells are being decommissioned; therefore, these findings offer a quantitative estimate for the State of Washington.

The second question of local policies, level of collaboration, and economic/demographic factors showed likely explanatory patterns in the five sample

counties, where each had its own set of local policies, collaboration, and economic/demographic factors. Three main themes emerged from these data. First, exempt wells have a major role in urban expansion. In addition, the type of local health board and local economic conditions, particularly the presence of a recession, affect the finding and decommission of exempt wells. Because the effect from local policies, collaboration, and economic/demographic factors was not strong, the conclusion is exempt well decommissioning should be studied from a broader perspective. It is recommended for future studies to approach the topic with a broad, landscape framework that includes urban-rural, public health (i.e. local health boards), and economic health factors in the analysis.

The Role of Policy and Collaboration in Decommissioning Exempt Water Wells in Washington State

by

Kathryn A. Moran

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

Kathryn A. Moran, Author

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CHAPTER 1. INTRODUCTION

The Groundwater Code of 1945 in the State of Washington was the starting point for the legal framework for managing groundwater resources within the State. At the time of the enactment of the Groundwater Code, the State took the position that small water, mainly rural wells pumping at low volumes and rates were insignificant to the groundwater resource and it would be too burdensome to track, record, and manage these small yielding wells. Therefore, the State included an exemption clause that allowed these small yielding, rural wells to become exempt from the water permitting system. Exempt wells are a special category of groundwater diversions that are primarily intended to provide rural landowners access to water for predominately domestic and agricultural needs. The rapid proliferation of exempt wells since the settlement of the West, particularly after World War II, has left the State of Washington with little knowledge of the existing number or location of many exempt wells. Washington is not alone with this issue. Many states are struggling to keep up with the vast number of water wells that puncture their landscape particularly in western states.

Exempt wells are creating issues for water availability and water quality by: (1) being used in suburban development to avoid the long and tedious water permitting process and (2) the lack of knowledge of the location of previous exempt wells that may be abandoned. Exempt wells left dotting the landscape act are potential conduits for pollution and are a risk for those who live, work, or play near them. Both the over use of exempt wells as a means to provide water to expanding urban development and abandoned wells that are not properly sealed and capped have the ability to impact a large number of Washington residences or other residences in states with a similar water law structure. Therefore, this is an important issue for water users and well owners to be aware of due to the potential environmental and health implications that can expand across entire groundwater aquifer systems that they live above and depend upon for their drinking water.

This study provides the opportunity to estimate patterns of how many and the types of wells being decommissioned each year. Providing a quantitative number to decommissioned exempt water wells will aid in the comprehension of what drives identification and proper decommissioning of exempt wells. This study seeks to answer

two main questions: (1) how do you identify exempt wells within the State; and (2) what local policies, level of collaboration, and/or social-economic and demographic factors influence exempt well identification and decommissioning. Data from 2001 through 2011 from five western Washington counties were used in this study to address the two primary research questions. The first question is answered through the development of an exempt well criteria process, which identifies potential exempt water wells. The second question is addressed by looking at local policies, level of collaboration, and local economic and demographic data that is unique for each county comprising the case study.

SIGNIFICANCE AND JUSTIFICATION OF RESEARCH

Over two billion people rely on groundwater for day-to-day needs; however, there is lack of management and protection of this finite resource (Hiscock, 2005). More than 98% of the world's freshwater reserves are accounted for by groundwater and soil moisture (Hiscock, 2005; World Bank, 2002). As population has increased, additional pressure is placed on surface waters to meet society's needs, including potable water, water for crop irrigation and water used in the production of energy. To relieve this mounting pressure many countries are turning to groundwater resources. Globally, humans use and have become dependent upon groundwater for their day-to-day needs, leaving many groundwater aquifers[1] vulnerable to an array of issues (World Bank, 2002). These changes in water consumption and sources have led to an increase in the number of potential conduits for pollutants to enter into aquifers. As a result, a variety of aquifers small to large and shallow to deep are faced with the threat of the degradation of water quality and water quantity (World Bank, 2002).

Within the United States, over 43% of the population relies on groundwater for drinking water (NGWA, 2010). In the State of Washington, groundwater supports over a quarter of the state's total water demand and supplies approximately 65% of the state's drinking water (Ecology, 2002). About 725,000 Washington residents receive their

[1] An aquifer is a "geological formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs" (WAC 170-160-111(4)).

drinking water from individual private wells (WDOH, 2013a). Wells that are abandoned[2], undocumented, or improperly decommissioned[3] can impact groundwater quality (Benton County, 2008). Most of the western states except for California and Utah operate under statutory and regulatory authority that allow particular uses of groundwater to be exempt from the traditional permitting process. The State of Washington was one of the states that enacted water well exemptions over 60 years ago when no one thought small yielding, predominantly rural wells were worth the time or money to regulate (personal communication, 2013). Over time, however, exempt water wells have become a weak point of water resources allocation, administration, and quality in Washington and other western states (Bracken, 2010). The number and location of exempt wells in Washington is unknown as is the number of historic wells created prior to a permitting system. The lack of comprehensive administrative record keeping, and the resultant uncertainty about the number or location of wells has left aquifers vulnerable to contaminants. These abandoned or improperly decommissioned wells create direct pathways for contaminants to reach local and regional drinking water aquifers (Benton County, 2008). At the same time, the wells also can present a general safety hazard to those living, working or playing in their vicinity. Wells that have not been properly decommissioned (capped and sealed) present both an unnecessary water pollution source and a safety hazard for people and animals around them. Taking into consideration that the number and locations of such wells are unknown, it is difficult to estimate the severity of the problem or how much worse the problem may become.

Objectives

This study offers insight to (1) policy incentives; (2) collaboration at the state and county levels; and (3) local social-economic conditions that impact the number of identified exempt wells and ensuring these wells are properly decommissioned in accordance with Washington State Code (WAC) 173-160. The regulations of WAC 173-160 are adopted under Chapter 18.104 of the Revised State Code (RCW). This study

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[2] Abandoned well is “a well that is unmaintained or is in such disrepair that it is unusable or is a risk to public health and welfare” (WAC 173-160-111(1)).

[3] Decommissioning means “to fill or plug a well so that it will not produce water, serve as a channel for movement of water or pollution, or allow the entry of pollutants into the well or aquifer(s)” (WAC 173-160-111(18)).

provides the opportunity to understand patterns of how many and the types of wells being decommissioned each year. Better knowledge of the number and types of decommissioned wells provides the opportunity to try to understand the influence of local policies. Through county case studies, this research determines (1) the policies at the county level that are effective in increasing the number of identified exempt wells and implementing and monitoring proper decommissioning of exempt wells; (2) a connection between collaboration at the county and state levels and the decommissioning exempt wells; and (3) if social-economic factors influence the number of identified and properly decommissioned wells. Regulators may also benefit from guidance on how to reduce the likelihood of pollutants entering into groundwater aquifers through inactive exempt wells; thereby protecting public health and safety by implementing effective policy tools.

The objectives of the research include:

- Show the pattern of exempt wells that are being decommissioned each year based on data from a sample of five Washington counties;
- Develop demographic, social-economic, policy, and collaboration indicators to describe each sample county and associate these with policy effectiveness;
- Determine whether policy incentives, collaboration at county level, and/or local social-economic conditions influenced the percentage of properly decommissioned exempt wells during the period of 2001 to 2011;
- Assess whether drinking water policies lead to more properly decommissioned exempt wells; and
- Estimate if policies can be extended across county and state boundaries to ensure future protection of groundwater aquifers.

BACKGROUND

The History and Legal Framework for Groundwater Management in Washington

Prior to statehood and during the state's infancy, Washington's Courts and Legislature had conflicting ideas on which water allocation theory to follow the: riparian doctrine or the prior appropriation doctrine (AGO, 2000). The eastern areas of the United States adopted the English common law riparian system where landowners adjacent or traversing a waterbody could have reasonable use of its water and all the

water belonged to the King who allowed the use of the water to benefit the people[4]. However, unlike the eastern United States and England, arid regions dominate the western areas of the United States. In addition, unlike the eastern United States that was ruled by England, the western portion of the United States did not development until after the United States became a country. Therefore, the west developed an alternative water allocation theory: prior appropriation. This doctrine originated to help regulate mining claims located on federal lands (AGO, 2000). Before the doctrine was enacted, any water user, such as a miner, was considered a trespasser unless they had received a federal patent (Ferrey, 2007). This approach led to disputes among the different water users (i.e. trespassers); therefore, the rule of *first in time, first in right* created the foundation of today's prior appropriation doctrine (AGO, 2000; Ferrey, 2007). Under this approach, the first trespasser had a superior right or priority to the water source over all later trespassers; however, all these rights were subordinate to federal power. The Acts of 1866 and 1870 along with the Desert Land Act of 1877 required the federal government to release all sovereignty over most of the western waters (Ferrey, 2007). Therefore, a battle between Washington's Courts and Legislature for a water allocation doctrine continued into statehood.

Washington's Courts initially followed California's approach of a mixed doctrine between the two water allocation structures (AGO, 2000). After becoming a state, however, the first Washington Legislature adopted in 1890 and 1891 general statues that supported the use of prior appropriation within the State[5]. In addition, the State followed the public trust doctrine with the State declaring in its Constitution and in statute that water is a resource that belongs to everyone and is held in trust by Washington for the people (AGO, 2000; RWC 90.03.010). The State of Washington became the trustee of the resource for the people and had the power to regulate waters within its boundaries (AGO, 2000; Ferrey, 2007).

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[4] The landowner did not have ownership of the water itself; however, had the right to use the water (Ferrey, 2007).

[5] In 1873 the Territorial Legislature established prior appropriation within Yakima County and 1886 included Kittitas County; however, it was not until the 1917 Water Code that the state held both a substantive and procedural permitting structure for water rights (Washington Territorial Laws, 1873; Washington Territorial Law, 1886; AGO, 2000).

In 1917, the Revised Code of Washington (RCW) 90.03 was enacted that included the State's first water code for surface water under the prior appropriation doctrine. The adopted 1917 Water Code created a standard for the adjudication[6] of existing rights and decreed surface water could only be appropriated with permission from the State.[7] The State was given the statutory authority and duty to oversee the surface waters of the state, so that "no diversion or use of water can be commenced until a permit has been obtained" (AGO, 2000 p. IV:14). As pressure mounted, the State enacted RCW 90.44 in 1945, also known as the Groundwater Code. The Groundwater Code of 1945 created the legal structure to manage Washington's groundwater resources in addition to surface waters and established particular exemptions from administrative control. Under State Code all diversions of surface state waters require a permit under RCW 90.03.250 and under the Groundwater Code this permit structure was expanded to include groundwater diversions (RCW 90.44.050). Prior to the Groundwater Code the state operated under a version of the *reasonable use doctrine*, which allowed groundwater users to use the resource without any volume or flow rate limits. Under the *reasonable* use doctrine, as long as the groundwater user was not "wasteful" they had the right to use the water without any consideration of injuries to other users (Ferguson and Stockton, 2009). Therefore, the Groundwater Code began creating the legal framework for managing groundwater within the state.

At the time of the ruling, the State took the position that small water wells pumping at low volumes and rates were insignificant to the resource and would be too burdensome to track, record, and manage. Therefore, RCW 90.44.050 included an exemption clause, which allowed certain wells to become exempt from the permitting system. These wells became known as exempt wells or permit-exempt wells. Exempt wells are a special category of groundwater diversions that are intended to provide rural landowners access to water for predominately domestic and agricultural needs. The adoption of RCW 90.44.050 was interpreted to include any withdrawal of groundwater

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[6] Any water rights that pre-date the regulatory creation of surface water rights (Water Code of 1917) and groundwater rights (Groundwater Code of 1945) are called vested rights. During adjudication, these vested rights become incorporated into the state's administrative permitting infrastructure (Ferrey, 2007).

[7] This task was incorporated into the Department of Ecology when the agency was created by the 1970 Legislature.

for stock-watering purposes[8]; single or group domestic uses; or for an industrial purpose in an amount not exceeding 5,000 gallons per day; and watering of a lawn or of a noncommercial garden cannot exceed 0.5 acre in area.

Washington's legal framework around groundwater management indicates an increase in the regulation over time as a function of population growth applying more pressure on the finite resource and as the knowledge of the hydrological and environmental connections between ground and surface water advanced (Ferguson and Stockton, 2009; AGO, 2000). The rapid proliferation of exempt wells since the settlement of the west, particularly after World War II, has left the State of Washington with little knowledge of the existing number and location of exempt wells. Washington is not alone with this issue. Many states are struggling to keep up with the vast number of exempt water wells that dot their landscapes. As Robert Glennon noted in Water Follies, "Most states have tens of thousands, or even hundreds of thousands, of exempt wells." (Glennon, 2002, p.59). This administrative nightmare begins with the lack of knowledge on the number of abandoned exempt water wells and their location.

> *"Most exempt wells present substantial hydrogeological and environmental risks to the aquifers relied upon for public drinking water supplies due to the general lack of adequate annular well seals. Because exempt wells are often inadequately, sealed, and because they represent the lion's share of all constructed wells, there should be great concern over the impacts of these wells to the ground water resource" (*2011 Exempt Wells Conference, 2011, p.3).

As the risk associated with groundwater wells continued to receive attention, subsequent regulations were set in place by the State of Washington. In 1971, the State passed the Washington Well Construction Act to provide oversight of the drilling of permitted water wells thereby protecting public health and safety (Ferguson and Stockton, 2009; Chapter 18-104 RCW). The Act delegated power to Department of Ecology (Ecology) to administer and create the Washington Well Log Database.

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[8] Between commencement of the Groundwater Code of 1945 to November 2005 the Washington Department of Ecology operated under the interpretation that stockwater pumping could not exceeding 5,000 gallons per day until the 2005 AGO Number 17 was released (McLeod, 2005). In November 2005 the Washington State's Attorney General and Deputy Solicitor General issued an opinion that stockwater lacks a volume and area limit by applying the Campbell & Gwinn "Plain Meaning" rule; in other words stockwater has no limit and Ecology cannot enforce a limit. (Leuba, 2007; AGO, 2005).

Ecology was required to enforce all permitted wells drilled and the well operator/owner was required to submit a notice of intent 72 hours prior to construction (Ferguson and Stockton, 2009; Chapter 18-104 RCW). These wells are recorded on a form and saved within Ecology's database along with the traditional water right information associated these wells. In 1973, recordkeeping was extended to requiring drillers to submit a drill well log for exempt wells. However, the logs do not always differentiate between permitted and exempt wells; therefore, Ecology has no method for tracking how many of the wells being decommissioned are exempt or permitted (personal communication, 2013). While regulation has increased over time, there are still a vast number of undocumented exempt wells that were drilled between 1945 and 1973 and a large data gap in tracking exempt and permitted well decommissioning. In addition, spotty record keeping over the decades resulted in only a small portion of logs being incorporated into the database until improvements were made in the 1990s.

In addition to extending the well log database to exempt wells, Minimum Standard for Construction and Maintenance of Wells (WAC 173-160) was adopted in 1973 in WAC (Washington Administrative Code). The adoption of WAC 173-160 gave authority to Ecology to regulate well construction and decommissioning. The purpose of this regulation was "to establish minimum standards for the construction and decommissioning of all wells in the State of Washington" (WAC173-160-010(1)). These regulations require the gap present between the casing and the bore wall be adequately sealed thereby preventing the creation of a conduit for contaminants to enter the aquifer system and preventing corrosion and perforation of the well's casing (Kitsap Water District, 2000). Further, Chapter 173-160 requires any well (1) no longer in use; (2) has been discontinued; (3) no longer practical to use due to disrepair; or (4) is an "environmental, safety, or public health hazard" must be decommissioned to remain in compliance with state law.

Delegation of Power and Local Authority within Washington

The allocation of power and authority within Washington is a key component to understand the institutional complexities that influence water well policy at a local and state level. The primary organizations that initiate water well policies are the Washington State Department of Health, Washington State Board of Health, local health jurisdictions, and Ecology. Local boards of health often direct the health priorities for a

local health jurisdiction and these priorities are often influenced by citizens and advisory groups not by the State (WBOH, 2004).

Local Health Jurisdictions

In 1889, the Washington State Constitution authorized the State Board of Health. Then in 1921 the Washington State Department of Health was established to preserve public health and general oversight of state healthcare activities (MRSC, 2013). The State Board of Health is a forum for the State citizens to develop (1) public health policy and state priorities and (2) strategies for budget and legislation requests to the Legislature. Today, the State's public health system includes the Washington State Department of Health, the State Board of Health, and local health jurisdictions. These three entities share the overall responsibility for the state's public health protection.

The Washington State Department of Health oversees the Public Drinking Water Program within the State and regulates the larger public water systems that have two or more connections or serves 25 or more people for at least 60 days (Group A Water Systems). Under WAC 246-291 the Washington State Department of Health shares regulatory oversight of Group B Water Systems, which include private wells with local health jurisdictions. The agreement known as the "Joint Plan of Responsibility" delineates each of the State's and local health jurisdiction's responsibilities. Based on this agreement, each local health jurisdiction either (1) maintains primary oversight; (2) shares oversight with the State; or (3) the State maintains full oversight of Group B Water System Programs (WDOH, 2013b).

There are 35 local health jurisdictions covering all 39 of the State's counties (WBOH, 2006). Table 1 lists and Figure 1 shows all 35 local health jurisdictions within

the State of Washington.

Figure 1. Local Health Jurisdictions in Washington (WBOH, 2006)

Each of these jurisdictions can form a health department or health district. There are 24 health departments within the State, including two combined city-county health departments. And there are 11 health districts within the State, which consist of one or more counties organized under RCW 70.05 and 70.46. Table 1 lists all state health departments and health districts.

Table 1
List of State Health Departments and Health Districts

Health Departments	
Adams County Health Department	Lincoln County Health Department
Clallam County Department of Health and Human Services [1]	Mason County Public Health***
Clark County Department of Public Health	Pacific County Public Health and Human Services Department
Cowlitz County Health Department	San Juan County Health and Community Services [1]
Grays Harbor County Division of Environmental Health***	Skagit County Public Health***
Island County Public Health	Skamania County Public Health
Jefferson County Public Heath	Thurston County Public Health and Social Services
Kittitas County Public health	Wahkiakum County Health and Human Services
Klickitat County Public Health	Walla Walla County Health Department
Lewis County Public Health and Social Services	Whatcom County Health Department [1]

Table 1 List of State Health Departments and Health Districts	
Island County Public Health	Whitman County of Public Health
Combined City-County Health Departments [2]	
Seattle-King County Public Health [1]	Tacoma-Pierce County Health Department [1]***
Health Districts	
Asotin County Health District	Okanogan County Public Health
Benton-Franklin Health District	Snohomish Health District[1]
Chelan-Douglas Health District	Spokane Regional Health District
Garfield County Health District	Northeast Tri-County Health District
Grant County Health District	Yakima Health District
Kitsap County Health District***	--
***Health Department or District within this study's case study counties [1]Charter counties (RCW 70.05.035) [2]Any city with a population of 100,000 or more and the county in which it is located may merge a combined city and county health department and appoint a director of health (MRSC, 2013)	

In 1993, the Health Services Act reorganized the governance structure of health departments within the State by moving authority to counties and removing city representation from local boards of health except by appointment. All jurisdictions under a health department, except for charter counties, have the board of county commissioners assigned as the local board of health (MRSC, 2013). Under RCW 70.05.035 counties under home rule charter have the authority to establish a local board of health by the county's legislature. The county legislature of these charter counties can determine the terms of office, compensation, and membership criteria for the local board of health. Further, the county legislative authority includes the ability to appoint elected officials from cities, towns, and other non-elected officials as long as the elected officials remain in the majority of the local health board. There are six charter counties in the State:

- Clallam County
- King County;
- Snohomish County;
- Pierce County;
- San Juan County; and
- Whatcom County (MRSC, 2013).

These charter counties with health departments have local board of health members appointed outside of the elected county commissioners. Both King and Pierce County are operating in combined city-county health department under a home rule charter.

Enacted in 1995 under RCW 70.05 70.46.090 health districts can consist of one to multiple counties. A single county legislature has the authority to pass a resolution or ordinance to organize a health district under RCW 70.05. Health districts of more than one county occur when the boards of commissioners pass a resolution to establish a health district encompassing multiple counties. The minimum number of members of the district board depends upon the number of counties within the health district. For a district of two counties, the district board must have at least five members and districts with more than two counties must have at least seven members (MRSC, 2013). For all health districts, the resolution or ordinance that established the health district can dictate the representation and membership to comprise the district board of health. County legislatures involved with a health district retain the authority to appoint elected officials from cities, towns, and other non-elected officials as long as the elected officials remain in the majority (MRSC, 2013). Lastly, each health district's board of health constitutes as the local board of health under RCW 70.46.060 and all expenses for delivering public health services will be assumed by each county within the health district.

The local health jurisdictions and local boards of health have been granted the authority and responsibility to protect the public's health through a broad range of local, state, and federal laws and regulations. While both the local health jurisdictions and local boards of health work together to protect the public's health, the local boards of health act as the governing body for the local health jurisdictions (WBOH, 2006). Under RCW 70.05, the local boards of health must create a policy framework for the jurisdictions and hold power to adopt local ordinances, resolutions, and approve budgets.

Department of Ecology

In early 1970, the Legislature created the Washington State Department of Ecology through the consolidation of four other state agencies[9]. The purpose of Ecology is to "protect, preserve, and enhance Washington's environment, and promote the wise management of our air, land, and water for the benefit of current and future generations

[9] Ecology preceded the creation of the federal Environmental Protection Agency (EPA) and was the first state within the country to create a state agency focused on environmental issues. Ecology served the model for many states creation of state environmental organizations (McLeod, 2005).

(RCW 43.21A). In addition, the Legislature directed Ecology to work with the State Board of Health and State Department of Health so "agencies concerned with the preservation of life and health and agencies concerned with protection of the environment may integrate their efforts and endorse policies in common" (RCW 43.20.035, RCW 43.70.310, and RCW 43.21A.140). Ecology works with federal, state, tribes, and local agencies (WBOH, 2004). To follow state law that Ecology must consult with "constituent groups, continue appropriate public involvement and outreach mechanisms designed to provide cost-effective public input on their programs and policies" (RCW 43.20A005). Therefore, Washington allows considerable use of local initiatives in dealing with water wells.

In 1992, the 52nd Legislature gave Ecology the authority to delegate portions of the water well program to local health districts or departments. These local entities must formally request the delegation of power of Ecology's wells sealing and decommissioning section of the water well program. Each local entity must prove it holds the resources, capacity, and knowledge to administer this portion of Ecology's water well program (e.g., adequate number of field inspectors) (Kitsap Water District, 2000). These delegated entities receive no direct funding and operate under an Interagency Agreement. Each agreement is unique and Ecology provides a portion of the notice of intent fee for each well drilled and decommissioned that is county inspected onsite (Kitsap Water District, 2000; personal communication, 2013). Further, any driller "working in counties that have delegated authority to inspect wells shall check with the county environmental health section for inspection requirements" is required to "obey all county notification and reporting requirements" as dictated under state code (WAC 173-160-040(2)). Pierce County was the first county to enter in this Interagency Agreement in 1992. Ecology currently has 17 of Washington's 39 counties operating under delegated authority from Ecology to inspect well construction and oversee the decommissioning of wells (person communication, 2013; Ecology, 2012). Starting in 2007, under WAC 173-160-073, Ecology conducts a yearly review of each delegated authority with an interagency agreement. This performance review includes the audit of "the construction inspections, decommissioning inspections, enforcement activities, variance decisions, training needs, technical assistance, coordination with drillers, and other driller interactions" that occur each calendar year. According to Ecology, Kitsap,

Clark, Pierce, and Thurston Counties are the most successful counties in terms of combined water well decommissioning work (Ecology, 2012). Ecology has four regional offices: Northwest, Southwest, Central, and East. Figure 2 shows the location of all of the counties within Washington (US Census Bureau, 2011). Refer to Table 3 for the case study counties' regional office jurisdictional area.

Figure 2. Map of Washington State Counties (US Census Bureau, 2011).

Growth Management Act

In 1990, the Washington State Legislature enacted the Growth Management Act (GMA) under CWA 36.70 in response to the mounting pressure from population growth within the State (Laschever, 1998). The RCW 36.70A.040 requires counties and cities that fall under a particular set of criteria to plan for the future growth within their jurisdiction (Laschever, 1998; Granger et. al. 2005). RCW 36.70A.040 requires these local jurisdictions to develop comprehensive local plans and development regulations. The GMA has 14 planning objectives that aid local governments in drafting comprehensive local plans and guiding development regulations (RCW 36.70A.020). Of the 14 planning objectives there are three environmental/resource planning goals providing guidance on natural resources, open space and recreation, and environmental protection. The environmental planning goal is directed to "protect the environment and enhance the state's high quality of life, including air and water quality, and the availability of water" (RCW 36.70A.020). Therefore, the GMA establishes a legal connection between land development management and water resource management by the use of local comprehensive plans and local development regulations (Ferguson and Stockton, 2009; RWC 36.70A.020).

Building code provisions related to water supply were codified under the GMA. Under the State Building Code Act, RCW 19.27.097 all building permit applications must prove there is an adequate potable water supply before the local authority can grant permits. In counties and local communities that do not fall under the planning goals for GMA, the county and state must collaborate to determine which areas must conduct water availability review during the building permit process. Therefore, this promotes county/state employees to physically inspect land tracts that require a building permit that may aid in locating abandoned or improperly decommissioned wells on the land under inspection for building permit(s).

ESTIMATED WELL LANDSCAPE

Exempt wells are creating issues for water availability and water quality by: (1) being used for many new subdivisions to avoid the long and tedious water permitting process and (2) the lack of knowledge of the location of previous exempt wells that may be abandoned are left dotting the landscape. Figure 3 shows the cumulative sum of all types of drilled water wells has surpassed 200,000 since 1971. A majority of these water

well logs are thought to be exempt wells (personal communication, 2013). As the population increased and as surface waters became over allocated and Ecology closed basins to new water right holders, the use of exempt wells often became a solution to providing water for new developments. Exempt wells had become so common in new development within the State that in 1997 the Washington State Attorney General issued an opinion that exempt wells cannot be used if the use impairs other water rights (Ferguson and Stockton, 2009, AGO, 1997; personal communication, 2013). Washington, like many western states, is taking legislative action to prevent the misuse of the infamous "exempt well loophole" (Kitsap Water District, 2000; personal communication, 2013). However, the use of exempt wells for new construction is still prevalent (personal communication, 2013).

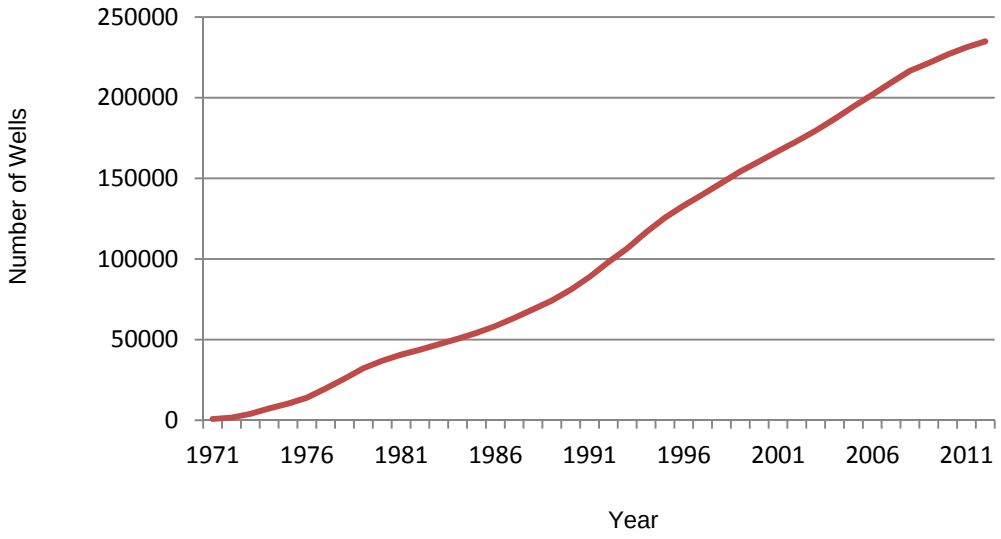

Figure 3. Cumulative Sum of Water Wells Drilled within Washington[10]

Regulators across the West appear to have a general lack of knowledge of the number of active and inactive exempt wells, location of these wells, and the actual volume of water pumped from the wells as demonstrated by Washington's last century of

[10] The data shown in Figure 3 is based from any well log that was identified as Water Well Log. Water Well Logs include permitted wells, exempt wells, and dewater wells. Dewatering wells are often temporary wells that are used during construction of a building or other structure to lower the water table within the area. It is likely that Ecology does not have records for all permitted and exempt water wells due to lost logs or logs never sent to Ecology. These missing logs most likely far outnumber the number of dewatering well logs within the data set. Therefore inclusion of the dewatering wells probably still underestimates the number of water wells that exist.

dealing with these small yielding water wells (Bracken, 2010). According to a Washington Department of Health report in August 1995, 404,000 single-family domestic wells puncture the state's landscape. However in contrast, the National Ground Water Association estimated the total number of household groundwater wells in Washington at 263,523 (Caldwell, 1998). And as of 2008, Ecology estimates there are 500,000 or more exempt wells within the state (this includes all exempt uses, not only domestic wells).

The trend over the last decade shows consistent growth of approximately 7,000 to 10,000, mostly exempt, wells are drilled each year (personal communication, 2013). The number tails off a little after 2008. Depending on the source, estimates range from 90% to 95% of the water wells being drilled are exempt wells; however, the number of exempt wells being decommissioned is unknown (personal communication, 2013). Figure 4[11] shows the annual number of water wells drilled from 1971 to 2012. It shows the largest number drilled in 1994 and drop in well drilling after 2008.

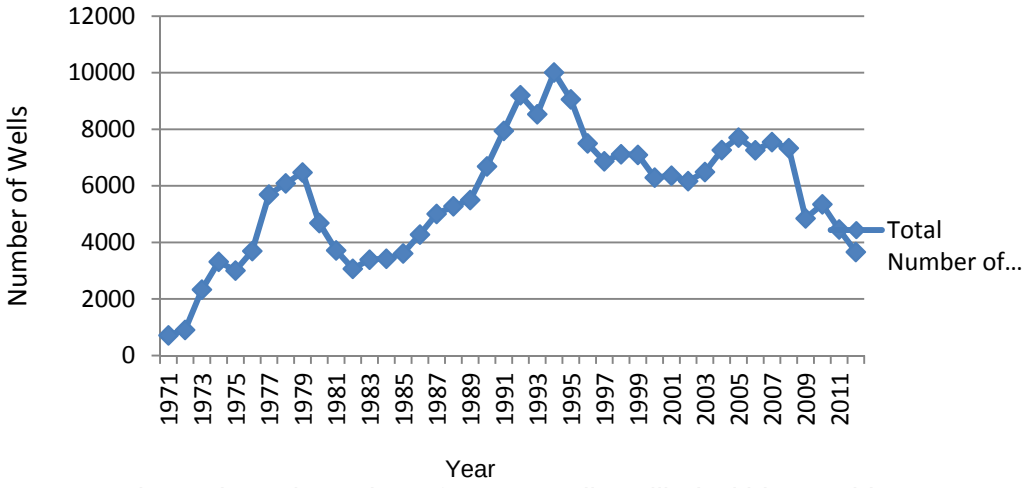

Figure 4. Estimated Total Number of Water Wells Drilled within Washington

[11] The data shown in Figure 4 is based from any well log that was identified as Water Well Log. Water Well Logs include permitted wells, exempt wells, and dewater wells. Dewatering wells are often temporary wells that are used during construction of a building or other structure to lower the water table within the area. It is likely that Ecology does not have records for all permitted and exempt water wells due to lost logs or logs never sent to Ecology. These missing logs most likely far outnumber the number of dewatering well logs within the data set. Therefore inclusion of the dewatering wells probably still underestimates the number of water wells that exist.

As of 2012, Ecology estimates the number of abandoned wells (exempt and non-exempt) to be anywhere from 10,000 to 100,000 within the State (Ecology, 2012). Often abandoned wells are left as a hole in the ground (i.e. hand dug well) or a pipe protruding from the ground or simply a pipe cut just below surface level (personal communication, 2013). These abandoned or undocumented wells are often overgrown by vegetation or development that has expanded into a once rural area, thereby concealing the wells (Treyens, 2010; Jarvis and Stebbins, 2012; Ecology, 2012).

There are four categories of contaminants that can affect water quality: (1) microbial; (2) inorganic; (3) organic chemicals; and (4) radiologic (Benton County, 2008). All of these contaminants can impact groundwater quality; however, exempt wells are particularly vulnerable to nitrates and pesticides present on the surface due to exempt wells' shallow nature[12] (Bracken, 2010). The Willamette Valley in Oregon shares similar geology and climate as the Puget Sound region of Washington. A study by the Oregon Department of Environmental Quality sampled 476 wells between 2000 and 2001. The study found 20% of the sampled wells had nitrate equal to or greater than 7mg/L with a maximum of 27mg/L[13]. In addition, septic tanks present within an abandoned well's capture zone[14] can lead to further water quality pollution (Benton County, 2008). Improperly decommissioned or abandoned exempt wells may (1) continue to promote water movement to the surface if a well taps an artesian[15] aquifer or; (2) may allow groundwater from different aquifers to mix by altering pressure within a confined aquifer system (Kitsap Water District, 2000). A single well that has not been sealed and capped can pose significant threat to an aquifer and can have "hundreds of thousands of dollars to millions of dollars in cleanup and remediation costs" (Ecology, 2008). This indicates that if environmental issues are not dealt with today these wells can cause significant

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[12] Exempt well depth varies depending upon local geology (personal communication with Ecology, 2013).

[13] 10mg/L is the maximum concentration for nitrate under the Federal Drinking Water Act (Benton County, 2008).

[14] Capture zone is the area of an aquifer (and all overlying material) that can contribute water to the well within a given period of time (Gig Harbor, 2007)

[15] Artesian well is "a well taping an aquifer bounded above and below by confining or impermeable rock or soil layers, or rock or soil layers of distinctly lower permeability than the aquifer itself. The water will rise in the well above the point of initial penetration (above the bottom of the confining or impermeable layer overlying the aquifer). This term includes both flowing and nonflowing wells" (WAC 173-160-111(5)).

health issues in the future and dramatically increase the price tag associated with its clean up. As stated by Environmental Health Manager Corinne Story, "The environmental issue of today is the health issue of tomorrow" in reference to the issue of abandoned, unknown, and improperly decommissioned water wells within the State.

Further, reports of horses, dogs, and even humans falling into abandoned wells demonstrate a safety hazard to the public. Every year in Washington, farm animals, pets, and humans (young children are at high risk) may be injured or die from falling into wells that have not been properly decommissioned (Ecology, 2012). This lack of knowledge on the number of active and abandoned exempt wells and their location is a critical policy issue since it creates a challenge for regulators to properly maintain and decommission wells to prevent pollution entering into the groundwater aquifer, manage water withdrawals, and assure public safety.

CASE STUDY BACKGROUND

Five counties were chosen and the process of selection is discussed in Chapter 3 Methods. Below is the general background information for each county from basic geographic location, demographic data, and summary of open-ended interviews. Figure 5 shows each county's population and Figure 6 shows population density for the entire study period. It is important to understand the similarities and differences between and within counties.

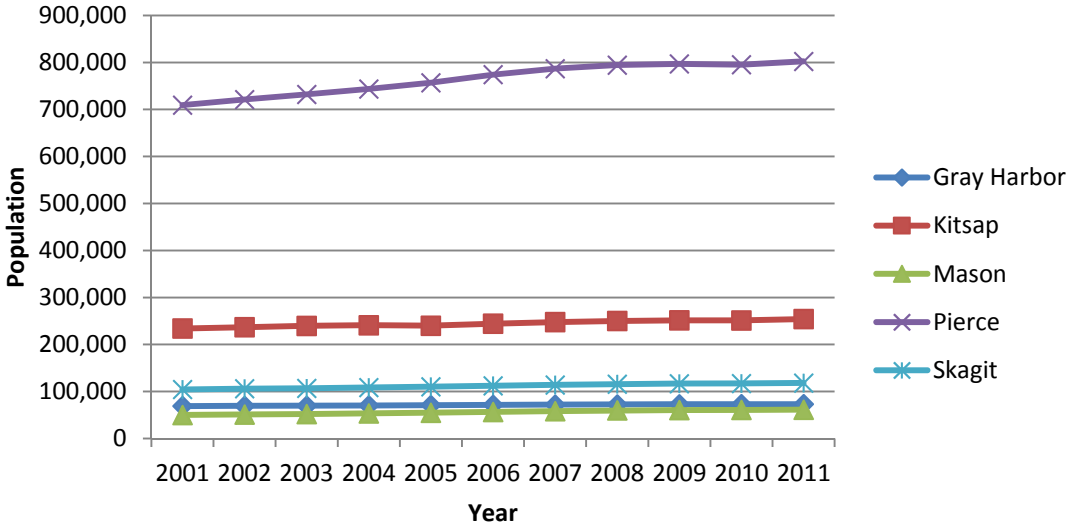

Figure 5. Case Study Population Change from 2001 to 2011

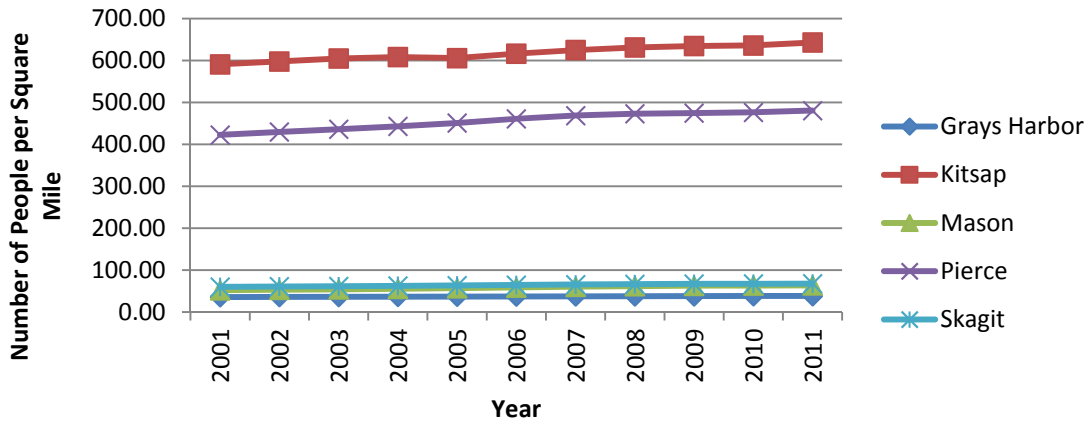

Figure 6. Case Study Population Density per Square Mile Change from 2001 to 2011

As seen in both figures, Kitsap and Pierce County are more urban than Grays Harbor, Mason, and Skagit Counties. Pierce County has a much higher population compared to the rest of the case studies.

Grays Harbor County

Grays Harbor County has the second smallest population and the lowest population density of the five case studies. From 2001 to 2011, the total population of Grays Harbor County increased by 6.10% and by the end of 2011 approximately 72,900 people called Grays Harbor County home. Grays Harbor County is bounded by the Pacific Ocean and four counties (including Mason County). Grays Harbor County is the only county of the five case studies that is not located within the Puget Sound Basin. Portions of the Quinault Indian Reservation, Olympic National Forest, and Olympic National Park are within the county. The Chehalis, Humptulips, and Hoquiam Rivers are the major surface waters within the county in addition to Lake Quinault and the Wynooche Lake Dam.

The county is mostly rural, but most of the population lives within the incorporated areas of the county. In particular, from 2001 to 2011 Ocean Shores City accounted for over 65 percent of the growth within the incorporated areas and over 24 percent of the county's overall population increase. A high volume of drilling logs submitted to Ecology from Ocean Shores City supports this finding. As of 2004, the

county passed an ordinance, which stated the county "discourages proliferation of small public water systems and private individual wells for domestic use" in areas where county, or municipal water supplies are available (Grays Harbor County, 2004, Section 9). However, within the same county ordinance potable water from surface waterbodies is prohibited for all new public water supplies unless a variance is approved by the county (Grays Harbor County, 2004). This policy of prohibiting new public water supplies for potable water from being appropriated from surface waters creates an incentive to use groundwater. Since many surface water sources are over allocated, the county is turning to groundwater for new public water supplies. Under WAC 246-291-125 a requirement to receive groundwater source approval includes a well site inspection[16] to be completed. In addition, under the 1990 GMA, there must be a review of potable water for building permits, which often involve a site visit for the building permit (RCW 19.27.097).

The primary staff members involved in the Grays Harbor County Drinking Water and Wells Program identify their role as promoting information about decommissioning under state regulations. While Grays Harbor County does not have any additional requirements than the State, the staff encourages well decommissioning of all abandoned wells. Since Grays Harbor does not have an Interagency Agreement to oversee a portion of Ecology's Well Program, the county receives no funding from the agency. Typically, there is little interaction between Ecology and the Grays Harbor County Drinking Water and Wells Program. Prior to the uploading the well logs online to the Ecology Well Log Database the county would mail in logs to Ecology. Today, the logs are submitted by the owner and driller, so the county has no record or estimates on how many potential exempt wells are drilled or decommissioned.

The primary interaction the county has with Ecology occurs with the land use reviews and determining water availability for new buildings under the 1993 guidelines (most recent updated according to county). Both of these still connect to water wells, since land use reviews and new buildings require a site visit of the property. In terms of

[16] Well site inspection means "a physical inspection of the area near an existing or proposed well location, and completion of a department or health officer-approved form that identifies the suitability of the site for a public water supply well" (WAC 246-291-125).

the water availability, site inspections also occur to ensure new private wells are not constructed next to an existing abandoned or currently in use well. The county is rural with large areas not currently being developed; therefore, it would be difficult to have a program for exempt wells or general abandoned water well (personal communication, 2013). When asked why some counties are more successful in decommissioning abandoned wells, it was considered having the agreements with Ecology might help create a greater focus around identifying and decommissioning abandoned wells (including exempt). The department recognizes abandoned wells are scattered across the county, but it's not considered a priority since it is thought there are very few present in the county. A county employee stated "people don't want to give up their wells" even abandoned wells, since there is a "perceived value" (personal communication, 2013). The only times water wells are considered by elected officials are during new development proposals (i.e., drilling).

While exempt well identification and decommissioning is not on a priority for the local board of health, the county is very aware of public water supplies and exempt water well drilling. Washington has been struggling with the exempt water loophole and the September 2009 AGO Opinion issued by Rob McKenna found Ecology lacks the authority to limit the 5,000 gallons per day quantity for exempt wells. Developers can now serve 14 lots with exempt well connections; prior to this it was only limited to 6 connections. The county is struggling with exempt well proliferation and regulation of public drinking water systems (Group B Water Systems). Grays Harbor County is predominantly rural with limited revenue and resources unlike larger counties.

Kitsap County

Kitsap County has the second largest population and the highest population density of the five case studies. From 2001 to 2011, the total population of Kitsap County increased by 8.54% percent and by the end of 2011 approximately 253,900 people called Kitsap County home. Kitsap County is located on the southwest edge of the Puget Sound and is one of the twelve Washington counties in the Puget Sound Basin. The county has over 220 miles of shoreline and is nestled between Hood Canal and Puget Sound, where the county drains to both waterbodies. There are four incorporated cities within the county: Bremerton, Bainbridge Island, Port Orchard, and

Poulsbo and all four experienced population growth between 2001 through 2011. In 2004, the Department of Defense established the Naval Base Kitsap (through merging existing bases in the area). This required the creation of housing for staff and additional services to accommodate the population increase. The county does experience population fluctuations based on the number of ships and staff stationed at these naval bases.

During the first half of the century, the county was predominately dairy farms. Recently, these farms have been divided and built on for residential and industrial uses. The east side of the county is the most densely populated area while the remainder of the county consists of small farms and forested lands. While the county borders Hood Canal and Puget Sound, the county does not have any large waterbodies or mountains that contain snowpack; therefore, the county relies heavily on groundwater for its drinking water supply. According to the Kitsap staff involved with the Drinking Water Program, their role in connection to water wells is protecting the groundwater supply. Kitsap County has received the delegated authority from Ecology to administer the well sealing, tagging, and decommissioning portions of the Ecology Water Well Construction Program under WAC 173-160. Ecology retains all other authority to regulate well drilling within the county, and while county has the autonomy to run well programs, the power of enforcement always remains with Ecology. Kitsap submits annual reports on the number and type of decommissioning since this is how Ecology determines how to allocate money to county programs. Basically, the higher percentage of wells decommissioned the more money is allocated to the county as one staff member noted this is the use of positive reinforcement. According to the primary staff, of the total water wells (decommissioned water wells are 98% to 99% exempt. From 2001 to 2011, only 7 or 8 permitted wells were estimated as decommissioned. These percent's of exempt to permitted and number of permitted wells are estimates based on experience not documentation. Also from experience, staff noted most decommissioned wells are old, private wells that never had a water right associated with the well. The staff also noted a similar pattern for drilled water wells. Most new drilled water wells (only considering permitted and exempt) are exempt with maybe 1 to 2 permitted wells each year.

The primary staff agrees that abandoned wells including exempt wells that have not been properly decommissioned are a problem, since they present a physical hazard and hazard to the groundwater resource. The main obstacle to decommissioning is finding the wells. Taking a step back, the county has hundreds of thousands parcels of land within its boundaries, and the county has very little interaction with these parcels. The main ways of finding these old wells is by getting out to the property and interacting with the landowners. Therefore, more interaction with the landowners will increase the number of wells identified. The second obstacle is cost. Once a landowner becomes aware of the cost associated with decommissioning old wells (whether permitted or exempt) they often become less truthful about wells on their property. This is why outreach with education is important according to the Kitsap staff.

In 1999, Kitsap Ordinance 1999-6 established wells no longer in use must be properly decommissioned in accordance with WAC 173-160 and all enforcement of decommissioning will be referred to Ecology. In addition, the health district requires site inspections for a variety of permits (e.g., onsite sewage, land use, etc.). In 2008, the county changed the septic tank rules to require property sale inspections. Currently, there is a high volume of requests for property sale inspections which provide the opportunity to find abandoned wells. When asked why some counties are more successful in decommissioning abandoned wells, the discussion of passive enforcement versus active enforcement was used to explain why some counties are more successful. According to Kitsap staff, some counties only request a site inspection when there is a building permit (as required under 1990 GMA) or a new well request (i.e. water appropriation). This leverage approach, of owners needing a permit and allowing the opportunity for county to request decommissioning before approving the desired permit is passive enforcement. Counties that are waiting for well owners to come to them before any action occurs to aid in identifying or properly decommissioning water wells is passive and is probably less effective. Counties that use active enforcement, such as Kitsap, have staff across programs and departments look for wells whenever on a property. Once an owner is identified, staff will pass information to the Drinking Water Program. Then staff sends a letter to the owner (1) notifying them they must decommission wells as required under state law and local ordinance; (2) providing education on why decommissioning is important; and (3) discussing the liabilities and

impact value of property associated with a well in need of decommissioning. Often people are simply ignorant of the law and will respond quickly to the letter. In the cases of owners not responding, a second letter is sent with more formal regulatory language and stating a timeline for decommissioning. This approach is effective in Kitsap, since the local board of health has created local ordinances with violations for not decommissioning wells. In addition, Ecology's enforcement authority is a motivator. Having local board of health support is useful, as well as drafting of local ordinances since, Ecology has never filed a violation and enforcement when well owners do not decommission abandoned wells.

Staff members were asked if they wanted to discuss any other issues associated with exempt wells. They noted in addition to decommissioning of wells, the impacts of new construction on water resources and water allocation is important. The exempt well loophole has created a significant issue across the state, more so on the east side (drier climate). Balancing the protection of both groundwater quantity and quality by regulating exempt wells is important for the future of the county and state.

Mason County

Mason County has the smallest population and second lowest population density of the five case studies, but most rapid growth. From 2001 to 2011, the total population of Mason County increased by 22.25% and by the end of 2011 approximately 61,100 people called Mason County home. The Skokomish Reservation, Squaxin Island Reservation, Olympic National Forest, and Olympic National Park are situated in the county. Mason County is located on the southwest edge of the Puget Sound and Mason County is one of the twelve Washington Counties in the Puget Sound Basin. The county has over 200 miles of coastline on Hood Canal and Puget Sound. Ten primary surface waterbodies contribute to the overall surface water in the county. Most of the surface waterbodies' headwaters are found in the Black Hills or Olympic Mountains. However, many of the county's surface waterbodies fall below the statutory minimum levels as specified in WAC. Therefore, many of these surface waters have been closed from further appropriations (i.e., surface water rights) for a portion of the year or closed for all months thereby making groundwater an important resource for new development.

Within the county, there are four major critical aquifer recharge areas[17]. Under Mason County Code these areas are subject to the county's health codes.

The county is mostly rural where most of the population lives within the unincorporated areas of the county. These residents' drinking water is supplied predominantly through private or small community wells (Group B Water Systems) (Mason County, 2005). In 2008, Mason County Public Health and Ecology approved an Interagency Agreement to allow the county to administer the well sealing, tagging, and decommissioning portions of the Ecology Water Well Construction Program under WAC 173-160. Under this agreement, Ecology pays Mason County 50 percent of the water wells (drilled and decommissioned) notification fees that are collected. The county felt the main purpose of the agreement was Ecology wanted staff present at well construction and decommissioning to confirm if well was constructed or decommissioned in accordance with WAC.

While the county does not know how many exempt wells are drilled or decommissioned each year, the staff noted very few permitted wells are decommissioned. Therefore, the main portion of water well decommissioning is exempt wells if dewatering wells are not considered. The primary staff noted abandoned wells that have not been properly decommissioned are a problem. The main obstacle to locating and properly decommissioning exempt wells is simply knowing where they are located. Adding to this obstacle is the lack of motivation of well owners to identify these wells. This lack of motivation by county citizens to properly decommission their wells is a significant problem. In some cases, citizens will put an abandoned well to irrigation use to avoid the cost of decommissioning. While this can save money for the well owner, it can pose risk since the well should be decommissioned in the opinion of some staff. The county noted there are no local policies currently in place to help identity and decommission exempt wells or other permitted wells.

[17] Under Mason County Code Section 17.01.080 critical aquifer recharge areas are those areas which are determined to have an important recharging effect on aquifers used as a source for potable water and vulnerable to contamination from recharge.

Pierce County

Pierce County has the largest population and second highest population density of the five case studies. From 2001 to 2011, the total population of Pierce County increased by 13.09% and by the end of 2011 approximately 802,150 people called Pierce County home. Pierce County is located on the southeast edge of the Puget Sound and Pierce County is one of the twelve Washington Counties in the Puget Sound Basin. The county has over 200 miles of coastline along Puget Sound. Portions of Mount Rainier National Park and Mount Baker-Snoqualmie National Forest are situated in the county. The Cascade Range crosses the eastern portion of the county where most of the major rivers in the county start from glaciers on Mount Rainier and flow to the Puget Sound. These major rivers are the Puyallup, Carbon, White, and Nisqually Rivers. The western side of the county is mostly poorly drained drift plain created from glacial and glaciofluvial processes.

The northwest portion of the county has been experiencing the most growth including around the area of Tacoma, which is the largest city within Pierce County. In addition, the county houses the Joint Base Lewis-McChord and Camp Murray military bases. The county uses a mix of surface and groundwater to meet its water needs. The South Tacoma Groundwater Protection District (STGPD) was created to protect the primary groundwater source (South Tacoma Aquifer) for Tacoma. Industrial lands cover the surface over this aquifer, which provides up to 40% of Tacoma's water during the summer in addition to providing a supplemental source throughout the year. In 1993, Pierce County was the first county to receive delegated authority from Ecology to administer the well sealing, tagging, and decommissioning portions of the Ecology Water Well Construction Program under WAC 173-160. Ecology retains all other authority to regulate well drilling within the county and while county has the autonomy to run well programs, the power of enforcement always remains with Ecology. Staff described their role to properly decommissioning abandoned wells as handling all decommissioning well applications and checking on well decommissioning process in the field. It often takes one to two days to completely seal a well, and this is the piece Ecology is most interested in checking for compliance. Once a notice of intent is submitted 48 hours prior to decommissioning, staff try to be present at some point in the sealing process. The primary staff interactions with Ecology include the southwest regional office and the

Ecology's manager of the Water Well Program. Further, Washington has an Advisory Board for Well Drilling in which the county is very active.

The primary staff agrees abandoned wells (including exempt) that have not been properly decommissioned are a problem. One staff noted this issue is a daily concern. Recently, the staff noted a 7 and a 9-year old child fell into an abandoned dug well that was 40 feet deep. The county has made an effort to use property sales as a tool to identify abandoned wells. One incentive used by the county is when citizens submit a Building Site Application at the same time as a Well Site Inspection and Construction Application they will receive a discount in price.

As for why the staff thought some counties are more successful than others in decommissioning abandoned wells (including exempt) they attributed it to a couple of factors (1) board of health; (2) Interagency Agreement with delegated authority from Ecology; and (3) county dedicating staff to inspecting properties. Within Pierce County, the staff noted it has become in-grained into their process to look and communicate for any abandoned wells found by staff in other departments. In addition, to collaborating across these department boundaries the support from the local health board is significant according to Pierce County staff. Each county has a local governing body and if the local governing body views abandoned wells as an issue the county is more successful. In addition, the staff noted their local board of health believes this is an issue so it does not cut corners like other counties that lack support on the issue from their local health board. Lastly, Pierce has created an additional funding structure to Ecology's small fee based funds. The county has allocated monies to the Drinking Water Program including allocating the county's fees for inspections and permits to the base funds from Ecology (based from the percent of wells inspectors are present at for decommissioning). By pulling together multiple funds, the county has been able to increase their decommissioning effort.

The main obstacle to locating and properly decommissioning exempt or general water wells is relying on others according the Pierce County staff. Letters are sent to landowners, but many will just cut corners to save on money. Therefore, the money and time spent drafting and identifying these landowners is money wastes in the view of some. Further, like any agency, there are the constraints of time and money. Wells will

remain unattended across the landscape, since the county lacks the resources to identify them in a timely manner, and then, a once rural area becomes developed many of these wells are simply missed and construction goes right over the well. According to staff, they will come across records of an old well, but when they inspect the property the well has already been developed with residential homes or shopping centers. Often these wells can be developed without proper decommissioning since no one noticed or called in the abandoned wells. The staff works with over 12 different programs; however, the on-site sewage program is where the most collaboration occurs. The on-site program has a high rate of on-site inspections that allows local officials out on the ground and interacting with landowners.

While the county does not know how many exempt wells are drilled or decommissioned each year, the staff noted very few permitted wells are decommissioned. As for drilled wells, the county knows the number of exempt wells peaked in 2005, and currently most of the drilled wells are new construction and exempt. Recently, decommissioning has become an area of growth for many well drillers and one driller within the county only does decommissioning. It was also noted that in addition to the exempt well issue the staff noted a few other issues associated with exempt wells. First, many drillers will try to avoid permitting by using exempt wells. The staff noted this is a huge issue in Thurston County. Again, the issue of both allowing the number of exempt wells to continue to increase along with leaving so many abandoned wells across the landscape creates the tension of deciding between focusing funds on water quantity or quality.

Skagit County

Skagit County has the third largest population and third highest population density of the five case studies. From 2001 to 2011, the total population of Skagit County increased by 13.15% and by the end of 2011 approximately 117,400 people called Skagit County home. Skagit County is located on the northeast edge of the Puget Sound and Skagit County is one of the twelve Washington Counties in the Puget Sound Basin. The county is located in the northeast side of the Puget Sound and is bordered by Whatcom County, Snohomish County, Okanagan County, and Chelan County. The Cascades occur in the eastern portion of the county and the Skagit River runs west and

empties into the Skagit Bay and Puget Sound. In addition, the county has many islands within its legal boundaries. About half the county uses surface water and the other half relies on groundwater. Of the rural population about 1/3 of them rely on drilled wells.

The staff describes their primary role as protecting the current and future health of its citizens including the county's groundwater resources. In 1998, Skagit County received delegated authority from Ecology to administer the well sealing, tagging, and decommissioning portions of the Ecology Water Well Construction Program under WAC 173-160. Ecology retains all other authority to regulate well drilling within the county and while the county has the autonomy to run well programs, the power of enforcement always remains with Ecology to administer the water well decommissioning portion of Ecology Water Well Program. The county must be present for well sealing (i.e. part of the decommissioning process) at least 80% of the time in order to receive funds from Ecology. The interaction with Ecology includes the county's public health department relying heavily upon Ecology for technical information. Staff also mentioned the Washington Advisory Board for Well Drilling and stated it is full of well drillers who often vote down new laws and regulations.

The primary staff agrees abandoned wells, including exempt wells that have not been properly decommissioned, is a "huge" problem since they present a physical hazard and a threat to the groundwater resource quality. The county is especially concerned about old, hand-dug wells, in addition to septic tanks being placed near old abandoned drilled wells. The 1990 GMA that was amended to include the requirement of examination of groundwater quality further pushed counties to become engaged with the issues associated with wells[18]. The Skagit County code (14.22.300-340) was drafted by a hydrogeologist, and in 1992, the county developed a program solely focused on wells.

As for why the staff thought some counties are more successful than others in decommissioning abandoned wells (including exempt) they attributed it to a couple of factors: (1) local boards of health; (2) local leadership to get buy in from local boards of

[18] The 1990 GMA framework was developed by copying a large portion of Oregon's 1973 statewide land use planning program.

health; (3) ability of staff to secure grant monies. Since 2008, the economic downturn forced the shrinking of many county budgets. The key for a well program to stay strong is securing money from a source whether its fees from the county general fund, permits, or grants. Skagit noted both Kitsap and Pierce have done a good job in securing funds even during economic downturn. Further, a strong leader who can make a case to the local board of health the need for supporting well decommissioning is important.

Skagit funds are from grants, fees, and a portion of the general county fund. Grant and fee money have restricted use (i.e., only certain tasks can be used with these funds) while the general county fund allows the Drinking Water Program more flexibility in deciding how to allocate funds. The County Commissioners make all decisions on budget and since the economic downturn the Drinking Water Program lost over a quarter of its employees and a large amount of money from the county's general fund. Prior to 2008, about 50% of funds were from grants and fees and today 90% of funds are from grants and fees. The Drinking Water Program is chronically underfunded, unlike Kitsap and Pierce which have been able to maintain a reasonable amount of funding.

The main obstacle to locating and properly decommissioning exempt or general water wells is simply knowing where they are located. While exempt wells are a rural issue that many urban people lack interest in, it should be a statewide issue since urban areas expand into these once rural lands and may further pollute aquifers. While the county does not know how many exempt wells are drilled or decommissioned each year, the staff noted resource protection wells and dewatering are also very common.

SUMMARY OF CASE STUDIES

Based from these case studies several common topics emerge—including the use of on-site inspections, policy incentives, local health board's role, exempt water loophole issues that promote urban development, and general lack of information or records on exempt wells. One important topic all these counties share is the importance of getting to properties, since this is the primary way to find abandoned, unknown, or improperly decommissioned wells. While this is perceived as the best way to identify wells, counties are limited in resources to interact with every parcel of land under their jurisdiction. This need for greater interaction with landowners is due to the lack of knowledge on well locations. All of the case studies, indicated no one had actual

numbers of exempt wells. Most counties and state staff could only provide estimates based from their personal experience. While experience can provide significant insight into the general trends of exempt well decommissioning, the lack of knowledge the actual numbers is a large gap to understanding exactly how well counties are preforming with identification and decommissioning.

All of the counties, except for Grays Harbor and Mason, noted the use of policy and incentives to encourage well decommissioned. All five counties stated these policy incentives make counties more successful in well identification and decommissioning. Lastly, the importance of local health board's support on the topic of well identification and decommissioning was discussed by all counties except Mason. The issue around exempt well drilling is highlighted by all counties as a critical issue to solve. The proliferation of exempt wells and the loopholes allowing builders to secure water is another side of the exempt well issue. This is partly connected to land use, as once rural areas have become or will become urban areas. All of the case study counties identified similar issues and solutions around the exempt well problem; however, some counties seemed more engaged and devote more resources to the problem and how to solve it. Kitsap, Pierce, and Skagit Counties used examples of positive versus passive enforcement, highly engaged local boards of health on the topic of well decommissioning, and the search and securing of extra funding for well programs as factors that differentiate a county from being highly engaged to less engaged.

CHAPTER 2. LITERATURE REVIEW

The identification and decommissioning water wells is an unexplored area with a significant knowledge gap about effective policies, collaboration, and economic influences. Studies to fill these gaps would benefit from the insights that other research fields offer on the effect of local and state organization, policy implementation and outcomes, and public leadership and collaboration on identifying and decommissioning of exempt water wells. Better understanding of the potential influences on exempt well identification and decommissioning can be gained by reviewing related literature. This section is divided into three units: (1) state and local agency sphere of influence; (2) collaboration across boundaries (i.e., leadership and collaboration); and (3) economic and demographic landscape.

STATE AND LOCAL AGENCY SPHERE OF INFLUENCE

The relationship and effectiveness of state and local policies and department structure offers several insights. Both state and local environmental and health agencies are major players in the formation and implementation of water well policies in Washington. Therefore, it is important to understand the relationship between state and local departments and their policies. Some studies show state influence on local government including public services is often greater for particular functional and programmatic areas such as health and environmental concerns (Defriese et al., 1981; ACIR, 1978). Environmental and health policies are considered to be in the interest of both the state and local governments; therefore, high state government participation is expected (ACIR, 1978). Functional areas such as health have a wide variation in the scope of coverage by state policies across the country (Lovell et al, 1979). Yet, public health is an area of strong regulatory power. On a smaller scale, studies have shown local government decisions and priorities concerning how public health can be influenced by local boards of health, thereby influencing the organizational structure and performance by local health departments (Defriese et al., 1981; Townsend, 1968).

Townsend (1968) found both local health boards and local political office holders maintain an influence on the administrative decisions and policy implementation from local health department directors. This finding is also supported by a Washington State Board of Health (2004) study that found local boards of health often direct the health

priorities in a county or jurisdiction and these chosen priorities are often influenced by citizens and advisory groups not by the state. Further, the study found through interviews with local health jurisdictions there is a lack of a systematic process and funding by the State to identify environmental health risks; therefore, they rely heavily on "staff knowledge, experience, anecdotal information, and limited data" (WBOH, 2004).

While there is some literature on identifying influences of local health departments, there are significant gaps on the relationship between health departments' structure and performance to health outcomes. Hyde and Shortell (2012) noted the connection between (1) health department's structure and performance and (2) health outcomes is a complex issue. Hyde and Shortell's multiple study review found mixed results on health outcomes and partnership performance on organization structure (e.g., centralized, decentralized, mixed), leadership, and jurisdiction (Hyde and Shortell, 2012). Based from Defriese et al. (1981), Townsend (1986), Hyde and Shortell (2012), and the State Board of Health (2004) findings, this study created variables to consider local health boards potential influence on a county's performance of identifying and properly decommissioning wells.

COLLABORATION ACROSS BOUNDARIES

The Washington State Board of Health (2004) study found in interviews that environmental health issues often were left out of general community health assessments within the Department of Health due to the small amount of collaboration between health and environmental staff members. A shift to a more complex, integrated organization within the public sector creates a completely new landscape and challenge for public managers. One of the most important challenges is reaching desired outcomes within deeply entrenched traditional legal and political structures. Collabration through developing formal and informal partnerships has become an important component of working across boundaries for many public leaders and managers (Newell, 2008; Huxham and Vangen, 2005). Therefore, the degree of collaboration is an important variable in determining how effective a department is at (1) delivering public sevices and (2) maintaining to serve the public interest while operating within the current public sphere. A substantial literature exists on collaboration; however, within the literature, the terms partnership, collaboration, and co-management are often used

interchangeably or misused (Plummer and FitzGibbon, 2003; Thomson, Perry, and Miller, 2007). This use of the three terms is understandable since partnerships, collaborative actions, and co-management all share similar elements: (1) actors share power; (2) actors share consequences; and (3) actors come to a mutual understanding through a process, action, or agreement (Plummer and FitzGibbon, 2003). These shared elements account for the overlap within the literature (Hall, 1999; Castro and Nielsen, 2001). Plummer and FitzGibbon (2003) tried to frame the connections among the three terms by noting "a partnership represents collaboration; collaboration may occur within co-management; and/or collaboration and co-management are forms of partnerships" (p. 67). Collaboration will be the term used to describe the mutual agreements used between county departments, Ecology, and other stakeholders. Collaboration is defined as multiple actors pooling resources (e.g., field inspectors, knowledge, information) together in order to solve problems (Gray, 1985; Ostrom, 1991; Daniels and Walker, 1996).

To complicate matters further, how collaboration is studied varies with scholars' conceptualization of the term. This creates signficant barriers to comparing between studies and ensuring measureable variables that actually represent collaboration (Thomson, Perry, and Miller, 2007). Therefore, there is no single framework to measure collaboration. The issue of scale (i.e. geographic area) is important to consider and a framework that can analyze elements of collaboration. For all regional problems, there will also be a variety of stakeholders engaged to work on the problem, the difference between a successful and failed regional collaboration movements are the elements used for the process of collaboration (McKinney, Scarlett, and Kemmis, 2010).

> *"All regional efforts are assemblages of cooperating interests and groups, and all have established some type of working arrangement – some more artfully framed than others. The differences appear in aspects such as the range of issues and concerns that bring them together, the size and complexity of the geographical area they are focused on, the strength of the structural relationships they have established in which to function, the type of official establishment within recognized public or private organizations, and their method of assuring (or not) a continuing presence*" (McKinney and Johnson, 2009 p.12).

McKinney, Scarlett, and Kemmis (2010) found there are ten key elements that are present in successful regional collaborations (refer to Table 2). The McKinney et al. (2010) regional collaboration framework is too board for this study because exempt well collaboration is not looking at an overall collaboration process, but instead is looking at the influence of collaboration on the performance of selected case study counties and Ecology. Of the ten McKinney et al. (2010) elements, three are used to understand and analyze how the counties' and the State collaborate on the identification and properly decommissioning of exempt water wells. Therefore, for this study the collaboration variable looks to see if (1) a catalyst is considered present; (2) influential leadership is present; and (3) representation is present.

Table 2
Ten Key Elements of Regional Collaboration

Ten Elements [1]		Elements Incorporated into Study Variables
Catalyst	The crisis, threat, or opportunity that compels people to think and act regionally	X
Leadership	The need for different types of leaders to catalyze, enable, and sustain action	X
Representation	The people, organizations, and jurisdictions needed to achieve the desired outcome	X
Regional Fit	The tension of matching the problem-shed with people's interest	--
Governance	The degree of decision-making authority, along with mechanisms for funding	--
Learning	The process of facilitating scientific and public learning	--
Strategy	The formulation of a vision, goals, and aspirations.	--
Implementation	A plan to move from vision to action	--
Outcomes	The agreements, policies, programs, and on-the-ground accomplishments achieved	--
Adaption	The ongoing process of monitoring, evaluating, and adapting as needed	--

[1] McKinney, Scarlett, and Kemmis, 2010

Determining if a catalyst is present and stakeholders are involved can be achieved fairly easily through deductive reasoning; however, determining the presence and quality of leadership requires more evaluation. Hyde and Shortell (2012) found mixed results on leaders' influence of health outcomes and partnership performance. For the study of decommissioning exempt wells, leadership and collaboration are tightly connected to each other. Therefore, in order to look at collaboration one must first understand leadership. Many of studies are about leadership in a broad context. Ribiere and Sitar (2003) found leadership is an important component for organizations,

and also found, it is critical for leaders to model behaviors (i.e., 'leading through a knowledge lens') and earn trust and commitment from workers if they want to evolve and achieve their organization's goals.

Fewer studies are specifically about public leadership; however, most of these studies concentrate on elected officials or high level officials (Chrislip and Larson, 1994; Heifetz, 1994, Svara, 1994). There is a lack of knowledge on leadership exhibited by many less visible public administrators trying to solve public issues. Van Wort (2003) notes this is an area of study that needs more attention. In particular, a large portion of public administration literature either ignores the topic or rejects the concept of leadership (Fairholm, 2004). An additional obstacle attached to studying leadership theories and approaches is how to define such a broad term. Stogdill (1974, p.7) stated "there are as many definitions of leadership as there are persons who have attempted to define the concept." Often leadership is studied based on the researcher's personal notion of leadership (Fairholm, 2004).

In addition to the research focused on highly visible public leaders, the gap in literature on public leadership is attributed to the fact the topic has been ignored within the public administration field. This is due to the deep-rooted, negative perceptions of the politics and administrative dichotomy; amount of discretion open to bureaucratic (i.e. public leaders); and bureaucratic power available to leaders. Fairholm (2004) describes this outdated perception of leadership within public administration using the "three D's": dichotomy, discretion, and domination. This includes (1) arguments associated with the politic-administration dichotomy that is concerned when leadership looks too much like politics; (2) administrative discretion arguments that leadership is detrimental to administrative prudence; and (3) domination arguments that suggest leadership creates space for individuals to expand their sphere of authority. This is dangerous because it allows areas of an organization to be left without checks and balances thereby providing an individual with too much power or domination (Fairholm, 2004; McSwite, 1997).

These perceptions of public leadership dismiss a critical link within the policy process and fail to shed light on the positive components of leadership within public organizations (Fairholm, 2004). Svara (2007) found today's public leaders must operate and thrive in this political world through the use of *authorized* discretion and authority (not domination) provided through the legal framework in order to participate in the policy

process from development to implementation and enforcement. Today's public mangers and leaders operate in a complex and dynamic environment and are expected to use critical thinking in order to solve public issues while dealing with constraints created by limited resources, pressure to have a high performance level, and the expectations to work across traditional organizational and sector boundaries (Salamon, 2005; Goldsmith and Eggers, 2004; U.S. GAO, 2003). This changing context of governance further clouds how to define public leadership. Today, public leaders are no longer confined to working within "silos" created by hierarchical organizations, but instead must cultivate partnerships across these old institutional boundaries (O'Toole, 1997; Huxham and Vangen, 2005). Newell (2008) notes it is important for public leaders to "align their values with the values of their partners as they collectively deliver public services". This value-based approach to leadership highlights the importance of collaboration for public leaders and mangers in order to achieve targeted outcomes.

The three components comprise the collaboration variable are based on McKinney, Scarlett, and Kemmis (2010): catalyst present, representation, and degree of leadership. First, the study looks to see if each county believes there is a problem with abandoned wells not being decommissioned. This is the catalyst element from McKinney, Scarlett, and Kemmis's collaboration framework since if something is not perceived as an issue there is no reason for people to think and act more broadly (McKinney, Scarlett, and Kemmis, 2010). Second, representation looks at all the stakeholders listed as involved with engaging in the water well identification and properly decommissioning process. The number and type of stakeholders involved in addressing an issue is directly connected to the success of a collaboration process according to McKinney, Scarlett, and Kemmis's framework. Lastly, the type and style of leadership is linked to how action is taken to address the issue. The presence of vision, trust, technical skill (i.e., experience), and working with others to solve problems are key components in if a collaboration process is successful

SOCIAL-ECONOMIC AND DEMOGRPAHIC LANDSCAPE

During this study's temporal focus, 2001 through 2011, the United States experienced the deepest recession since the Great Depression. A study (Willard, Shah, Leep, and Leighton, 2012) looked at local health departments across the United States

between 2008 through 2010 to understand the impact of the economic recession on the departments. Willard et al. (2012) found more than half of the local health departments experienced funding cuts by 2010; however, it was unclear if the economic recession reduced the departments' ability to perform and provide core services. Therefore, economic conditions have the potential to influence the ability or desire of agencies, well drillers, and well owners to identify and properly decommission wells. Demographic information will also be used in this study since Hyde and Shortell (2012) found a relationship between greater population size, hence more urbanization, served by a public health department leads to an increased capacity to provide services; therefore, a smaller local health department will struggle with providing services and holding high performance rates because it has fewer resources.

Since exempt wells are often associated with domestic use in areas outside of municipal water systems or service water districts, comparing (Benton County, 2008) between areas with low population density (rural) to high population density is an important variable to consider. In addition, to population density and population size the wealth of the area may influence local boards of health or departments priorities; therefore, median household income is included for each sample county. Based on previous studies the following social-economic and demographic variables are utilized in the analysis: county population, county population density, urban-rural classification, median household income within county, state's construction sector (percent of unemployed), and economic climate (recession or not). For population growth, annual changes were noted. After reviewing some of the growth issues, building permits for each year, 2001-2011, were added.

CHAPTER 3. METHODS

This exploratory study has two parts: (1) development of exempt well criteria to isolate exempt water wells from other well types and (2) an analysis of the influence of State and county policies, collaboration, and economic and demographic components on the actions of counties and the State with respect to identifying and properly decommissioning exempt wells. Two research methods were used to explore each component: (1) open-ended interviews with state and county employees and well drillers; and (2) data on wells from the Ecology's Well Log Database. A flow chart of the approach to the two-part research problem is provided in Figure 7.

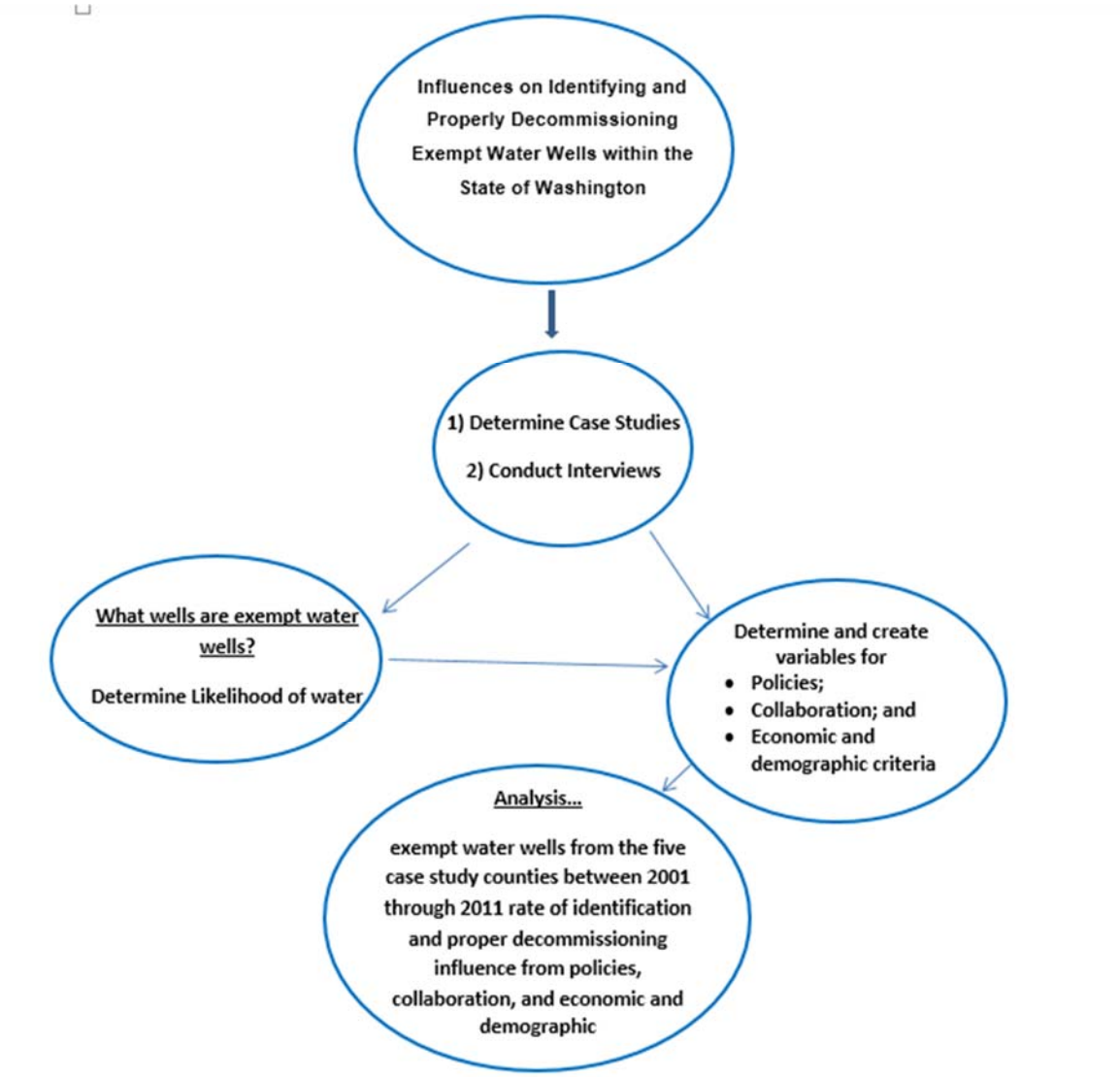

Figure 7. Methods Process

CASE STUDIES

Five western Washington counties were selected as case studies. The counties are similar in geological, environmental, climatic, and socioeconomic features (refer to Chapter 1). Table 3 summarizes characteristics of the five counties (e.g., population, land area, density, and Ecology's Region). One county, Thurston, was concerned about releasing exempt-well information and declined to participate and it was replaced by Pierce.

Table 3
Case Studies Counties

County	Population	Area [1]	Density [2]	Ecology Region [3]
Ecology Retains Authority to Oversee Well Program				
Grays Harbor	72,546	1,902.03	38.3	Southwest
Delegated Authority from Ecology to Oversee Well Program				
Kitsap	254,633	394.94	635.9	Northwest
Mason	61,019	959.42	63.3	Southwest
Pierce [4]	795,225	1,669.51	476.3	Southwest
Skagit	118,109	1,731.20	67.5	Northwest

[1] Square miles
[2] Persons per square mile
[3] Ecology's Regional Districts
[4] Original case study was Thurston County; however, county declined interview participation and recommended Pierce County as replacement case study.
Sources: US Census Bureau, 2011 and Ecology, 2012.

Four of the five counties hold delegated authority to oversee exempt-well drilling, decommissioning, and recordkeeping from Ecology. Grays Harbor County was picked as a comparison county since the county lacks delegated authority from Ecology. This means that Ecology has kept all authority in Grays Harbor, with no local policies or county departments having control of well drilling or decommissioning. Of the four delegated authority counties, two counties are located in the northwest region and the remaining two are within the southwest region. Population density serves as an indicator of the urban and rural counties in each Ecology Region (Table 3). For background information on counties refer to Chapter 1.

INTERVIEWS

After the case studies were identified, opened-ended interviews were conducted with county and state officials and well drillers. All participants in the study are adults over the age of 18 and were identified as retaining a high degree of working knowledge with water wells drilling and decommissioning. The participant population is based on current or past jobs held within the State of Washington or case study counties. The targeted population includes participants that work for Ecology, county level health or water resource departments, and well drillers who operate within the state and were recommended by county officials as knowledgeable interview subjects. The study used email and open-ended interviews via telephone or in-person. The state-level emails and open-ended interviews primary functions were to (1) develop criteria to identify exempt

water wells from other wells within Ecology's Well Log Database; (2) record participant's description of current and past polices as well as their thoughts on these policies; and (3) understand the perspective of state agencies sharing power with some counties. Next, open-ended, email or telephone, and/or in-person interviews were conducted with the case study county employees. The objective of these interviews was to collect data on (1) current policy structures within the county; (2) how the policy is implemented; (3) interaction between Ecology and the county; and (4) the level of collaboration that occurs to support identifying and decommissioning wells. Finally, additional email, open-ended, telephone and in-person interviews with well drillers provided context about exempt and permitted well-drilling activities in the region and how polices impact well owners and drillers.

Fifteen participants were involved in the open-ended survey questions. For confidentiality all responses are reported in aggregate form where participants are not readily identifiable. Due to the low number of participants at the state and local level, exact responses cannot be provided without risking inclusion of some readily identifiable information about participants. Table 4 lists the open-ended questions that were developed to target the participants' connection with water wells. The three versions of the broad interview questions were created for each participant group: (1) state employees with Ecology; (2) county employees; and (3) well drillers.

Table 4 **Open-ended Interview Questions**
Department of Ecology
Please describe your past education and years of experience with wells?
Please describe potential ways to identify exempt wells from permitted wells within the Ecology's well log database.
Explain the interaction between Ecology and counties (delegated and un delegated).
Do you think abandoned wells not being decommissioned is a problem?
What current state regulations are in place to deal with identifying and decommissioning exempt wells (or water wells in general)?
Why do you think some counties are more successful than others in increasing the number of exempt wells being decommissioned?
What are your personal opinions on the current policies in place at the state level? Your view on the county level policies?
What is the largest obstacle in locating and properly abandoning exempt wells?
What factors affect the different success rates in data recording and decommissioning of wells in the counties?
County Departments
Please describe your past education and years of experience with wells?
How is your role connected to identifying wells that need to be decommissioned and ensuring they are properly decommissioned?
Does your county receive funding from Ecology to oversee decommissioning of wells?
Do you think abandoned wells not being decommissioned is a problem?
What is your opinion on the interaction between Ecology and your county?
What polices are in place within your county? What are your thoughts on these policies?
Why do you think some counties are more successful than others in increasing the number of exempt wells being decommissioned? Which ones?
What is the largest obstacle in locating and properly abandoning exempt wells?
For the purpose of this study I will be looking at 2001-2011. How many exempt wells are decommissioned each year within your county? How many exempt wells are drilled each year within your county? You can give estimate ranges if you do not know exact numbers.
Within your county explain any collaboration that occurs to aid in the process of identifying exempt wells that need to be decommissioned both within your department and other external groups.
If so, how often do you work with other departments/groups to aid in identifying wells?
What type of groups are you collaborating with? Please list these other departments and groups.
On a scale of 1 to 5, where 5 is the highest possible level of collaboration, how would you rate your collaboration with others to aid in identifying and decommissioning exempt wells?
Are there any other topics on exempt wells at a local or state level you would like to discuss?
Well Drillers
Please describe your past education and years of experience with wells?
Explain your interaction with Ecology and counties you operate within.
Do you think some counties are more successful than others in increasing the number of exempt wells being decommissioned? Why do you think some counties are more successful?
What is the largest obstacle in locating and properly abandoning exempt wells?
Are there any other topics on exempt wells at a local or state level you would like to discuss?

The responses from these interviews were a combination of qualitative and quantitative data. The two quantitative variables that were based on participants' responses are policies present within the county and county collaboration. The remaining responses were analyzed using content analysis following guidance from Bernard (2002). Content analysis allows for a systematic process to classify and identify themes from the open-ended responses from participants. While the quantitative portion of this study uses deductive reasoning and allows hypotheses to be tested, the inductive portion of the open-ended interviews provides insight into the participants' view of the well water system that operates within each sample county. The goal is to illuminate themes that aid in understanding the situation rather than trying to infer results solely from the quantitative data on water wells. Weber (1990) notes, that it is best to use both qualitative and quantitative methods for content-analytical studies. This study uses both methods to paint a fuller picture of the issues and successes of identifying and properly decommissioning exempt wells.

WELL LOG DATABASE

Once the five counties were identified and opened-ended interviews were conducted all county well data about drilled and decommissioned wells had to be obtained from Ecology's Well Log Database. Working with these data required multiple steps to extract only exempt well logs for this study. Ecology's literature suggests exempt wells may be up to 95% of all water wells; however, it has not been clarified if this is all water wells or a portion of the four types that are considered water wells. A very low percentage of exempt wells were identified. Thus, obtaining the best estimate possible for exempt wells was a critical and time-consuming first step.

Ecology Well Log Database

Ecology's Well Log Database contains well logs that have spaces to record ownership, location, type of well, and basic physical attributes of the well. Ecology is divided into four regions: northwest, southwest, central, and east. Each regional office is responsible to review submitted well logs and add new well logs to the database. Each original log filled out by a driller is uploaded to the Ecology Well Log Database; therefore, the available information within the database is directly linked to how complete, accurate, and readable each well log was at the time of submittal. The

database has four search options for well type: (1) All Well Logs; (2) Drilled Water Well Logs; (3) Drilled Resource Protection; and (4) Decommissioned Well Logs. Water Well Logs include four types of water wells: permitted; exempt; test; and dewatering. The Ecology Well Log Database lacks information to separate out the four types of water wells. Further, the decommissioned well logs include all well types (water wells and resource protection wells) while drilled wells are already separated by water well and resource protection for the basic search option. All of these well types serve different purposes and are regulated differently under WAC. All drilled water well logs from each sample county were downloaded to create the database for drilled wells. Next, all Decommissioned Well Logs (i.e., water well and resource protection wells) from each sample county were downloaded into a second, decommissioned well database.

Resource protection wells and water wells are the two main categories of wells. A resource protection well is “a cased boring intended or used to collect subsurface information or to determine existence or migration of pollutants within an underground formation” (WAC 173-160-410(13)). A wide variety of well types are included under resource protection wells including: monitoring wells, observation wells, piezometers, spill response wells, remediation wells, environmental investigation wells, vapor extraction wells, ground source heat pump boring, grounding wells, and instrumentation wells (WAC 173-160-410). Well drillers use a variety of well log forms for resource protection well reporting depending on the well’s purpose or use. The three most common resource protection wells reported in county well logs between 2001 through 2011 include: environmental investigation, geotechnical soil boring, and monitoring wells.

There are four types of water wells: permitted water wells, test wells, exempt wells, and dewatering wells. Under WAC 173-160-111 (21) dewatering wells are defined as “a cased or lined excavation or boring that is intended to withdraw or divert ground water for the purpose of facilitating construction, stabilizing a land slide, or protecting an aquifer.” Dewatering wells are most commonly used in areas with shallow aquifers present in the project area of road and utility rights-of-way or building foundation

construction. Under WAC 173-160-111(49) test well[19] is defined as "a well (either cased or uncased), constructed to determine the quantity of water available for beneficial uses, identifying underlying rock formations (lithology), and to locate optimum zones to be screened or perforated". As discussed in Chapter 1, RCW 90.44.050 states permitted wells require approval from Ecology (i.e. water permit) and included an exemption clause that allows certain wells to become exempt from the permitting system. Permitted wells regulate larger water quantities and pumping rates of the state's groundwater, while exempt wells are targeted for small water uses.

Ecology's Well Log Database allows all logs from any of the four search options to be downloaded by county. Two pieces of information were collected from each Ecology well record: (1) copy of the original written well log in a PDF format; and (2) an Excel file that describes the ownership, location, Notice of Intent (NOI) tracking number, and basic physical attributes of the well (diameter and depth). For each sampled well record, the PDF copy of the written log was opened and the Excel file with the well record's basic information were compared and data was transferred to an Excel spreadsheet. This merged information for each well record that was transferred to the Excel spreadsheet became the database for the county.

The following information from each original written log was extracted to include into the study county's database: well form (i.e., water well, or resource protection), beneficial use, if well was dug, and permit number (if provided). In addition, each well log was double checked to ensure the original form matches the basic data from Ecology's data set. Often, diameter was provided on the original log but was not transcribed into the well log's Excel information. All logs outside the January 1, 2001 through December 31, 2011 period are excluded. Due to the time required to review each individual copy of the original well log and then merge the data with the basic well information from Ecology, it was impractical to include the entire population in the database. A simple random sample was taken from each county's records of wells

[19]"If a test well is constructed with the intent to withdraw water for beneficial use, it must be constructed in accordance with the minimum standards for water supply wells, otherwise they shall be constructed in accordance with the minimum standards for resource protection wells" (WAC 173-160-111(49)).

decommissioned or drilled from January 1, 2001 through December 31, 2011 to serve as a sample for the study.

By utilizing a simple random sample, all cases (i.e., well logs) have the same probability of being selected from the overall population (Bernard, 2002). The RANDBETWEEN function from 2010 Excel was used in this study (i.e., Excel's random number generator). Table 5 shows the total number of decommissioned logs or records Ecology maintains within each county for each year from 2001 through 2011. In addition, each county's sample population (n) is provided and the percentage of the n that is represented in water wells and resource protection wells that were decommissioned. The goal was to come up with approximately 60 exempt wells for each county in each the drilled and decommissioned well databases, providing a sample of approximately 300. This sample size would have been satisfactory for statistical analysis, with each county weighted equally (Bernard 2002). It became clear that because of information being absent from the well logs, the number exempt wells could only be estimated. In Table 5, there is a wide range of total logs for each county between 2001 through 2011. Sample counties had considerable variation in how many of the wells were water wells versus resource protection; however, resource protection wells overall were the leading well category for all counties.

The random number generator was used for each county and data were collected until about 60 logs of potential permitted and exempt wells were found and data from the logs transferred into each county's database (excluding known water wells with a dewatering use). Two databases, one for decommissioned and one for drilled wells were now completed for each of the five sample counties. Each county had a random sample of roughly the same size. By far, the largest number of well logs in the decommissioned database are resource protection (Table 5), then dewatering, and smallest in number are permitted and exempt wells. Further, only a small percentage of permitted and exempt wells were identified from the well logs.

Table 5
Summary of Decommissioned Wells by County Between 2001-2011

County	Total Logs	Sample Size (n) [1]	Water Well Logs[2]	Resource Protection	Sample as of Total Logs [3]
Grays Harbor	1,751	1,751	37.7%	62.4%	100.0%
Kitsap	3,613	265	30.6%	69.4%	7.3%
Mason	542	317	18.9%	81.1%	58.5%
Pierce	11,057	1,000	12.3%	87.7%	9.0%
Skagit	2,274	898	35.1%	64.9%	39.5%
Sum		4,231			

[1] Sample Size was based on reaching approximately 60 potential exempt well logs
[2] Water Well Logs percentage includes permitted, exempt, and dewatering
[3] Percentage of sample out of total population (total logs)

Table 6 shows the total number of drilled water well logs or records Ecology maintains within each county for years 2001 through 2011. Each county's sample population for drilled water wells was 100 logs except for Grays Harbor. Resource protection wells that are drilled were not included in this database. The database used to check the criteria for identifying exempt wells had 519 cases. Of these 102 were identified as exempt.

Table 6
Summary of Drilled Wells by County Between 2001-2011

County	Total Logs [1]	Water Well Logs [2]	Water Wells as Percent of Total Logs
Grays Harbor	1,374	119	8.7%
Kitsap	2,299	100	4.3%
Mason	2,075	100	4.8%
Pierce	4,220	100	2.4%
Skagit	2,438	100	4.1%

[1] Ecology maintains separate databases for water well logs and resource protection wells for drilled wells
[2] Water Well Logs and Sample Size are the same since water wells only include permitted, exempt, and dewatering. The number of Water Well Logs (or the Sample Size)for drilled logs was based on reaching approximately 60 potential exempt well logs

Exempt Well Criteria

Once each county's sample population data entry was completed, the next step involved applying the criteria developed with Ecology staff to estimate the number of exempt wells (personal communication, 2013). By applying the exempt well criteria to the sample populations, the output would filter exempt wells from permitted and dewatering wells that are also included under the water wells category. It was determined that wells with a diameter between 2 to 6 inches or hand dug wells and domestic beneficial use were most likely attributes for identifying exempt wells.

Ownership was another potential variable that could be used to aid in exempt well identification, since owners would be individuals applying for an exempt well. Discussions concluded ownership was a variable that could aid or hinder identifying exempt wells, but was worth trying to see how it would impact exempt well predictability. Depth was noted to be a poor indicator since it varies by county depending the local geology; therefore, depth was removed from database.

Two versions of exempt well criteria were developed: (1) two criteria applied: diameter and bore method and beneficial use; and (2) three criteria applied: diameter and bore method, beneficial use, and ownership. Table 7 shows the four main elements used to create variables for exempt well criteria. All four elements were gathered from the copies of original well logs. These data for each element were coded into a group for the database. For example, diameter was coded into the database as:

- 1 includes 0.00''-1.99'';
- 2 includes 2.00''-6.00''; and
- 3 includes 6.01''and above.

These groups coded in the database were further broken into sub-groups in order to create the exempt well criteria. As shown in Table 7, the well elements of diameter and bore method were merged to create the variable called Diameter and Bore Method which consisted of sub-groups that aid in predicting exempt wells.

Table 7
Well Elements Used to Create Exempt Criteria Sub-Groups

Well Elements	All Groups Coded in Database	Exempt Criteria Sub-Groups	
Diameter	0.00''-1.99''	Diameter and Bore Variable	• Unknown • 0.00''-1.99''
	2.00''-6.00''		• 2.00''-6.00''
	6.01''and above Unknown (none provided)		• 6.01'' and above
Bore Method	Bored (not hand dug) Unknown (none provided)		• Hand dug
	Hand dug Highly likely to be hand dug		• Highly likely to be hand dug
Use	Domestic	Use Variable	• Domestic
	Stock		• Stock
	Unknown (none provided)		• Unknown
	Irrigation		• Irrigation
	Municipal		• Municipal
	Test Well		• Test Well
	Dewater Environmental Investigation Geotechnical Boring Resource Protection Monitoring Remediation Piezometer Extraction	N/A [1]	
Ownership	Individual	Ownership Variable	• Individual
	Federal		• Federal
	Construction Building Companies		• Construction Building Companies
	Unknown (none provided)		• Unknown
	State		• State
	County		• County
	Local/City		• Local/City
	Private Companies (except construction building)		• Private Companies
	Water District		• Water District

[1] N/A (not applicable) since these uses were filtered out prior to creating exempt criteria sub-groups since these uses are known not to exist for exempt wells. Note if a water well log had a dewatering use the log was filtered out along with resource protection wells.

In Excel 2010 nested if statements were used to create a decision tree process to identify exempt wells. Based on interviews with Ecology discussed in the above section, diameter is the best indicator for an exempt well, followed by beneficial use, and third potentially by ownership. For each version of exempt well criteria (two criteria

version and three criteria version) each criteria was used as a level in order of Ecology's decision of best indicator. For example, under the three criteria version the following levels were created to be addressed in order of influence—diameter and bore, beneficial use, and ownership variables, respectively. Within each level the nested if statements coded the sub-group criteria in order to create a weight of importance between variables. These weights or percent of influence designated to each sub-group where derived from interviews with Ecology. Refer to Table 8 for each variable's sub-group criteria designated influence percent (i.e., how each sub-group was weighted).

Table 8
Exempt Criteria Sub-Groups Designated Influence

Variable	Weight Attached to Each Exempt Well Criteria Sub-Groups [1]				
Diameter and Bore Method	0.95	0.9	0.7	0.5	0.2
	2.00''-6.00''	Hand dug	Highly likely to be hand dug	Unknown	0.00''-1.99'' 6.01'' and above
Use	0.95	0.5	0.10	0.01	--
	Domestic Stock	Unknown	Irrigation	Municipal Test Well	--
Ownership	0.95	0.7	0.5	0.3	0.1
	Individual	Federal Construction Building Companies	Unknown State County Local/City	Private Companies	Water District

[1] Each variables weight was based on responses during open-ended interviews with Ecology

Each weight identified by level (e.g., Diameter and Bore Method, Use, and Ownership) was then multiplied together to create a percentage of likelihood to be an exempt well. For example, case 1 under the three criteria version had 0.95 for diameter and bore method variable times 0.95 for use variable times 0.5 for ownership variable equals 45.13% likelihood of being an exempt well.

Once each well log had exempt well criteria applied to the water well logs and provided an output of percent of likelihood of being exempt, the next step was to divide the percent outputs into groups. Four groups were developed and placed on a scale of

1 to 4 where 1 is highly likely to be exempt to 4 very unlikely to be exempt (personal communication, 2013). Each well log was sorted into a group. The first two groups (highly likely to be exempt and likely to be exempt) were combined for both the three and two criteria versions. These criteria were compared against known exempt wells from within the dataset. The breakdown into the four groups is described in Table 9 below. Of the known 102 exempt wells ("Exempt Well" was marked in water log), the exempt well prediction was 91% accurate and predicted 93 out of 102 known exempt wells using the two criteria approach. Therefore, this is exported to all water wells minus dewatering wells.

Table 9
Exempt Well Likelihood Scale and Description of Scale

Percentage Range	Exempt Well Likelihood Scale	Description of Exempt Well Likelihood Scale
95.0% - 60.0%	1	Highly Likely to be Exempt
59.9% - 25.0%	2	Likely to be Exempt
24.9% - 4.0%	3	Unlikely to be Exempt
3.9% - 0.0%	4	Highly unlikely to be Exempt

COUNTY SUCCESS RANKING

During the open ended-interviews particular counties were listed as more successful in identifying and properly decommissioning exempt water wells. Kitsap County and Pierce County were labeled by Ecology as successful counties in multiple interviews. Thurston County was also considered successful; however, the county declined to participate and recommended Pierce County as a replacement case study. These perceived rankings of county success are used as a dependent variable. Kitsap County and Pierce County are urban counties ranked as successful while Grays Harbor County, Mason County, and Skagit County, rural counties, are considered by Ecology as average. See Table 10 for the coding of the dependent variable of county ranking.

Table 10
Dependent Variable: County Success Ranking

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Success Ranking	Average	High	Average	High	Average
Variable Code	0	1	0	1	0

CONSTRUCTION OF VARIABLES

The second component of the study looks at how policies, collaboration, and economic and demographic dimensions influence how well counties identified and

properly decommissioned exempt water wells. The identification and proper decommissioning of exempt water wells are defined in two different databases. Both the number of exempt water wells decommissioned and the ranking of counties are the dependent variables in this study. Open-ended interviews and general research on each county provided the data in order to construct variables to address each county's policies, collaboration, and economic/demographic indicators.

Policy Variables

Based on open-ended interview data and research into each sample county, nine policy variables were created to compare and contrast differences between the five counties. Below is the description of how each policy variable was constructed and coded in preparation for statistical analysis.

General County Policy Variables

The first general county policy variable is the Delegated Authority Policy variable. Delegated Authority was coded as being a delegated authority or lack of delegated authority (i.e., retention of authority by Ecology). Table 11 shows four counties have delegated authority while Grays Harbor County has not received delegated authority from Ecology. Delegated Authority has three categories: (1) no delegated authority; (2) lacked delegated authority and then received delegation during study period; and (3) had delegated authority throughout.

Table 11
General County Policy Variable: Delegated Authority Policy by County

Variable	Grays Harbor	Kitsap	Mason [1]	Pierce	Skagit
Delegated Authority	--	X	X	X	X
Ecology Retains Authority	X	--	X	--	--
Variable Code [2]	1	3	2	3	3

[1] Mason County did not receive authority from Ecology until October 2008.
[2] Variable Code 0 means the county lacks delegated authority from Ecology. Variable Code 1 means the county has no delegated authority from Ecology. Variable Code 2 means the county both lacked delegation authority of Ecology and received delegation authority within 2001 to 2011. Variable Code 3 means the county has delegated authority from Ecology.

The second general county policy variable is the County Water Well Identification and Decommissioning Policies. This set of policy variables is whether pre-and post-policy analysis of implemented county policies impact on the number for exempt wells decommissioned from 2001 to 2011. This variable is constructed from only the

responses to open-ended interviews about policies currently in place within each county that aid in the identification and decommissioning of water wells and/or exempt wells. Table 12 shows the local policies implemented for water well identification and decommissioning. Grays Harbor and Mason Counties stated they have no policies in place. Further, Mason County did not receive delegation from Ecology until 2008. While Kitsap and Skagit both had existing policies that were put in place during the 1990s. In 2008, Kitsap County added another policy requiring property inspections for all property sales. Pierce County had existing policies that were put in place during the 1990s and then in 2009 the county added an additional local policy.

Table 12
General County Policy Variable: County Water Well Identification and Decommissioning Policies

Year	Grays Harbor	Kitsap	Mason	Pierce	Skagit
2001	Ecology maintains authority over well program	Existing Policies	Ecology maintains authority over well program	Existing Policies	Existing Policies
2002					
2003					
2004					
2005					
2006					
2007					
2008		New Policy Added	No existing policies		
2009				New Policy Added	
2010					
2011					
Variable Code	0	3	2	3	1

All information was based on responses to open-ended interviews with counties

Local Health Jurisdiction Policy Variables

Based from Defriese et al. (1981), Townsend (1986), Hyde and Shortell (2012), and the Board of Health (2004) findings, local health jurisdiction policy variables were constructed to considered variations of local health boards between the case study counties and the influence these local health boards (if any) had on county performance of identifying and properly decommissioning wells. This led to the development of two local health jurisdiction policy variables: (1) the structure of governance and (2) the size of local boards of health. Governance refers to how each county identified their local board as a primary funding source or found the board supportive for the county's well programs.

The first local health jurisdiction policy variable is known as the Health Jurisdiction Governance variable that compares different local health jurisdictions

between the case studies. In Chapter 1, local health jurisdictions are divided between variations of health departments or health districts. Grays Harbor County, Mason County, and Skagit County have health departments where the elected county commissioners make up the local board of health. Pierce County partnered with the City of Tacoma to create a county-city health department and Pierce County's Legislature adopted a home rule charter in order to establish the authority to appoint and elect members of the local board of health in place of the elected county commissioners to comprise the local board of health. Lastly, Kitsap County's Legislature adopted a health district that only covers the incorporated area of the county (i.e., single county district). Table 13 shows each case studies local health jurisdiction.

Table 13
Local Health Jurisdiction Policy: Health Jurisdiction Governance by County

Organization	Grays Harbor	Kitsap	Mason	Pierce [1]	Skagit
Health Department [2]	X	--	X	--	X
Combined City-County Health Department [3]	--	--	--	X	--
Charter County [4]	--	--	--	X	--
Health District (single county) [5]	--	X	--	--	--
Health District (multi county) [5]	--	--	--	--	--
Variable Code	1	2	1	3	1

[1]Pierce County established a home rule charter and partnered with the City of Tacoma to create a health department and elect members of the a local board of health instead of elected county commissioners being the sole members comprising the local board of health.
[2] In 1993, the Health Services Act reorganized the governance structure of health departments within the State by moving authority to counties and removing city representation from local boards of health except by appointment. All jurisdictions under a health department commissioners assigned as the local board of health (MRSC, 2013).
[3]Any city with a population of 100,000 or more and the county in which it is located may merge a combined city and county health department and appoint a director of health (MRSC, 2013).
[4] Under RCW 70.05.035 counties under home rule charter have the authority to establish a local board of health by the county's legislature. The county legislature of these charter counties can determine the terms of office, compensation, and membership criteria for the local board of health. Further, the county legislative authority includes the ability to appoint elected officials from cities, towns, and other non-elected officials as long as the elected officials remain in the majority of the local health board.
[5] Under RCW 70.05 70.46.090 health districts can consist of one to multiple counties. A single county legislature has the authority to pass a resolution or ordinance to organize a health district under RCW 70.05. Health districts of more than one county occur when the boards of commissioners pass a resolution to establish a health district encompassing multiple counties.

The Health Jurisdiction Staffing variable compares the number of members serving on each county's local board of health. Grays Harbor County, Mason County, and Skagit County all have three members serving on the local board of health. While Kitsap and Pierce have a much higher number due to the county's legislature granting

the county the authority to selected local board of health members in addition to the elected county commissioners. Health Jurisdiction Governance (i.e., jurisdiction) and Health Jurisdiction Size (i.e., board count) are directly related since if a county board enacts a county ordinance or resolution the county has the ability to expand and select local health board members. The number of members serving each board were divided into three categories coded 1 for low member numbers to 3 representing a high number of members serving. Boards with 1-5 members were coded as 1, boards with 6-10 members were coded as 2, and boards with more than 10 members were coded as 3. Refer to Table 14 for the construction of Health Jurisdiction Staffing variable.

Table 14
Local Health Jurisdiction Policy: Health Jurisdiction Staffing by County

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Number of Members on Local Board of Health	3	7	3	12	3
Variable Code[1]	1	2	1	3	1

[1] Boards with one to five members were coded as 1, boards with 6-10 members were coded as 2, and boards with 10 and above members were coded as 3.

The Washington State Board of Health (2004) study found that local boards of health often direct the health priorities in a local jurisdiction. Thus, a variable is needed to consider which local boards of health make water wells a priority. Therefore, the last local health jurisdiction policy variable is the Health Jurisdiction Support that identifies the level of support by local jurisdiction of health. It is based on open-ended interview responses. The level of support is coded low to high on a scale of 1 to 3 where 3 is considered a high level of support. These rankings were based on comments about local health board's support on policies and funding directed towards water wells by county employees. In addition, to each county noting level of support within their board of health, they also would comment on other case study counties' local boards. Therefore, each county's support level rank was derived from combining county employees' comments on support level from their health board and the comments from other counties about how supportive the board was with water wells. Table 15 shows each case study county's support level received from the local jurisdiction of health.

Table 15 Local Health Jurisdiction Policy: Health Jurisdiction Support by County					
Variable	**Grays Harbor**	**Kitsap**	**Mason**	**Pierce**	**Skagit**
Support Level[1]	Low	High	Low	High	Medium
Variable Code	1	3	1	3	2
[1] Support Level is based from open-ended interviews. The level of support (low to high) was determined by comments about local health board's support on policies and funding directed towards water wells. In addition, to each county noting level of support other case study counties noted areas with lower and higher levels of support from local health boards. All of this information was combined to create the support level indicator.					

Drinking Water Program Policy Variables

The third policy area constructed variables to assess if a strong drinking water program leads to greater success in identifying and properly decommissioning exempt water wells. Drinking Water Program Policy variables were constructed from research and open-ended interview responses for each county's drinking water program including: (1) what entity has oversight of Group B Water System Programs; and (2) range of staff members within the overall department that oversees the Drinking Water Program (often a wide variety due to budget cuts); and (3) the number of primary Drinking Water Program employees connected to water wells.

The first Drinking Water Program Policy Variable is the Drinking Water Program Oversight Authority. This variable assesses each county's primary entity that has oversight of the Group B Water System Programs, which includes private wells. Grays Harbor County, Kitsap County, Mason County, and Pierce County all have the local health jurisdiction overseeing the Group B Water System Program. Skagit County has a shared oversight of the program between the State (Department of Health) and local health jurisdictions. Table 16 shows each county's oversight authority coding.

Table 16 Drinking Water Program Policy Variable: Drinking Water Program Oversight Authority by County					
Variable	**Grays Harbor**	**Kitsap**	**Mason**	**Pierce**	**Skagit**
Local Health Jurisdiction Oversight	X	X	X	X	--
Shared Oversight	--	--	--	--	X
Variable Code	1	1	1	1	3
Source: WDOH, 2013b					

The Environmental Health Department/District Staffing variable shows a range of staff within the overall department/branch that oversees each county's drinking water programs from 2001 to 2011. This is an important variable, since other county

environmental health programs along with the drinking water program may collaborate with each other. By understanding how large an entire department/branch is within each county, it can accentuate how many additional employees are/could be utilized in identifying and properly decommissioning exempt wells. These numbers are based from county budget books, responses from open-end interviews, and review of online information for each county's oversight department of the drinking water program. The ranges are estimates since not all counties had data about the percentage or number of employees laid-off during budget cuts, and county budget books reporting on staffing were not consistent (i.e., provided annually for each county). Therefore, these ranges were developed by utilizing all the known information about a staffing and creating the lowest and highest ranges based on known information. By using three different sources of information and using the highest and lowest staffing numbers, this is the best approximation to each case study's overall department size that houses the drinking water program. The variable code for Drinking Water Program Staffing has three categorical buckets: small, medium, and large. Each county's highest staff range was used to separate the variable codes. All counties with 10 or fewer staff members are coded small, staff counts from 11 to 30 are medium, and all staff numbers above 30 are large department/branch. Refer to Table 17 for the construction of the Drinking Water Program Staffing variable.

Table 17
Drinking Water Program Policy Variable: Environmental Health Department/District Staffing by County

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Environmental Health Department/Branch [1]	6-10	37-46	9-14	8-13	5-19
Variable Code[2]	1	3	2	2	2

[1] These numbers are based from county budget books, responses from open-end interviews, and review of online information for each county's overseeing department of the drinking water program.
[2] Each county's highest staff range was used to separate the variable code into small, medium, or large. All counties with the number of staff ten and below is considered small (code 1), staff counts between 11 to 30 is considered medium (code 2), and all staff numbers above 31 is considered a large department/branch (code 3).

The Drinking Water Program Well Staffing variable uses the number of primary Drinking Water Program employees connected to water wells. This variable is more well-focused than the Drinking Water Staffing variable and is based on responses from open-end interviews and review of online information about each drinking water

program. The well-staff count is an estimate of the number of staff directly related to water wells within the drinking water program. The estimate further assumes little change of the total number of primary staff members (e.g., manager, point of contact, etc.). Refer to Table 18 for the construction of the Drinking Water Program Policy Variable for Drinking Water Program Well Staffing by County.

Table 18
Drinking Water Program Policy Variable: Drinking Water Program Well Staffing by County

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Primary Drinking Water Program Employees connected to Wells [1]	2	2	2	4	2
Variable Code [2]	1	1	1	2	1

[1] These numbers are based from responses from open-end interviews, and review of online information about each county's drinking water program.
[2] 0-2 primary drinking water staff working with wells is code as 1; 3-4 primary drinking water staff working with wells is code as 2.

The fourth Drinking Water Program Policy Variable is the Drinking Water Program Experience that groups the level of experience each county's primary staff has with the drinking water program and well construction and inspection. The level of experience for each county was constructed from average range of experience documented from primary staff at each county during the open-ended interviews. Mason County is coded as low on experience level with the drinking water program, which means the primary staff has 5 or less years of experience. Grays Harbor County is coded as moderate experience level, which means the primary staff has 6-15 years of experience with the drinking water program and well construction and inspection. Kitsap County, Pierce County, and Skagit County all have primary staff members with significant experience with the drinking water program, which means they have over 15 years of experience. However, Skagit County has a significant experience with the drinking water program with only a moderate experience level on well construction and inspection, while Kitsap County and Pierce County have significant experience with both the drinking water program and well construction and inspection. Refer to Table 19 for the construction of the Drinking Water Program Policy Experience variable.

Table 19
Drinking Water Program Policy Variable: Drinking Water Program Experience by County [1]

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Level of Experience	Moderate	Significant[2]	Low	Significant[2]	Significant[3]
Code	2	3	1	3	2.5

[1] To protect identities of participants each county was coded on an average of all primary staff that participated in the interviews for each county. The code for experience level is low, moderate, or significant years of experience. Low (1) = 5 or less years, Moderate (2)= 6-15 years, Significant (3) = greater than 16 years
[2] Significant experience with drinking water program with a high focus on well construction and inspection
[3]Signifciant experience with drinking water program with a moderate experience level on well construction and inspection

Collaboration Variables

Collaboration is measured using three variables based on McKinney, Scarlett, and Kemmis (2010): catalyst, leadership, and representation (refer to Table 2). Representation was divided into internal and external collaborations, which became the third and fourth collaboration variables. The fifth variable was based on state and county participant's responses when asked to rate the degree of collaboration that occurs to aid in identifying and decommissioning exempt water wells that created the county collaboration indicator. The function of the fifth variable (Collaboration Assessment) is to have a check on understanding the level of collaboration occurring within each county. The first four variables that are identified by McKinney, Scarlett, and Kemmis (2010) and represent one approach to looking at collaboration and the fifth (Collaboration Assessment) is based from each county's own perspective of how well they are collaborating. Based on open-ended interview data and research for each sample county, five collaboration variables were created to compare and contrast differences between the five counties. Below is the description of how each collaboration variable was constructed and coded in preparation for statistical analysis.

Catalyst Collaboration Variable

The Catalyst Collaboration variable was based on the responses from county participants when asked if they felt it was a problem to have abandoned or unknown wells not properly decommissioned. A scale of 1 to 5 is used, where 1 represents the county did not recognize a collaboration problem and 5 in which the county felt better collaboration was a problem should be improved. Refer to Table 20 for the construction of the Catalyst Collaboration variable.

Table 20
Collaboration Variable: Catalyst Collaboration by County [1]

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Is there a problem?	Not Really	Significant	A Problem	Significant	Significant

Table 20 Collaboration Variable: Catalyst Collaboration by County [1]					
Variable	**Grays Harbor**	**Kitsap**	**Mason**	**Pierce**	**Skagit**
		Problem		Problem	Problem
Variable Code [2]	2	4	3	4	4

[1] Based on interview responses to if not identifying and properly decommissioning water wells is considered a problem.
[2] A scale of 1 to 5 was used were 1 represents the county stated there is no problem to 5 which the county felt like it was a huge problem that should be the main problem the county must work on improving.

Leadership Collaboration Variable

The county Leadership Collaboration variable was based on interviews with county leaders. It rates the ability to lead based on the presence of vision, trust, technical skill (i.e., experience), working with others to solve problems, and examples of active leadership taken between 2001 through 2011. Refer to Table 21 for the construction of the Leadership Collaboration variable.

Table 21 Collaboration Variable: Leadership Collaboration[1]					
Variable	**Grays Harbor**	**Kitsap**	**Mason**	**Pierce**	**Skagit**
Leadership	High Leadership	Very High Leadership	Low Leadership	Moderate Leadership	High Leadership
Variable Code [2]	4	5	2	3	4

[1] Based on interviews and each county was provided a score of ability to lead. This score was developed based on the presence of vision, trust, examples of leadership action in between 2001-2011, technical skill (i.e., experience), and working with others to solve problems.
[2] A scale of 1 to 5 was used were 1 represents a low level to provide leadership to 5 where a high degree of leadership skills and abilities are present and put to action.

Representation Collaboration Variables

The Representation Collaboration Variable is constructed based on participants' responses when asked to list whom and what type of groups or individuals they collaborate with to support well identification and proper decommissioning. The Representation Collaboration Variable is based on interview responses listing significant internal (within water program/department) and external (all other departments/agencies, well drillers, other stakeholders) representation to aid identifying and decommissioning water wells. A scale of 1-5 was developed where 1 is 1 or 0 connections (representation of other programs, departments, agencies) to 5 where five or more connections known. The Representation Collaboration Variable is separated into two variables: Internal Representation Collaboration (internal) and External Representation Collaboration

(external). Refer to Table 22 for the construction of the Internal Representation Collaboration variable.

Table 22
Collaboration Variable: Internal Representation Collaboration by County[1]

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
Internal	1	5	4	6	5
Variable Code [2]	1	5	4	5	5

[1] Based on interviews and each county was provided a score of ability to lead. This score was developed based on the presence of vision, trust, examples of leadership action in between 2001-2011, technical skill (i.e., experience), and working with others to solve problems.
[2] A scale of 1-5 was developed where 1 has one or zero connections (representation of other programs, departments, agencies) to 5 where five or more connections known.

Refer to Table 23 for the construction of the External Representation Collaboration variable.

Table 23
Collaboration Variable: External Representation Collaboration by County [1]

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
External	0	7	2	4	3
Variable Code [2]	1	5	2	4	3

[1] Based on interviews and each county was provided a score of ability to lead. This score was developed based on the presence of vision, trust, examples of leadership action in between 2001-2011, technical skill (i.e., experience), and working with others to solve problems.
[2] A scale of 1-5 was developed where 1 has one or zero connections (representation of other programs, departments, agencies) to 5 where five or more connections known.

Collaboration Assessment Variable

The Collaboration Assessment variable is based on state and county participant's responses when asked to rate the degree of collaboration that occurs to aid in identifying and decommissioning exempt water wells, which created the county collaboration indicator. This is a second approach to understanding the level of collaboration that is occurring within each county from the perspective of the county staff who participated in interviews. Refer to Table 24 for the construction of the Collaboration Assessment variable.

Table 24
Collaboration Policy Variable: Collaboration Assessment by County [1]

Variable	Grays Harbor	Kitsap	Mason	Pierce	Skagit
External	2	5	2	4	3
Variable Code [2]	2	5	2	4	3

[1] Based on interview responses on how they ranked their county's level of collaboration
[2] A scale of 1-5 was developed where 1 is low collaboration to 5 with a high degree of collaboration.

Social-Economic Variables

The social-economic variables are used to look for patterns between counties and within counties over a temporal scale. Based on the Willard, Shah, Leep, and Leighton (2012) study, the influence of the economic landscape is an important consideration. Economic conditions have the potential to influence the ability or desire of agencies, well drillers, and well owners to identify and properly decommission wells. A snap shot of the economic landscape from 2001 to 2011 was made through median household income and the number of building permits approved. Also, based on demographics used by the Benton County Water Project (2008) the landscape pattern of low population density (rural) to high population density is an important variable to consider. To include an urban-rural classification variable, the Rural-Urban Commuting Area (RUCA) System was chosen to construct the urban-rural classification variable (WDOH, 2009). The US Department of Agriculture and Health and Human Services along with the WWAMI Rural Health Research Center constructed this coding system in the 1990s. The classification is based on census tract or zip code data instead of a blanket approach covering one county like most classification systems (WDOH, 2009). RUCA System has ten primary codes, which can be further sub-divided in multiple ways to target the desired level of scale. The ten primary codes fall into four general classification: (1) Metropolitan (urban); (2) Micropolitan (large rural town); (3) Small Rural Town; and (4) Isolated Rural (WDOH, 2009). Based from the counties over all cumulative group of these four general classifications, Pierce and Kitsap Counties are Micropolitan (both high density urban and rural present within counties) and the remaining three counties fell into small rural town since the counties are mostly rural areas with little dense, urbanization present.

In addition, to population density and population size, the wealth of the area may influence local boards of health or departments priorities; therefore; median county household income is compared. The social-economic data come from U.S. census and Washington Revenue Department. While some of the data are actually based on U.S. Census years, the remaining years are estimates provided by the agencies. The last social-economic variable utilized was the present or absence of a recession. Each year

was coded as a recession or non-recession year. While the recession officially started in the end of 2007 and went through June 2009, this study coded 2007, 2008, and 2009 as recession years and 2001-2006 and 2010-2011 as non-recession years. The

Summary of Constructed Variables

Twenty-one independent variables were constructed to assess potential influences on the identification and decommissioning of exempt water wells. Table 25 provides a summary of all twenty-one variables. Table 25 has nine policy, 5 collaboration, and 7 demographic/economic variables.

The constructed variables were used not only to look at a wide variety of potential factors, but to measure the same factor from multiple angles. For example, the Local Health Jurisdiction Policy variables all are constructed to measure the influence of local health jurisdiction by measuring the type of governance (e.g., local heath board, health, district, and health charter), the number of staff, and the perceived level of support from the jurisdiction. Nine policy variables were constructed to assess the potential influence of local health jurisdictions, drinking water programs, general county policies. These policy variables were constructed with guidance from the literature as possible factors in the identification and decommissioning of exempt water wells (Defriese et al., 1981; Townsend, 1986; Hyde and Shortell, 2012; and WBOH, 2004). Five collaboration variables were used to measure the presences of a catalyst, leadership, and representation based from McKinney, Scarlett, and Kemmis (2010) regional landscape collaboration framework. Seven social-economic variables were constructed to determine if the identification and decommissioning of exempt wells is correlated and influences to economic and demographic factors (Willard, Shah, Leep, and Leighton, 2012; Benton County, 2008).

Table 25
Summary of Independent Variables

Independent Variables		Summary of Variable Description
Policy Variables	General County Policy Variables	
	Delegated Authority Policy	Divides counties into groups that received delegated authority for Ecology's well decommissioning program prior to 2001, counties that received delegated authority from 2001 - 2011, and counties that Ecology maintains control
	County Water Well Identification and Decommissioning Policies	Temporal variable constructed to measure pre-/post-policy implementation(s) of exempt well decommissioning at the county level
	Local Health Jurisdiction Policy Variables	
	Health Jurisdiction Governance	Separates counties by type of local health jurisdictions
	Health Jurisdiction Staffing	Number of members serving on each county's local health jurisdictions (e.g., board, district)
	Health Jurisdiction Support	Level of support by local health jurisdictions
	Drinking Water Program Policy Variables	
	Drinking Water Program Oversight Authority	Divides counties by the entity that has oversight of county's Group B Water System Program
	Environmental Health Department/Branch Staffing	Number of staff active at Environmental Health Department/Branch
	Drinking Water Program Well Staffing	Number of primary Drinking Water Program staff directly working with water wells
	Drinking Water Program Experience	Level of experience primary staff has with drinking water program and well construction and inspection
Collaboration Variables	Catalyst Collaboration	Presence of a problem: Is it an issue to not properly decommissioned or leave unidentified wells open
	Leadership Collaboration	Presence of vision, trust, technical skill, working with others to solve problems, and examples of active leadership taken between 2001 through 2011
	Internal Representation Collaboration	Number of internal and external representation to aid identifying and decommissioning water wells.
	External Representation Collaboration	
	Collaboration Assessment	Rank of collaboration that occurs to aid in identifying and decommissioning exempt water wells
Social-Economic Variables	Medium Income	Measure county wealth by year
	Number of Housing Permits Granted	Number of privately owned-residential building permits (modification or new development) that received approval by year
	Population	Total population by year
	Population Density	Total population divided by the county's total area by year
	Pre/Post Recession	Divides years into two groups: pre-recession (2001-2007) and all years after 2008
	Recession Years	Divided year into two groups: recession years (2008 and 2009) and non-recession years (2001-2007; 2010-2011)
	Urban-Rural Classification	Aggregation of delineated areas within each county was identified as urban or rural based on the RUCA System

CHAPTER 4. EXEMPT WELL DATA ANALYSIS

Chapter 4 is divided into two sections. The first section provides an analysis of exempt well data log records used to develop the exempt well criteria and the success of the exempt well's predictability criteria developed to determine exempt wells from other well types. The first section's information is based on a database with 671 total cases (decommissioned n= 286 and drilled n= 385) to determine of these decommissioned (and drilled) water wells which cases are exempt wells. This database is referred to as the Exempt Well Criteria Database. All of the information within the Exempt Well Criteria Section below is from this database. The second section analyzes exempt well data by drilled, decommissioned, county, and year. This second database, referred to as the County and Year Database, was created after the exempt well criteria was applied and has 55 cases representing exempt wells decommissioned for each county by year. Five counties times the eleven year study period creates the 55 cases within the database to conduct comparisons between counties and years. Statistical Package for the Social Sciences (SPSS) is the software package used for all statistical analysis for both databases.

EXEMPT WELL CRITERIA

As discussed in Chapter 3, exempt well criteria were constructed to focus solely on identification of the wells most likely to be exempt wells. Therefore, a random sample from each county was taken. The sample included water resource protection wells and water wells for the decommissioned database.

Table 26
Total Number of Log Records for All Decommissioned Wells [a] (Washington Department of Ecology data)

Year	Grays Harbor	Kitsap	Mason	Pierce	Skagit
2001	25	121	12	270	44
2002	23	113	39	295	43
2003	87	120	9	395	56
2004	21	149	9	339	31
2005	83	172	14	422	93
2006	56	460	39	521	120
2007	176	408	103	1770	174
2008	120	621	68	1602	510
2009	722	359	78	1529	579
2010	169	498	190	1648	232
2011	275	538	80	2304	401
Total	1,757	3,559	641	11,095	2,283

[a] Log records include water protection wells, permitted wells, and exempt wells

Table 26 shows the total number of log records for all decommissioned wells and Figure 8 shows the same information graphically. It becomes clear the overall trend for all decommissioned well log records is a general trend to increase over time that is dominated by increases from Pierce County. Pierce County has the highest increase from below 500 to above 2,000 log records of decommissioned wells from 2001 to 2011. Pierce County decommissioned a very large number of dewatering wells during these years. The other counties look very similar within the study period as seen in Figure 8.

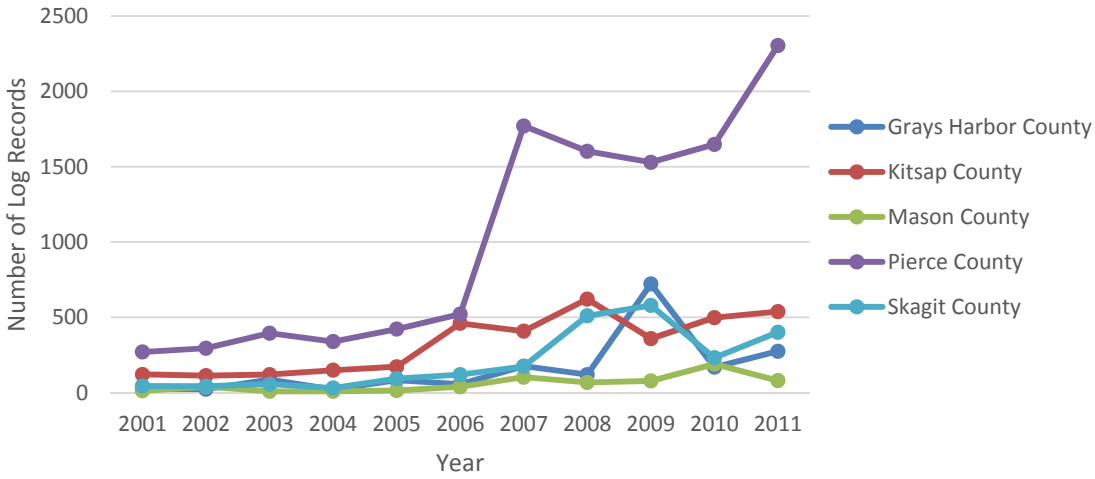

Figure 8. Total Number of Log Records for All Decommissioned Wells shows a general trend of increasing in the total number of decommissioned well logs.

Once the exempt well criteria were applied, a verification of the accuracy of the criteria was tested. This was done by comparing against known exempt wells identified within the random sample while reviewing each well log submitted to Ecology. The two criteria version accurately predicted 91% of the known exempt wells, while the three criteria version (ownership variable included) predicted only 81% of the known exempt wells. Therefore, the two criteria version was applied to the entire sample population for both drilled and decommissioned databases to get an estimate of exempt wells. The ability to predict 91% of the known exempt wells, still means an under-representation of

exempt wells in the total database. Any bias is to predict fewer than the actual number of exempt wells.

Table 27 shows by county the percentages of exempt water wells for both decommissioned and drilled. From a total sample size for decommissioned (n=286) and drilled (n=385) from the Exempt Well Criteria Database, all counties combined had 80.8% of exempt wells decommissioned and 96.9% exempt wells were drilled. During interviews and general information provided from Ecology, the drilled estimate of exempt wells was often quoted at 95%. Through this sample size and exempt well criteria, the 96.9% of drilled water wells are exempt; therefore, the estimate is within range of previous drilled estimates. Exempt wells being drilled are often used to provide water for new rural residential subdivisions.

The decommissioned exempt well ratio is lower for decommissioned exempt wells (80.8%). While previous estimates were discussed on a narrative level for exempt well decommissioning, there currently is a lack of information on how many water wells being decommissioned are exempt. This finding, using the exempt well criteria defined in this study, provides an estimate of how many exempt wells are being decommissioned within Washington. Based on this analysis 80.8% of water wells being decommissioned (excluding dewatering wells) are exempt wells. This is a useful number since it finally provides regulators and policy staff an idea of how many of the wells are identified as exempt. It is known there is a high volume of exempt wells across the landscape within Washington, and the 80.8% leaves room for improvement in identifying and decommissioning these wells, since in recent times around 96.9% of all newly drilled water wells are exempt. Table 27 shows the range of exempt wells in the decommissioned group varies by about 20% between the highest and lowest counties where Pierce County is the lowest (68.3%) and Kitsap County with the highest amount of decommissioned wells (89.0%).

Table 27
County Percentages of Exempt and Permitted Water Wells for Both Decommissioned and Drilled

County	Decommissioned (n=286)	Drilled (n=385)
	Exempt[1]	Exempt[1]
Gray Harbor	80.0	98.0
Kitsap	89.0	97.9
Mason	75.0	95.0
Pierce	68.3	100.0

Table 27 County Percentages of Exempt and Permitted Water Wells for Both Decommissioned and Drilled		
County	Decommissioned (n=286)	Drilled (n=385)
	Exempt[1]	Exempt[1]
Skagit	87.5	93.9
Totals	*80.8*	*96.9*
[1]Cell entries are percentages (%) of exempt wells out of all water wells except for dewatering wells		

To further breakdown these data from the Exempt Well Criteria Database, Table 28 merged all counties together by year and shows the count and percentages of exempt water wells for both decommissioned and drilled groups. As seen in the table the yearly n size ranges from 7 to 53. The percentages for decommissioned exempt wells range of 66.7% to 100.00% and exempt drilled range from 87.5% to 100%.

Table 28 General Summary of Combine County Database of Decommissioned and Drilled Wells				
Year	Decommissioned (n=286)		Drilled (n=385)	
	Exempt		Exempt[1]	
	Count	Percent[1]	Count	Percent[1]
2001	12	70.6	38	97.4
2002	19	70.4	31	96.9
2003	24	82.8	42	93.3
2004	23	85.2	51	98.1
2005	24	80.0	53	98.1
2006	28	80.0	48	96.0
2007	31	79.5	46	95.8
2008	27	96.4	26	100.0
2009	16	100.0	18	100.0
2010	13	76.5	7	87.5
2011	14	66.7	13	100.0
Sum	231	80.8	373	96.9
[1]Cell entries are percentages (%) of exempt wells out of all water wells except for dewatering wells				

Figure 9, shows the change in percentages of decommissioned exempt wells across all counties from 2001 to 2011. With all the counties combined the total percentage of exempt wells being decommissioned shows an increase for 2008-2009. There is a very slight increase in the ratio of exempt wells being decommissioned each year across all five counties as shown in the blue dotted trend-line in Figure 9.

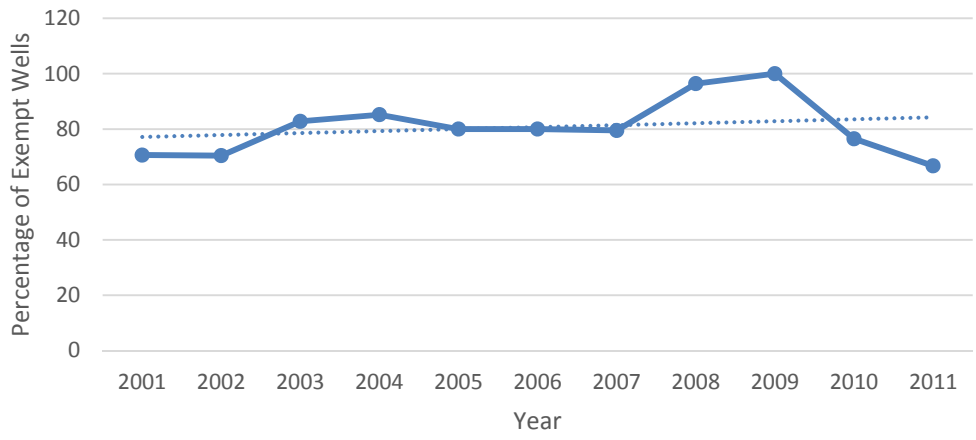

Figure 9. Percentage of Exempt Wells Decommissioned per Year across All Counties shows little variation in the percentage of exempt wells over the study period

Figure 10, shows the change in percentages of drilled exempt wells across all counties from 2001 to 2011. During the study period, the percentage of drilled wells out of the total water wells (minus dewatering wells) is mostly exempt wells (refer to Figure 10). This makes sense since many areas within Washington are over allocated in water availability and new development relies predominantly on exempt wells in order to secure water sources. This curve shows no significant increase or decrease over time.

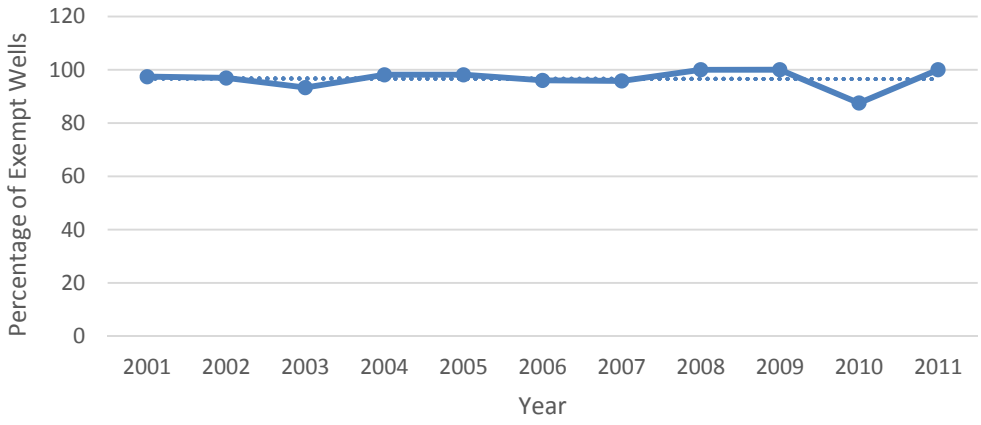

Figure 10. Percentage of exempt wells drilled per year across all counties shows little variation in the percentage of exempt wells drilled during the study period

EXEMPT WELL DATA COMPARISONS BY COUNTY AND YEAR

To compare between counties and by year the County and Year Database data was used to compare the ratio of exempt wells drilled and decommissioned by year from 2001 through 2011 (refer to Figures 11 through 15). The main purpose of the County and Year Database was to identify local policies (temporal and non-temporal), collaboration, and/or economic and demographic factors influence exempt well decommissioning. This database had a case for every year for each case study county along with all of the constructed variables developed for each county and/or year. It is important to note that each county is equally weighted. A quota random sample of each county represents the county taking out the effects of population size and county area. Figure 11 shows Grays Harbor County increased in the amount of exempt well decommissioning from 2001 to 2011. The main increase occurred from 2001 to 2004 and the then after 2006 exempt well decommissioning stabilized at 100% decommissioning. Overall the amount of drilled exempt wells remains predominantly unchanged.

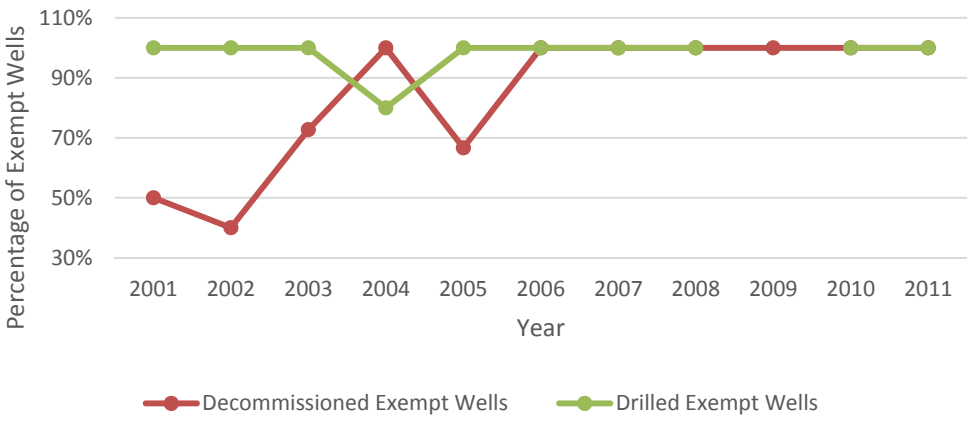

Figure 11. Grays Harbor County: Percentage of Exempt Wells Drilled and Decommissioned by Year

Figure 12 shows Kitsap County increased in the amount of exempt well decommissioning from 2001 to 2011. The main increase occurred from 2001 to 2007 and the then after 2009 exempt well decommissioning stabilized at 100% decommissioning. Overall the amount of drilled exempt wells remains unchanged.

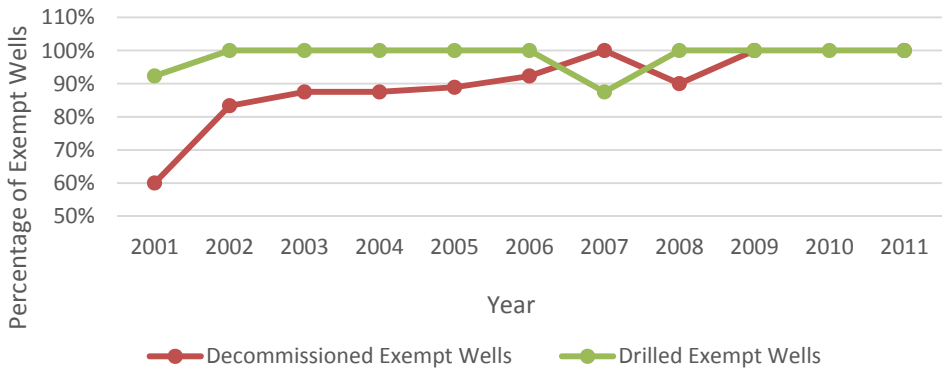

Figure 12. Kitsap County: Percentage of Exempt Wells Drilled and Decommissioned by Year

Figure 13 shows Mason County has considerable variation in exempt well decommissioning from 2001 to 2011, but no pattern of increase or decrease is indicated. The county experienced high exempt well decommissioning in 2002, 2003, 2006, and 2008-2010 and low rates of decommissioning in 2004 and 2007. Mason County has a wider range in the rate of drilling throughout the study period and the county experienced a large drops in drilled exempt wells in 2004, 2007, and 2011.

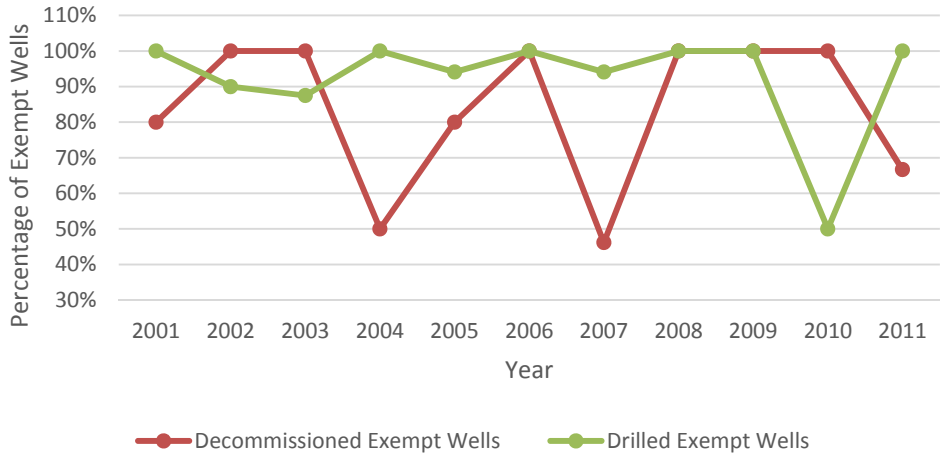

Figure 13. Mason County: Percentage of Exempt Wells Drilled and Decommissioned by Year

Figure 14 shows Pierce County generally increased in the amount of exempt well decommissioning from 2001 to 2009 and then experienced a significant drop in 2010 to 2011. Pierce County has a high rate of drilled exempt wells (100%), while the decommissioning of the exempt wells has more variation with a range from 25% to 100% during the eleven-year study period.

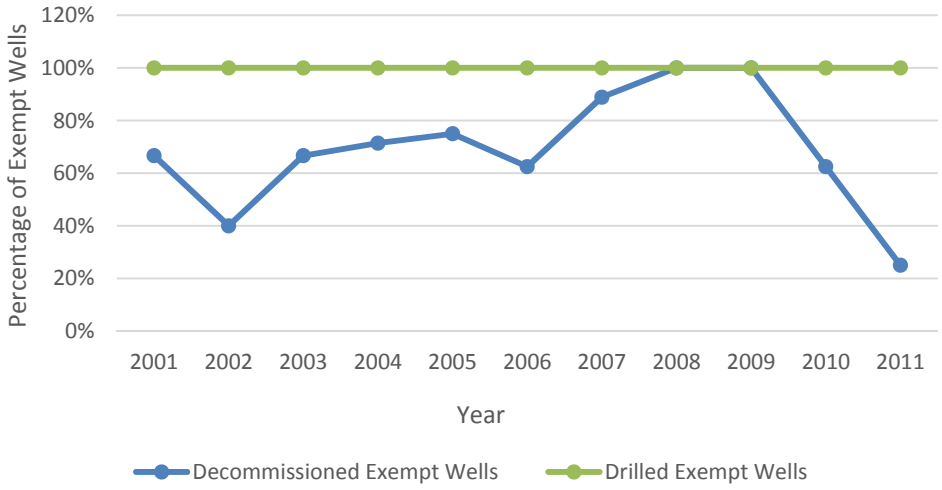

Figure 14. Pierce County: Percentage of Exempt Wells Drilled and Decommissioned by Year

Figure 15 shows Skagit County, like Mason County, experienced variation in exempt well decommissioning from 2001 to 2011. The county experienced high exempt well decommissioning in 2001, 2004 – 2005, and 2007-2009 and low rates of decommissioning in 2006 and 2010-2011. Mason County drilled exempt wells remain fairly consistent except for two drops in exempt well drilling in 2003 and 2006.

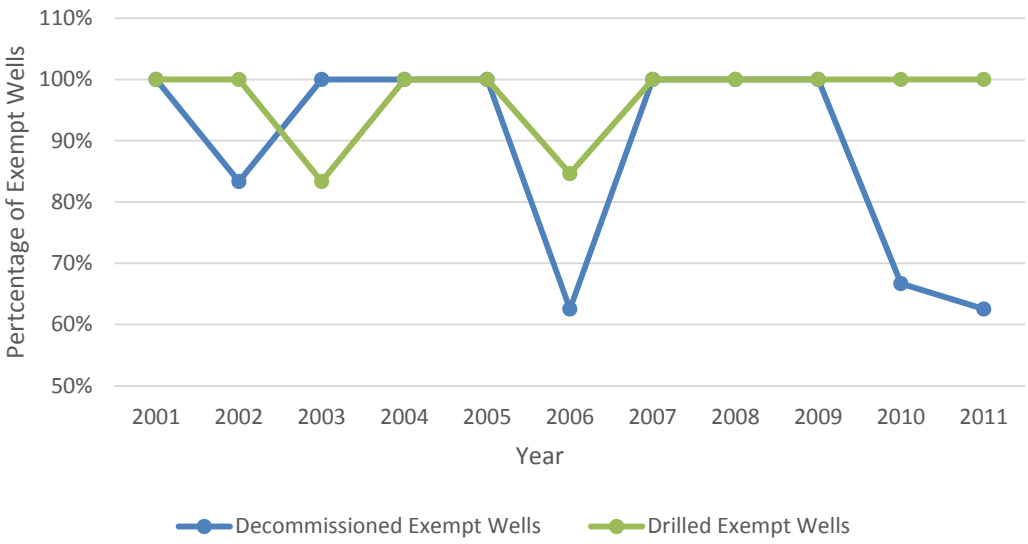

Figure 15. Skagit County: Percentage of Exempt Wells Drilled and Decommissioned by Year

As Figures 11 through 15 demonstrate each county has its own pattern of variation in the percentage of exempt well decommissioning during the study period. It is important to note based from these data there is no relationship between drilled and decommissioned exempt wells during the study period. This is expected since different drivers are creating the need for new exempt wells to be drilled versus the need to decommission existing exempt wells. Overall, drilled exempt wells account for most of each county's new drilled water wells, while there is more variation for decommissioning of exempt wells. The temporal scale across all five counties' exempt well decommissioning ratios were compared. Figure 16 shows all five county's decommissioning percentages. These data show no positive or negative correlation between the counties. The random sample allows the comparison between counties although the small sample size could skew results; however, there is no pattern associated with exempt well decommissioning.

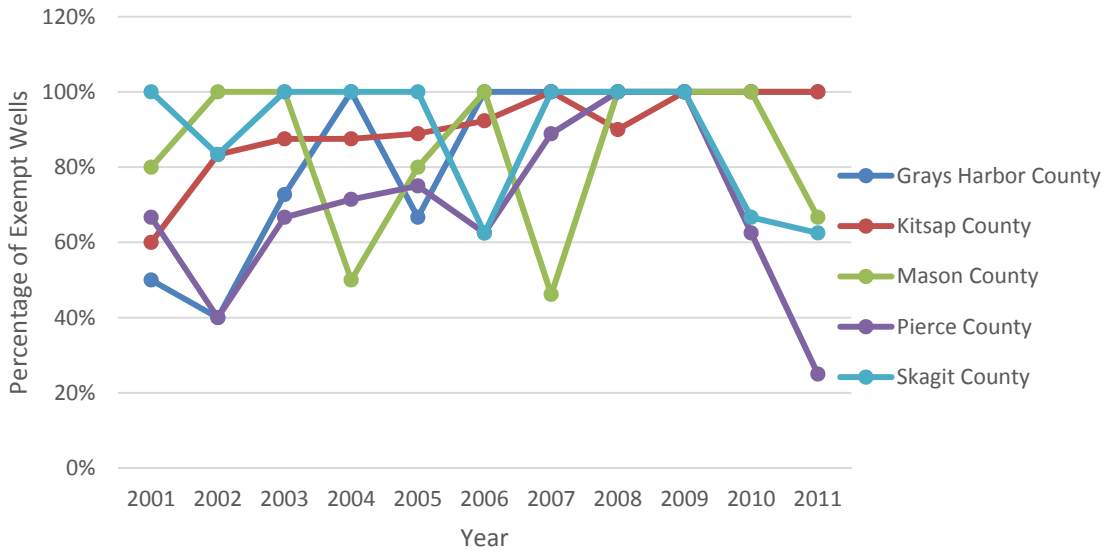

Figure 16. Percentage of Exempt Wells Decommissioned per Year for Each Case Study County

Figure 17. Percentage of Exempt Wells Drilled Per Year for Each Case Study County

No pattern of growth or decline in exempt well decommissioning is apparent and the lack of variation among the counties is shown in Figure 18.

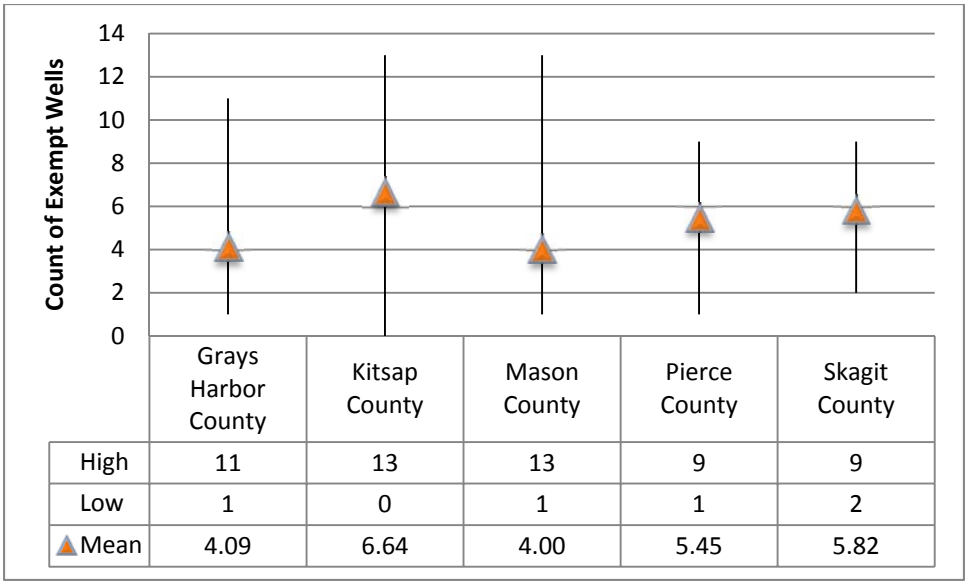

Figure 18. Lack of Variation Between Counties for Exempt Well Decommissioning

SUMMARY

The exempt well criteria has a 91% success rate in predicting exempt wells. This was corroborated by having very similar percentages of drilled exempt wells provided through other estimates. This criteria could be applied on a broader scale since all of the criteria variables are not regionally specific; therefore, this criteria could help predict the number of exempt wells in other counties, states, or potentially countries.

Neither exempt well decommissioning nor exempt well drilling shows a pattern of growth. The drilling of exempt wells becomes nearly 100% of all wells drilled and is growing in the ratio of wells drilled during the 2001-2011 time period. This shows that exempt well issues will continue in the future within the State. During the recession years, when home construction is low, from 2008-2011, fewer exempt wells are drilled. This drop points to the use of exempt wells to provide water for rural residential development.

CHAPTER 5. VARIABLE ANALYSIS

A statistical analysis of the policy, collaboration, and social-economic variables that could explain exempt well decommissioning was conducted. Two databases were constructed. One was actual and predicted exempt wells decommissioned in the sample counties from 2001-2011. This database had 286 cases for decommissioned wells, and the other was by county with the ratio of exempt wells decommissioned by year. This database had 55 cases. The first section discusses the process of sampling and the outcomes from both these databases. The second portion of this chapter describes the themes that were suggested by the statistical analyses.

SAMPLING

Chapter 3 Methods outlined the utilization of a simple random sample for all water well logs to ensure each log record had the same probability of being selected from the overall population within each county. Therefore, the simple random sample of each county's total decommissioned well log records are representative of the population (i.e., decommissioned wells). Of course there is sampling error present since the sample is limited in its power to perfectly describe the total well population and since only some of the well log records were sampled (Dillman, 2000). Table 29 shows the total number of decommissioned well logs Ecology maintains within each sample county from 2001 through 2011. As seen in the table, the number of known and predicted exempt wells is a small sub-population within the decommissioned well logs. Grays Harbor County sample includes all logs and even then only 2.1% of 1,751 decommissioned well logs fall within the actual and predicted exempt well criteria.

The actual and predicted decommissioned exempt wells for each county provided a database in which the decommissioning of exempt wells could be evaluated over time. In order to remove the influence of county size (population and area), the random sample had a target of around 60 exempt wells for each county (i.e., quota sample). Since exempt wells had to be predicted for a majority of exempt well logs that were not known exempt wells, the quota sample had to be larger than the estimated number of exempt wells. Quota sampling gives each county equal weight in terms of decommissioned wells (Bernard, 2002). These quota samples for decommissioned

wells within each county are designed to be a representative reflection of the subpopulation's actual and predicted exempt wells in each county (Bernard, 2002).

Table 29
Summary of Sample Size of Decommissioned Wells by County Between 2001-2011

County	Total Logs	Sample Size (n) [1]	Sample as of Total Logs [2]	Known and Predicted Exempt Wells Percent of Total Sample Size
Grays Harbor	1,751	1,751	100.0%	2.1%
Kitsap	3,613	265	7.3%	24.5%
Mason	542	317	58.5%	10.4%
Pierce	11,057	1,000	9.0%	4.1%
Skagit	2,274	898	39.5%	6.2%

[1] Sample Size was based on reaching approximately 60 potential exempt well logs
[2] Percentage of sample out of total population (total logs)

Once each county's exempt well sub-population was identified these data were compared between counties since the sampling method removed the influence of each county's different size in both area and population. Assuming truly representative samples for each county, this allowed all five counties to be compared. Table 29 shows that Kitsap had the highest percentage of exempt wells of the total wells decommissioned, followed by Mason. An initial hypothesis was that the two urban counties, Kitsap and Pierce, might have similar patterns, while the two rural counties Mason and Skagit would be similar. Grays Harbor should be different from both rural and urban because it was not involved with Ecology. No such patterns emerged either looking at Figure 19 or in statistical analyses.

Each county's yearly number of exempt wells decommissioned was divided by the total number of exempt wells decommissioned within each county during the study period (Figure 19). A larger variation among counties was expected since certain counties are perceived as more successful and a wide range of policies, collaboration, and other local factors exist within each county throughout the study period. Further, a trend toward higher percentage of exempt well decommissioning would reflect the impact of programs and policies established either in counties or by Ecology and state law. Figure 18 and 19 suggests that neither of these patterns occurred. A statistical analysis comparing counties, yielded limited significant results (Table 30).

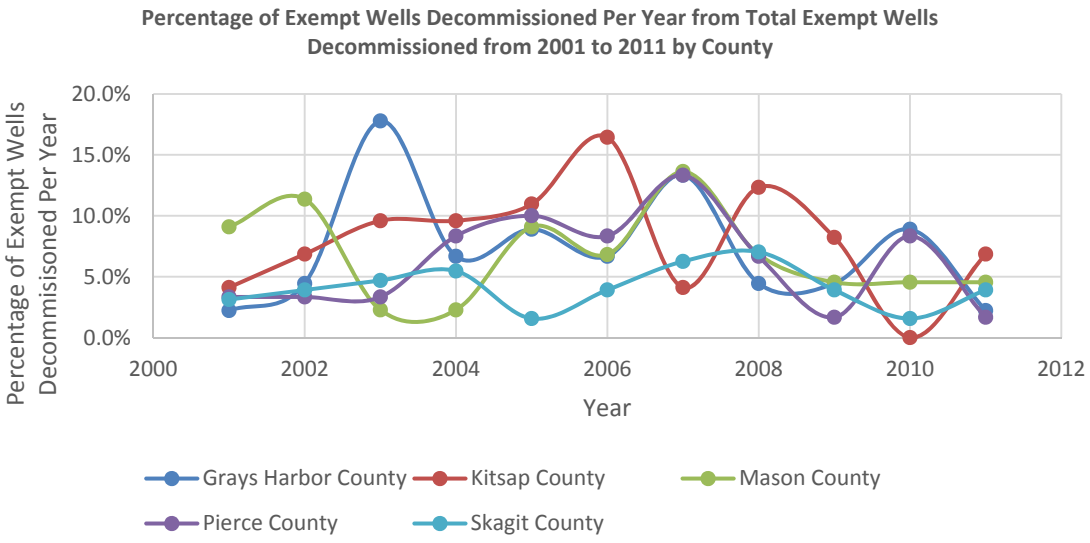

Figure 19. Percentage of Exempt Wells Decommissioned Per Year from Total Exempt Wells Decommissioned from 2001 to 2011 by County

The outcomes of little variation between counties and no temporal pattern suggests that well decommissioning does not vary by urban versus rural county, and should be looked at from a broader perspective since each county had many unique, local attributes that failed to highlight more successful counties from the others. Analysis of all of the independent variables with two data bases (one with exempt wells by year for the five counties and one with the five counties) were analyzed to see if any variables could aid in understanding what themes might need to be considered when dealing with wells from a regional or some other broader perspective.

VARIABLES

Based on open-ended interview data, policy variables were created to identify relationships between the counties and annual exempt well decommission patterns. Chi-square tests were used to determine if there were any relationships between the variables, along with the Likelihood Ratio, since it is best for small sample sizes. Chi-square *p*-value lacks enough information about the strength or nature of the relationship between the variables therefore effect size is included (Cramer's V-effect size). Effect size is interpreted as minimal, typical, or substantial (Vaske, 2008). Also, correlations, pattern analysis, and OLS regressions were run on variables to determine influences on

exempt well decommissioning. Pattern analysis was used predominantly on the economic data. Prior to the regression analysis, a correlation was completed. Spearman's rho was selected since it does well with small sample sizes compared to Pearson's. The two main purposes of the Spearman's rho correlation (nonparametric) was to measure the strength of association (i.e., effect size) and to determine if a relationship exist between variables. While correlation provides information on if a relationship is present it does not inform which variables influence the dependent variable. The OLS regression uses the significant variables from the correlation to assess which independent variable(s) can best explain the dependent variable (percentage of exempt wells). The policy, collaboration, and economic/demographic variables analysis was conducted and Table 30 shows which variables were significant. The purpose of Table 30 is to provide snapshot of which variables emerged as significant.

Table 30
Summary of Independent Variables Identified to be Significant by Percentage of Exempt Wells Decommissioned Each Year

Independent Variables		Significant Relationship Present with Percentage of Exempt		
		Chi-square test [1]	Spearman's rho Correlation [2]	OLS Regression[2]
Policy Variables	General County Policy Variables			
	Delegated Authority Policy	--	--	--
	County Water Well Identification and Decommissioning Policies	N/A	--	--
	Local Health Jurisdiction Policy Variables			
	Health Jurisdiction Governance	X	X	X
	Health Jurisdiction Staffing	X	X	
	Health Jurisdiction Support	--	--	--
	Drinking Water Program Policy Variables			
	Drinking Water Program Oversight Authority	--	--	--
	Environmental Health Department/Branch Staffing	--	--	--
	Drinking Water Program Well Staffing	X	X	--
	Drinking Water Program Experience	--	--	--
Collaboration Variables	Catalyst Collaboration	--	--	--
	Leadership Collaboration	--	--	--
	Internal Representation Collaboration	--	--	--
	External Representation Collaboration	X	--	--
	Collaboration Assessment	X	--	--
Economic Variables	Medium Income	N/A	--	--
	Number of Housing Permits Granted	N/A	X	--
	Population	N/A	X	--
	Population Density	N/A	--	--
	Pre/Post Recession	N/A	--	--
	Recession Years	N/A	X	X
	Urban/Rural Classification	N/A	--	--

[1] Temporal analysis by county per year (n=286)
[2] Temporal analysis was conducted by county where all years were represented within county (n=55)
N/A = Not Applicable (no analysis was conducted for variable)
X = Significance at a 0.05 or 0.01 level
-- = Not significant (greater than 0.05)

Based on these results, some common themes emerge. The rural-urban relationship did not explain success in decommission wells. The health jurisdiction, drinking water staffing size, external collaboration, housing permits, county population, and if a recession is present variable all had a connection to the percentage of exempt

wells for counties by year and/or for all years combined per county. However, the OLS regression only found the health jurisdiction and recession year independent variables explained the percentage of exempt wells on a temporal scale as seen in Table 31. However, these variables only explain less than a quarter of the variance (R^2=0.219).

Table 31
OLS Regression Results for Percentage of Exempt Wells Decommissioned

Variables	R	R^2	Beta (unstandardized)	Std. Error	Significance
Recession Year	.468	.219	16.861	5.569	.004
Local Health Jurisdiction (Governance and Staffing Size) [1]			-7.053	3.097	.027

[1] Local Health Jurisdiction Governance and Local Health Jurisdiction Staff are directly linked. The type of governance chosen by local heath jurisdictions determine the number of staff hired. Therefore, in OLS regression the only combination of variables that explain the percentage of exempt well decommissioning per year within each county is Recession Year and Local Health Jurisdiction Governance or Recession Year and Local Health Jurisdiction Staffing.

Ecology's Success Ranking independent variable was used to look at correlations among independent variables in a county-oriented database. Spearman's rho correlation for Ecology's Success Ranking found significant relationships for many of the variables at a 0.01 significance level (refer to Table 32). This large number of independent variables determined to have a significant relationship compared to only six variables with the percentage of exempt may be due to perceptions. It is thought that if a county has more policies, more construction, a better drinking water program, and highly involved local health jurisdiction, then the county is perceived as highly successful in exempt well decommissioning. However, the differences between the two dependent variables show that none of these factors explain exempt well decommissioning other than the Local Health Jurisdiction Governance and Staffing and if a recession is present/absent.

Table 32 Summary of Independent Variables Identified to be Significant by Ecology's County Success Ranking		
Independent Variables		**Significant Relationship Present with Ecology's Success Ranking**
		Spearman's rho Correlation
Policy Variables	General County Policy Variables	
	Delegated Authority Policy	.000
	County Water Well Identification and Decommissioning Policies	N/A
	Local Health Jurisdiction Policy Variables	
	Health Jurisdiction Governance	.968**
	Health Jurisdiction Staffing	.968**
	Health Jurisdiction Support	.913**
	Drinking Water Program Policy Variables	
	Drinking Water Program Oversight Authority	-.408**
	Environmental Health Department/Branch Staffing	.645**
	Drinking Water Program Well Staffing	.889**
	Drinking Water Program Experience	.889**
Collaboration Variables	Catalyst Collaboration	.645**
	Leadership Collaboration	.296**
	Internal Representation Collaboration	.645**
	External Representation Collaboration	.866**
	Collaboration Assessment	.889**
Economic Variables	Medium Income	.591**
	Number of Housing Permits Granted	.779**
	Population	.849**
	Population Density	.849**
	Pre/Post Recession	.000
	Recession Years	.000
	Urban/Rural Classification	.667**

N = 55
N/A = Not Applicable (no analysis was conducted for variable)
*Correlation is significant at the 0.05 level
**Correlation is significant at the 0.01 level

THEMES

Based from the OLS regression and the correlations, certain variables showed some explanatory power to exempt well decommissioning. In particular, the type of health jurisdiction and absence of a recession; however, additional themes include the drinking water staffing size, external collaboration, housing permits, and county population. None of the counties had large variations in exempt well decommissioning which means none of the local policies, local collaboration, or economic/demographic factors play a significant role influencing county exempt well decommissioning. This

points to the need to control exempt well decommissioning on a broader scale; therefore, it is useful to look at themes that emerged from this study that could potentially be applied on a larger scale.

Health Jurisdiction

As discussed in Chapter 1, Grays Harbor County, Mason County, and Skagit County have health departments where the elected county commissioners make up the local board of health. Pierce County partnered with the City of Tacoma to create a county-city health department and Pierce County's Legislature adopted a home rule charter in order to establish the authority to appoint and elect members of the local board of health in place of the elected county commissioners to comprise the local board of health. Lastly, Kitsap County's Legislature adopted a health district that only covers the incorporated area of the county. Each of these types of governance has a direct relationship with local board size (i.e., Health Jurisdiction Staffing).

The Health Jurisdiction Governance and Health Jurisdiction Staffing variables were significant for the chi-square test, correlation, and OLS regression. The Health Jurisdiction Governance variable measures the different types of governance each county selected within their Health Jurisdiction. The largest percentage of exempt well decommissioning occurred within a single county Health District (89.0%). Health Departments are slightly smaller percentage of 81.7%. Pierce County was both a Combined City-County Health Department and was also a Charter County with the lowest, 68.3%, of exempt well decommissioning. Local Health Jurisdiction Staffing is similar to Local Health Jurisdiction Governance since the type of governance dictates the number of members involved (WBOH, 2013a). The variable compares number of members serving on each county's local board of health. The largest percentage of exempt well decommissioning occurs in counties with local health boards with 6 to 10 members (89.0%). Followed by local health boards with 0 to 5 members with 81.7% of decommissioned exempt wells. This variable is significant (p-value < 0.05) therefore there is a relationship between size of local boards of health and percent of exempt well decommissioning. Both of these variables are significant ($\boldsymbol{x}^2$=9.01 and p-value < 0.05). Therefore, there is a relationship between the type of local health jurisdiction and percent of exempt well decommissioning as shown in Table 33. However, the type of relationship cannot be determined by this test.

Table 33
Local Health Jurisdiction Policy: Health Jurisdiction Governance and Staffing by County

Water Well Type	Health Department and 0-5 Members	Combined City-County Health Department and Charter County and Greater than 10 Members	Health District and 6-10 Members	Total Number of Wells in Sample[1]	x^2	*p*-value	Cramer's V effect size
Exempt	81.7	68.3	89.0	80.8	9.01	.011	.18
Non-Exempt	18.3	31.7	11.0	19.2			

[1]Cell entries are percentages (%) of exempt and permitted wells
n=286

As shown, in Table 30 the Health Department is least affected by exempt well decommissioning per year (Grays Harbor, Mason, and Skagit Counties) while Health Districts and Combined City-County Health Departments and Charter Counties have more influence on the percentage of exempt wells decommissioned on a yearly basis. While chi-square and correlations show there is a relationship between the variables, the OLS regression shows that the more members serving on the local health board (which is determined by the type of jurisdiction) explains the changes in the percentage of exempt well decommissioning. Local health jurisdictions and local boards of health have been granted the authority and responsibility to protect the public's health through a board range of local, state, and federal laws and regulations. While both the local health jurisdictions and local boards of health work together to protect the public's health, the local boards of health act as the governing body for the local health jurisdictions (WHSB, 2006). Under RCW 70.05, the local boards of health must create a policy framework for the jurisdictions and hold power to adopt local ordinances, resolutions, and approve budgets. Health Departments are the standard governance structure; however, jurisdictions have the option to be more hands-on by developing a district health or combination governance structure. Therefore, the case study counties that are more engaged and proactive about public health are opting out of the basic Health Department governance where only the county board of commissioners are placed on the board of health; therefore, allowing specialists and agency staff participate in local boards of health along with the elected county commissioners. Both district health and combined counties (Kitsap and Pierce) have the authority to place additional staff on the local board of health.

Drinking Water Program

During interviews with Ecology and general information often stated a strong drinking water program leads to better well decommissioning within a county. Of the four drinking water program policy variables, the only variable that was significant in the county with all years combined chi-square test and percentage of exempt for each county by year was the Drinking Water Program Staffing. However, based on these data the variable does not explain the percentage of exempt decommissioned wells by county per year. As for comparing counties with all years combined, the Drinking Water Program Staffing connected to wells had the largest percentage of exempt well decommissioning in counties with 0-2 primary staff (84.1%). Followed by 3-4 primary staff (68.3%) of decommissioned exempt wells. This variable is significant (*p*-value < 0.05). Refer to Table 34.

Table 34
Analysis of Drinking Water Program Policy Variable: Primary Drinking Water Program Staffing Connected to Wells

Water Well Type	0-2 Primary Staff [1]	3-4 Primary Staff [1]	Total Number of Wells in Sample[1]	x^2	*p*-value	Cramer's V effect size
Exempt	84.1	68.3	80.8	6.91	.009	.16
Non-Exempt	15.9	31.7	19.2			

[1]Cell entries are percentages (%) of exempt and permitted wells
n=286

Overall, a strong drinking water program does not mean a county will perform better in exempt well decommissioning than a county with a smaller drinking water program.

Collaboration

External Representation is one component of the regional collaboration framework from McKinney, Scarlett, and Kemmis (2010). External Representation compares the number of external collaborations (i.e., are all of the players on the field) with the percentage of decommissioned exempt wells. This variable is significant (*p*-value < 0.05). Refer to Table 35. External Representation had no significant relationship by year for each county according to the correlation.

Table 35
Analysis of Collaboration Representation Policy Variable: External Representation

Water Well Type	Grays Harbor	Kitsap	Mason	Pierce	Skagit	Total Number of Wells in Sample[1]	x^2	*p*-value	Cramer's V effect size
Exempt	80.0	75.0	87.5	68.3	89.0	80.8	11.90	.018	.21
Non-Exempt	20.0	25.0	12.5	31.7	11.0	19.2			

[1]Cell entries are percentages (%) of exempt and permitted wells
n=286

Social-Economic and Demographic Factors

The social-economic and demographic factors utilized in the analysis included:

- County population density by year;
- County population by year;
- Median household income by year;
- Recession present;
- Number of building permits issued by year; and
- Urban-rural classification.

However, only county population and the presence/absence of a recession had a significant correlation to exempt well decommissioning on a temporal scale. As discussed, the OLS regression found the presence/absence of a recession influences the percentage of exempt well decommissioning. Therefore, it is important to consider the economic health when looking at exempt wells from both a local to broader scale. Surprisingly the rural-urban dimension did not show up as important. It was important in Ecology rankings because urban counties have more resources and do not need extensive supervision from Ecology. One might also expect to find the rural-urban political divide showing up in this research. Given the variables used, this did not emerge.

LIMITATIONS OF RESEARCH

Limitations associated with this exploratory study include the lack of a single, relevant theoretical framework to assess this complex issue, lack of high quality data

from historical records, and a limited sample size due to the time intensive process of isolating desired data (i.e., exempt wells), and small population size in some counties for the total study. The lack of a single theoretical framework to assess the situation within the state led to the construction of multiple variables informed by several theories. In part, this was intentional since by looking at an array of theories and casting out a wide net over the question of exempt well decommissioning, the analysis would be able to provide insight into different factors that are connected with well decommissioning.

The lack of high quality data and the time intensive process of merging these data into a reasonable sample size prevented the study from having adequate sample sizes by years to understand the temporal issues. In some cases, the entire population within the study period simply lacked enough exempt well logs (e.g., Grays Harbor County had 100% of its cases represented in the study's sample). Therefore, a longer study period over a larger region is recommended for future study. Most importantly, the sample size should be larger, although this might require substantial resources due to the labor intensive process of interpreting and coding large numbers of written well logs. These case studies provide an initial glimpse into Washington's exempt well decommissioning rates and potential themes that may aid in addressing exempt well decommissioning in a broader context. Further, this study only focused on well decommissioning issues. Therefore, a larger study looking both at the decommissioning progress and the exempt well loophole associated with development would be informative since the number of drilled exempt wells is increasing over time within Washington. In addition to the exempt well loophole within the State, future studies should assess the impact of well decommissioning from a monetary standpoint of well drillers. Decommissioning exempt water wells could be used as an incentive for well drillers to aid the State and county to seek out exempt wells in need of decommissioning. The topics of the exempt well loophole's impact on the future of the State's groundwater management and providing incentives for well drillers to focus more on well decommissioning were only lightly discussed within this study and are themes that deserve more attention in future studies.

CHAPTER 6. CONCLUSION

The two main research questions were: (1) how do you identify exempt wells within Ecology's database; and (2) what local policies, collaboration, and/or economic and demographic factors influence exempt well decommissioning. The first question was addressed through designing exempt well criteria that can predict if a well log is from an exempt well. The exempt well criteria found pipe diameter, bore method, and beneficial use to be the best criteria in the identification process and had 91% success rate. The second question of local policies, collaboration, and economic/demographic factors showed less clarity in explaining exempt well decommissioning among the five sample counties. The limited effect of local policies, collaboration, and economic/demographic factors point to the conclusion that exempt well decommissioning should be studied from a broader perspective than the county level. While none of the local policies, collaboration, or economic/demographic factors highlighted a county as more effective in identifying and decommissioning exempt wells a few important themes did emerge from this study. Both the type of local health jurisdiction (which dictates the composition of local health boards) and local health boards are important to exempt well decommissioning, which was supported by comments from the open-ended interviews. Therefore, exempt well decommissioning is a relevant health policy topic. Further, the absence of a recession plays a role in greater use of exempt wells.

As demonstrated through the open-ended interviews and background information, identifying and then decommissioning exempt water wells is a complex process. While the study found indications that both the local board of health and the general health of the economy may impact the decommissioning of exempt wells, a study using a larger sample size would be helpful to confirm local policies, collaboration, and economic/demographic factors do not increase a county's rate of decommissioning. A larger sample size could point to factors that have an impact on exempt well decommissioning. Further, the open-ended interviews also revealed the current and future complications of exempt wells in the State due to the exempt well loophole within the State's regulatory structure. The exempt well loophole supports the rapid proliferation of exempt wells as a way to avoid securing water rights for new development. As this continues within the State this further intensifies the issues around

water quantity (i.e. groundwater mining) and water quality (i.e., the increase of more potential conduits for pollution into the aquifers). It is recommended for further study to look at both sides of exempt wells (drilling and decommissioning) as a combined wicked problem and how the State can avoid further degradation of its water quality and quantity from exempt wells.

Exempt wells started predominately as a rural area phenomenon and when abandoned wells often become overgrown by vegetation or development of urban areas expands into a once rural area, it leaves aquifers vulnerable to contaminants and create a general safety hazard to those living, working or playing in their vicinity. While these wells began as a rural phenomenon, development is expanding into once traditionally rural areas. This expansion of development is also promoted by exempt wells since the creation of the exempt well loophole; however, at the same time urban counties have more resources to deal with exempt wells. Therefore, the role of rural and urban areas impact where and how exempt wells are used today. Yet the rural-urban variable and patterns comparing rural and urban counties did not provide clear insights and implies that the issue of exempt well decommissioning has more complex dimensions.

These case studies only provide a glimpse into Washington's exempt well decommissioning rates and potential themes that may aid in addressing exempt well decommissioning in a broader context. Therefore, it is recommended for further studies to approach the topic with (1) a broad, landscape framework that allows for the incorporation of public health and economic health as factors in the analysis that spans a longer period of time; (2) a focus on the potential increase in well decommissioning through motivating well drillers to aid in identifying and properly decommissioning exempt wells through a well after-life program; (3) a framework to understand landowners' roles in the decommissioning process, particularly during land sale transfers for well identification and clearly appointing an owner responsible for wells maintenance; and (4) a broad study including both sides of the exempt well issue – well decommissioning and the use of the exempt well loophole for well drilling. Further, case studies from other states and comparing the exempt well criteria's predictive power would have offered further insight into potential ways to improve the criteria's predictive power.

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