Regulation and Impervious Surfaces: A Case Study Looking at Changes in Total Impervious Area (TIA) and Impervious Surface Regulations for the Black Lake Region

By

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Abstract

This thesis establishes a process for evaluating regulatory effectiveness, using total impervious area data in combination with an implementation timeline for relevant land-use regulations. The findings determine that such evaluation is possible and has multiple benefits. A case-study was done for the Black Lake region of Thurston County Washington. An analysis of total impervious area was done for Black Lake's 200 foot shoreland region for eight different years over a 68 year time span. An implementation timeline for relevant land-use regulations was created and used in combination with the total impervious area data to measure regulatory effectiveness. The primary regulations evaluated are the State Growth Management Act (1990) and Shoreline Management Act (1972), that mandate Thurston County adopt land-use regulations pertaining to impervious surfaces. The two primary Thurston County regulations evaluated in this case-study are the Comprehensive Plan (1995) and Shoreline Master Program (1976). The results of the case-study analysis determined that neither set of regulations have effectively slowed the rate of increase in impervious areas within the case study region.

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Chapter 1: Introduction

Lake ecosystems are particularly fragile since they are closed systems--what enters the soil or water has no means of escape. When development occurs within lake ecosystems the landscape and relationships present are often detrimentally altered. The consequences of these alterations involve a multitude of problems associated with issues of water quality, flooding, the loss of species within an ecosystem, erosion, landslides, contamination of groundwater, and dead zones within lakes. Many efforts have been undertaken to address these challenging problems. The development of new methods of predicting, preventing, and solving these problems is very important for the creation of sustainable relationships between people and the ecosystems we inhabit.

A vital component of these efforts is an understanding of how landscapes have changed over time, and the limits to development. This thesis uses historical and current landscape information, policy information, and mapping software to determine the amount of landscape alteration that has taken place over time, as well as, how effectively land-use regulations have limited development. The method for this analysis is detailed in a case study of the Black Lake region, in Washington State.

The four main research questions addressed by this thesis are:

1. Has the amount of impervious surface in the case-study region changed over time?
2. How are impervious surfaces regulated within the case-study region?

3. Have land-use regulations effectively limited increases in impervious surfaces within the study area?
4. What are the benefits and limitations associated with the use of total impervious area data as a tool for evaluating regulatory effectiveness in this part of Thurston County?

Impervious surfaces are those materials that prevent the infiltration of water into the soil. It is important for the purposes of this project to note that surfaces actually have different degrees of imperviousness. For instance, concrete roadways, sidewalks, and patios are 100% impervious, whereas compacted soils, gravel drives, and manicured lawns are not 100% impervious, but allow for less water infiltration than natural ground cover such as forests. (Thurston Regional Planning Council, 2003; Arnold and Gibbons, 1996; May et. al., 1997)

To address these research questions, a case-study was done in Thurston County using the shoreline around Black Lake within 200 feet of the lake's edge. This region was selected after initial research revealed that it is affected by relevant land-use regulations, and because aerial photosets were available for eight different years over a 68 year time span. Any effort to expand the study area would have required the use of a culling method to identify where different regulations were in effect individually and where they overlapped. After exploring this alternative, it was abandoned due to limits on continuous coverage areas for the available photosets and the decision that it would unnecessarily complicate research efforts.

To address the first research question, the total impervious area analysis method was used to measure the change in impervious surfaces within the case-study area. Total impervious area is defined as the percentage of land within a given area that is impervious to water. (May et. al., 1997) This includes the number of acres covered by rooftops, paved surfaces, and compacted earth. (May et. al., 1997) This type of analysis was chosen because it is derived from land-use/land-cover data, and is a key indicator of ecological conditions. (May et. al., 1997) The outputs of this analysis are represented using a percentage. This is a consequence of the calculation performed that multiplies the quantity of a specific land-cover type by a coefficient referred to as the 'percent impervious value' for the land-cover type. This calculation is done for each type of land-cover present within the study area. The results are then added together to determine the total impervious area for a specific time period. The results of the analyses done showed a continuous increase in the amount of total impervious area present within the case-study region over the 68 year time span. Chapter 6 provides a more detailed analysis of the results.

The second research question required analysis of land-use regulations that limit impervious surfaces in this part of Thurston County. These regulations were identified and analyzed for their applicability to the study area. This thesis evaluates how successful these regulations have been at achieving their goals and serving the purposes intended. The overall objective is to identify the impervious surface regulatory structure and background for the study region. The results of this analysis and a regulatory adoption timeline are provided in Chapter 6. It is

important for everyone from policy makers to citizens to monitor and evaluate the effectiveness of laws and regulations for the sake of the environment and all its inhabitants, and to recommend amendments or adjustments to these regulations to improve their efficacy as needed. (R.C. Wissmar, 1993)

The third research question was considered by looking at the total impervious area in conjunction with policy analysis data. The rate of change for impervious surfaces was evaluated for different time periods, based on the regulatory implementation and adoption timeline. The results show that the rate of change in impervious area varied for different time periods. To be more specific, the rate of change for impervious surfaces within the study region continued to rise despite Thurston County's implementation of the Shoreline Management Act (SMA) (via adoption of its Shoreline Master Program) in 1976, and the implementation of the Growth Management Act (via adoption of its GMA compliant Comprehensive Plan update) in 1995. This topic is discussed in more detail in Chapter 6.

The fourth research question evaluates how successfully total impervious area analysis data can be used to measure the effectiveness of impervious surface regulations both in this case study and in general. The results indicate that although there were significant restrictions to the depth of analysis that could be done when evaluating regulatory effectiveness associated with Black Lake's shoreland region, in general this method is both thorough and useful. For instance, future studies could improve results by using different base data sources or more specialized software. Overall, the benefits of this type of analysis are

extensive and allow for a thorough evaluation of how effectively regulations limit increases in impervious surfaces.

Chapter 2 – The Effects of Impervious Surfaces on Ecosystems

There is considerable scientific evidence indicating that an increase in the amount of impervious surfaces results in ecosystem degradation. Increases in impervious surfaces come from the transformation of landscapes by a variety of human activities, commonly referred to as urbanization. Urbanization results in changes to the amount of impervious surfaces within drainage basins, which alters hydrological systems, the quantity and toxicity of stormwater runoff, water quality, habitat availability, natural flow channels for surface water, water temperature, and vegetative cover. (The Center For Watershed Protection, 2003; Booth, 1991; Arnold and Gibbons, 1996; Grant et. al., 2000; and Booth, 2000) All of these changes lead to ecosystem and drainage basin degradation, particularly for closed systems such as lakes.

As the amount of impervious surfaces increases so does the volume, rate (peak discharge) and duration of stormwater runoff. (Thurston Regional Planning Council, 2003) This increase in runoff results in a change to the quantity and quality of the water that enters the groundwater supply, lakes, streams, rivers, and wetlands. (Thurston Regional Planning Council, 2003) "Nationwide, the EPA reports that urban runoff has resulted in, or contributed to, the impairment of: …8 percent of total assessed lake acres." (U.S. Environmental Protection Agency, 1998) This statistic illustrates why it is important to remember that any pollutant deposited or derived from an activity on land will likely end up accumulating in stormwater runoff. (The Center for Watershed Protection, 2003)

Closed lake systems are threatened by negative impacts to their water columns, and sediments from stormwater pollutants, including sediment, phosphorus, other nutrients, bacteria, metals, hydrocarbons, chlorides, and trash/debris. (The Center for Watershed Protection, 2003) For example, increases in phosphorous levels have been directly linked to increases in impervious surfaces in lake watersheds. (The Center for Watershed Protection, 2003) This is a concern because phosphorus leads to eutrophication. (The Center for Watershed Protection, 2003) Eutrophication is the process of increased nutrient input to a lake over the natural supply. This increased lake fertilization usually results in an increase in the biological production that occurs in the lake, stimulating excessive plant growth (algae and nuisance plant weeds). (The Center for Watershed Protection, 2003) More than 80% of urban lakes show some symptoms of eutrophication. (The Center for Watershed Protection, 2003) Increases in plant growth ultimately results in changes to dissolved oxygen levels that degrade wildlife habitat, recreational opportunities and other beneficial uses. (Hinman, 2005)

Water quality is not the only variable negatively affected by changes in the quantity and toxicity of the runoff. Urban runoff can also have severe environmental impacts such as flooding, habitat loss, and erosion. (Booth, 1991; Grant et. al., 2000; U.S. Environmental Protection Agency, 1997) Other side effects of changes to runoff are the associated adjustments of water flow channels and a change in water temperature. (Thurston Regional Planning Council, 2003; Grant et. al., 2000)

As shorelines are converted from natural landscapes to developed environments, the natural flow channels for surface water are typically altered. (Thurston Regional Planning Council, 2003; Booth, 2000) Runoff may contain "water heated on hot pavement and rooftops [which] may cause an elevation in water temperature in streams, lakes, and wetlands." (Grant et. al., 2000; Thurston Regional Planning Council, 2003) The reduction in the amount of vegetative cover along a lake or stream shoreline may result in a reduction of shade, which can contribute to the increase in water temperature. (Arnold and Gibbons, 1996; Thurston Regional Planning Council, 2003) This increase in water temperature is a concern because it can result in a decrease in dissolved oxygen levels, as well as, changes to the amount and type of nutrients present in lakes or streams. (Grant et. al., 2000; Thurston Regional Planning Council, 2003) These types of changes in nutrient concentrations often create the perfect environment for algae blooms in lakes, which can also negatively affect coldwater fish and insects. (The Center for Watershed Protection, 2003; Thurston Regional Planning Council, 2003) The reproductive capabilities and health of many coldwater fish and insects are very sensitive to changes in water temperature. (Grant et. al., 2000; Thurston Regional Planning Council, 2003)

Changes in groundwater levels also pose a significant threat to the health of a water body. Increases in impervious surfaces lead to decreased infiltration, which results in reduced groundwater supplies. A decrease in infiltration will cause the water table to lower and it may also "cause a stream or wetland to dry out during months when precipitation is low," since lakes, wetlands, and streams

rely on a consistent and continuous ground water supply. (Thurston Regional Planning Council, 2003; Arnold and Gibbons, 1996)

Over the past 68 years, Thurston County has experienced urbanization and corresponding increases in impervious surfaces that have led to issues with water quality and habitat loss. According to the Thurston Regional Planning Council, "water quality in many of the basins in Thurston County has been degraded due to the effects of urbanization." (Thurston Regional Planning Council, 2003) Habitat has also been degraded as land has been paved over for development purposes. In Thurston County a variety of regulations have been adopted that address the issues associated with increases in impervious surfaces and some that specifically limit the amount of impervious surfaces allowed. The adoption of these regulations was mandated by state laws such as the Growth Management Act and the Shoreline Management Act, which will be discussed in later chapters. Other legislation that apply to the study area will also be discussed in later sections.

Chapter 3: Policy Analysis

Overview

There are City, County, and State regulations applicable to the study area that limit development and impervious surfaces. This thesis focuses on County regulations, but includes the State regulations that mandate County action, when applicable. The scope of analysis for this thesis is limited to the identification of relevant regulations by analysis of their goals, policies, and objectives in order to establish a regulatory implementation timeline. Data limitations did not allow for parcel-level analysis.

The primary regulations analyzed were Thurston County's Shoreline Management Plan, Thurston County's Comprehensive Plan, and Thurston County's Development Regulations. There are multiple elements within these three main bodies of regulations, which individually address impervious surfaces and limit development. These include Thurston County's: zoning regulations, Critical Area Ordinance, Joint Plan with the City of Tumwater, and its Drainage Design and Erosion Control Manual. Some State laws and regulations are also addressed because they required the County to take action. The two primary ones mentioned are the Shoreline Management Act and the Growth Management Act. Other State regulations, such as the Department of Ecology's Stormwater Management Manual, are applicable to the study area, but since these regulations focus primarily on permitting and parcel-level regulations for impervious surfaces, they are not directly addressed by this thesis.

General Background

In 1937, counties and cities received the authority from the State Legislature. (Washington State History Link, 2007) No requirements regarding such activities were enacted, however, so any action on the part of counties and cities was purely optional. (Washington State History Link, 2007) The Shoreline Management Act (SMA), which regulates development within Washington State's shoreline regions, was passed by the Legislature in 1971 and adopted via public referendum in 1972. (Gates, 2003) The SMA (RCW 90.58) was adopted around the same time (early 1970's) as the State Environmental Policy Act (SEPA), when environmental activism exerted political force here in Washington State. (Washington State History Link, 2007) During that same time period, there was also some support for the establishment of a state-wide, land-use planning act, although draft legislation aimed at this goal was not passed by the Legislature. (Washington State History Link, 2007) It wasn't until the early 1990's that the public once again began to push the legislature to develop and adopt a state-wide, land-use planning act. In 1990 these efforts were successful. The Growth Management Act (GMA-RCW 36.70A) was adopted by the Washington State Legislature in 1990 on the last day of a special legislative session. (Washington State History Link, 2007; RCW 36.70A)

Shoreline Management Act: Background Information

The Shoreline Management Act was adopted in order to "prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines." (Gates, 2003) The SMA balances the desire and need for water-related uses, residential development, public access, and the goal of protecting shoreline environments and water quality. (Gates, 2003) The SMA seeks to protect shoreline environments and aquatic ecosystems, while allowing for preferred uses. (RCW 90.58; Gates, 2003) Under the Act preferred uses are identified that "include single family residences, ports, shoreline recreational uses, water dependent industrial and commercial developments and other developments that provide public access opportunities." (RCW 90.58) The SMA requires strict mitigation of adverse environmental impacts caused by these preferred uses. (RCW 90.58) These mitigation standards are intended to preserve the aesthetics and natural character of the shoreline regions. (RCW 90.58) The details regarding what uses are allowed and what environmental protections are stated in each jurisdictions' Shoreline Master Program. (Gates, 2003)

Shoreline Master Programs

The SMA requires counties and cities to develop and adopt a Shoreline Master Program (SMP). (Gates, 2003) An SMP is a combination of plans and regulations detailing what type of development, uses, and activities can occur in shoreline areas. (Gates, 2003) Since the adoption of the GMA, these programs must be incorporated into the comprehensive plans of local jurisdictions. Many local governments either incorporate them via reference or add them as another

element of their comprehensive plans. (Municipal Research and Services Center of Washington, 2007) An SMP is "based on state laws and rules but tailored to the specific geographic, economic and environmental needs of the community." (RCW 90.58; Gates, 2003) The Washington State Department of Ecology has approval authority over all SMP amendments, as a safeguard to ensure that the standards of the SMA are met within all adopted SMPs. (RCW 90.58)

Requirements for the Shoreline Management Act's Purview to be Applied:

The SMA applies to all marine waters, streams with an average annual flow greater than 20 cubic feet per second, lakes with surface areas 20 acres or larger in size, upland areas called "shorelands" that extend 200 feet landward from the edge of these waters, and the following areas when they are associated with one of the above: biological wetlands and river deltas; and some or all of the 100-year floodplain including all wetlands within the 100-year floodplain. (RCW 90.58; Gates, 2003) The SMA also identifies shorelines of statewide significance: Pacific Coast, Hood Canal, certain Puget Sound shorelines, all waters of Puget Sound and the Strait of Juan de Fuca, lakes or reservoirs with surface areas of more than 1,000 acres, larger rivers (1,000 cubic feet per second or greater for rivers in Western Washington, 200 cubic feet per second and greater east of the Cascade crest), and wetlands associated with the areas listed above. (RCW 90.58; Gates, 2003) The SMA states that "the interests of all the people shall be paramount in the management of shorelines of statewide significance." (RCW 90.58; Gates, 2003) The Shoreline Management Act applies to more than 20,000

miles of shorelines: 2,300 miles of lake shores, 16,000 miles of streams, and 2,400 miles of marine shoreline. (Gates, 2003)

Thurston County's Shoreline Master Program – Goals, Policies, and Objectives Relating to Impervious Surfaces

Thurston County's Shoreline Master Program (SMP) was originally adopted in 1976 and has since been updated twice, most recently in 1990. One of the stated policies of the County's SMP is:

> "Uses shall be preferred which are consistent with control of pollution and prevention of damage to the natural environment or are unique to or dependent upon use of the State's shoreline." (Thurston County Shoreline Master Program, 1976, Section Two (III.))

The SMP's policies indicate that the allowed land-uses within shoreland areas must be designed and orchestrated in a way that causes only minimal damage to the ecosystem of the shoreline area, to the extent feasible. (Thurston County Shoreline Master Program, 1976, Section Two (III.)) The SMP gives priority to the protection of the natural character of the shoreline and the shoreline's ecology. (Thurston County Shoreline Master Program, 1976, Section Two (IV.)) Thurston County goes beyond listing the protection of water quality and shoreline ecosystems as a priority. It specifically requires all development to avoid adversely affecting aquatic habitats and water quality. (Thurston County Shoreline Master Program, 1976, Section Two (V.))

More specific restrictions are found within the specific standards for each of the Shoreline Environment designation categories. A shoreline environment designation area is a category of shoreline that is applied to regions based on the

amount of man-made development present and the uniqueness of the area. There are five categories of shorelines specified within Thurston County's Shoreline Master Program, and they are: Natural, Conservancy, Rural, Suburban, and Urban Environments. (Thurston County Shoreline Master Program, 1976, Section Two (VII.)) Each of these five categories has their own specific goals and purposes. The restrictions on impervious surface coverage, and development in general, is different for each category. The Natural category is the most restrictive in that it seeks to limit development and public access at a level that is compatible with maintaining the area's unique undeveloped environment. (Thurston County Shoreline Master Program, 1976, Section Two (VII.)) Each subsequent category is less restrictive in terms of the amount of development and impervious surface coverage allowed. These unique environmental designation areas are applied to specific regions of Thurston County, and supercede other land-use regulations for those areas that are less restrictive. (Thurston County Shoreline Master Program, 1976). The application of the standards for these categories on the shorelines of Thurston County are aimed at providing protection for aquatic and semi-aquatic ecosystems, while still allowing human uses within shoreland areas.

The Growth Management Act: Background Information

The GMA lays out a state-wide, land-use planning system that seeks to guide development, while protecting environmental, economic, and private property interests, through the adoption of plans, policies, and regulations at the local-government level. Since its adoption in 1990, the GMA has been amended

multiple times, first in 1991 to create enforcement entities called the Growth Management Hearings Boards, which deal with "allegations of non-compliance with the GMA." (RCW 36.70A) Other amendments have been added in subsequent years to clarify and/or expand the Act's provisions. (RCW 36.70A)

> "The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, preparing comprehensive plans and implementing them through capital investments and development regulations." (RCW 36.70A)

The GMA ensures that counties and cities undertake comprehensive land-use planning efforts. Local governments are required to adopt comprehensive plan policies and development regulations to implement those policies. (RCW 36.70A)

The Growth Management Act's Planning Goals

The GMA specifically identifies and states 13 planning goals to guide jurisdictions in the preparation of their comprehensive plans and development regulations. These are found in the following section of the GMA: RCW 36.70A.020 Planning Goals. (Washington State History Link, 2007) No priority is given to any one planning goal. (RCW 36.70A) This demonstrates the legislature's intent of requiring jurisdictions to balance the goals, in an attempt to give them equal consideration when developing plans and regulations. Goal number ten addresses the environment: "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)

The Growth Management Act: How it Applies to The Study Area – Overview

The Growth Management Act pertains directly to the study area, as it is the mandate that requires Thurston County to draft its Comprehensive Plan and Development Regulations. Zoning districts are identified in the Thurston County Comprehensive Plan, and regulations stipulating what activities are allowed within each zoning district are outlined in the corresponding development code. The Thurston County Critical Area Ordinance and Shoreline Master Plan are housed in the County development regulations. The drainage design and erosion control manual is also a part of the County code. The City of Tumwater and Thurston County Joint Plan applies to the Tumwater urban growth area, which covers the eastern portion of the study region. The joint plan is incorporated into the County's Comprehensive Plan.

Thurston County Comprehensive Plan – Goals, Policies, and Objectives Relating to Impervious Surfaces

Chapter 9 of the Thurston County Comprehensive Plan addresses the natural environment. The language found throughout this chapter acknowledges the importance of protecting the County's natural environment and the challenge of doing so, while balancing the need to sustain human uses. As stated in Chapter 9, county-wide planning policies 9.1 through 9.8 call for jurisdictions in the county to protect ground and surface water from degradation, and to plan for sustainable growth so that human uses can be accommodated without jeopardizing the County's livability and environmental quality. (Thurston County

Comprehensive Plan, 1995a, Chapter 9) Appendix 1 in this thesis lists the specific policies stated in chapter 9 of the County's Comprehensive Plan that address the protection of the natural environment from the effects of increased impervious surfaces. These effects include the degradation of groundwater and surface-water supplies. These policies specifically call for limitations on development in order to protect and improve the water quality and biological health of lakes and other water bodies or aquatic systems throughout Thurston County. (Thurston County Comprehensive Plan, 1995a, Chapter 9(III.)(C)) Limitations on the amount of allowed development are also recommended to protect groundwater quality and quantity. (Thurston County Comprehensive Plan, 1995a, Chapter 9(III.)(B)) Limitations to impervious surfaces are being construed as limitations to development; however, it is important to note that limitations to impervious surfaces are also specifically called for in the County's policies and goals. In summary, Thurston County's Comprehensive Plan outlines clear goals, objectives, and policies that seek to prevent ecosystem degradation by evaluating and limiting the amount of impervious surfaces.

Urban Growth Areas and Joint Plans

An Urban Growth Area (UGA) is an area outside a city boundary that is designated for future urban growth. (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 1) Within the urban growth area, the County enforces the City's zoning regulations and environmental standards. The GMA requires counties and the cities that they encompass to "establish a 20-year growth boundary for each urban area." (The City of Tumwater and Thurston County Joint

Plan, 1995b, Chapter 1) These UGAs are areas where the counties and cities plan for future development at urban densities. (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 1)

A joint plan is essentially a comprehensive plan for the unincorporated portion of a city's urban growth area, developed through a cooperative effort between a city and the county. (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 1) The joint plan is then "adopted by each jurisdiction as a comprehensive plan amendment." (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 1) The Joint Plan is developed to establish guidelines for the transition from rural to urban development densities that are intended to occur within a UGA. (The City of Tumwater and Thurston County Joint Plan, 1995b) As both cities and counties are subject to the GMA, the Act's provisions and planning goals serve as the framework for the creation of joint plans, just as they do for the creation of comprehensive plans and development regulations.

City of Tumwater and Thurston County Joint Plan – Goals, Policies, and Objectives Relating to Impervious Surfaces

Goal number 6 of the City of Tumwater and Thurston County Joint Plan is to reduce the impacts from flooding, encourage efficient stormwater management, and ensure that the groundwater of Tumwater is protected and preserved. (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 3) The policy objectives listed for goal number 6 seek to ensure that future land use and development conform to the County's and City's standards for groundwater

(wellhead and aquifer) and surface-water protection. (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 3) These policy objectives are listed in their entirety in Appendix 2.

Goal number 8 also addresses the need for protecting the County's water resources, and environmentally sensitive areas. The stated goal is: "[To] ensure that physical limitations of the land are observed during the development process." (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 3) This goal addresses the actual development or construction processes, yet it also broadly calls for the jurisdictions to "prohibit or set conditions on development based on anticipated adverse environmental impact[s]." (The City of Tumwater and Thurston County Joint Plan, 1995b, Chapter 3) Additional details regarding goal number 8's policy objectives are found in Appendix 3. The following is a summary of the land uses and zoning districts found within the study area.

Development Regulations

Jurisdictions draft development code language, which includes zoning, subdivision, landscaping, critical areas, and other development regulations, in order to implement comprehensive plan policies. (Municipal Research and Services Center of Washington, 2007) Consistency is therefore required between comprehensive plans and development regulations. (Municipal Research and Services Center of Washington, 2007)

Zoning Regulations:

Zoning regulations are the component of development regulations that control the density of development throughout the county or city. Zoning districts are blocks of land with identified boundaries where specified activities and development densities are allowed. Zoning regulations have associated zoning maps that show a county with blocks of land shaded in different colors to signify their zoning. Zoning densities are typically defined in terms of how many dwelling units are allowed on a specified number of acres. For example, a zoning density of 1:5 means that one dwelling unit (house) is allowed per five-acre parcel. Zoning regulations also set up specific zones for different types of land-uses. Commercial, Industrial, Long-Term Agriculture, Long-Term Forestry, and Rural Residential are typical zoning districts found in most counties. Each zoning district has regulations pertaining to allowed uses, environmental protection, and development density—to name a few. Simply put, zoning is a tool that jurisdictions use to say where and in what quantities or types development can occur.

Critical Area Ordinances:

Under the GMA, a required component of development regulations for local governments are those pertaining to environmentally critical areas. (RCW 36.70A) This body of regulations is commonly referred to as a Critical Areas Ordinance (CAO). The definition provided for Critical Areas in the GMA is as follows: " 'Critical areas' include the following areas and ecosystems: (a) wetlands; (b) areas with a critical recharging effect on aquifers used for potable

water; (c) fish and wildlife habitat conservation areas; (d) frequently flooded areas; and (e) geologically hazardous areas." (RCW 36.70A) The CAO establishes regulations to protect these environmentally critical areas and limit the amount and type of development that can occur on or around such areas.

Thurston County's Critical Area Ordinance – Goals, Policies, and Objectives Relating to Impervious Surfaces

Thurston County's Critical Area Ordinance states as one of its main purposes the goal of protecting unique, fragile, and vulnerable elements of the environment. (Thurston County Development Code, 1997, Chapter 17.15) Each type of critical area has a separate section of code that distinguishes goals and policies for its protection. For example, the main goals for the Critical Aquifer Recharge Area section are the prevention of degradation to groundwater sources and the maintenance of groundwater recharge. (Thurston County Development Code, 1997, Chapter 17.15) The section on geologic hazards is primarily aimed at protecting people from the hazards of landslides, erosion, and seismic and volcanic activities. In addition, the protection of stream quality, fish and marine shellfish is also set forth as a primary purpose. (Thurston County Development Code, 1997, Chapter 17.15) The section on important habitat and species deals with the protection and preservation of wildlife habitat areas, especially habitat areas for wildlife native to Thurston County. (Thurston County Development Code, 1997, Chapter 17.15) Finally, the floodplains, streams, and wetlands portion lists numerous policies relevant to impervious surfaces that Thurston County is mandated to accomplish. The policies are: a) to preserve natural flood

control, stormwater storage and drainage or stream flow patterns; b) to control siltation, protect nutrient reserves and maintain stream flows and stream quality for fish and marine shellfish; c) to prevent turbidity and pollution of wetlands, streams and fish or shellfish bearing waters and to maintain the associated wildlife habitat; and d) to minimize the loss of wetlands and to increase the quality and function of wetlands within Thurston County. (Thurston County Development Code, 1997, Chapter 17.15)

All of the purposes and policies noted for each section of the Critical Areas Ordinance relate to protection of water quality, habitat, and groundwater or surface-water supplies. The exact standards or limitations for impervious surfaces for each section include restrictions on lot coverage, density and allowed development or uses within critical areas. These are not detailed further in this section. Only the effectiveness of the broad goals, policies, and purposes are being evaluated as a part of this thesis.

Thurston County's Drainage Design and Erosion Control Manual – Goals, Policies, and Objectives Relating to Impervious Surfaces

Thurston County has its own Drainage Design and Erosion Control Manual, which was adopted in 1994. Thurston County and its cities are currently working collaboratively to update the 1994 manual. The general intent of the manual is to:

> "Define policies, minimum requirements, minimum standards, and procedures for the design, construction, and maintenance of drainage facilities and for the control of erosion on construction sites. Where structures are necessary to treat runoff and to control flow…[the] manual

> will promote the construction of multiple use drainage facilities." (Thurston County Drainage Design and Erosion Control Manual, 1994)

The manual "also provides standard procedures for estimating flow from and establishes allowable runoff criteria for developed property." (Thurston County Drainage Design and Erosion Control Manual, 1994) Guidelines for construction of stormwater facilities (conveyance, detention, retention, and infiltration), which must be followed by jurisdictions located in Thurston County, are also included in the Drainage Design and Erosion Control Manual. This manual limits the amount of allowed impervious surface at the parcel level. It has specific standards for individual parcels relating to building footprints and the amount of impervious surfaces allowed during and after the construction phase. It also has specifications for stormwater infiltration, retention, and treatment for specific parcels. These specific standards were not analyzed as a part of this thesis.

Chapter 4: Case-Study - Overview

Characteristics of the Study Area

Black Lake (Figure 1) is a cold water lake located in northwestern Thurston County. It is 570 acres and approximately 2.4 miles long, with a mean depth of 19 feet and a volume of 11,000 acre/feet. (Thurston County Department of Environmental Health, 2005) The lake drains through a ditch on the north end into Percival Creek. (Thurston County Department of Environmental Health, 2005) Historically, the lake drained to the south through the Black River, but this route is now blocked by beaver dams and vegetation. (Thurston County Department of Environmental Health, 2005) Black Lake's shoreland area is also characterized by the presence of some small wetland areas, with limited areas of hydric soils and small patches of high groundwater hazard areas. For the most part, these areas are found on the north and south tips of Black Lake, although there are also wetlands located on the lake's east side, where two tributaries originate. (Thurston County Department of Environmental Health, 2005) On the lake's west side there is one larger tributary and several intermittent streams that flow into the lake. (Thurston County Department of Environmental Health, 2005) The soils in the shoreland area are primarily variations of loam including silt loam, very gravelly loam, clay loam, and sandy loam. (Thurston County Geodata Center, 2007)

Figure 1. Black Lake 2005 Aerial Photo with 200 foot Shoreline Area

Aerial photos for this image are provided by the Thurston County Geodata Center - www.geodata.org

During 2005, the water quality of Black Lake was assessed by Thurston County staff. On a rating scale of "Excellent, Good, Fair, and Poor," Black Lake was rated as having "Fair" general water quality. (Thurston County Department of Environmental Health, 2005) Major issues with the water quality in Black Lake include: a) the occurrence of blue-green algae blooms, which can prevent recreational use of the lake; b) beaver activities in outlet ditches on the north section of the lake, which can lead to rises in water levels and the flooding of yards and docks; and c) the occurrence of swimmer's itch on a regular basis during the summer, which is a health concern for recreational users. (Thurston County Department of Environmental Health, 2005) Overall, the 2005 assessment found the lake to have moderate to high nutrient concentrations that led to blue-green algae growth in late summer and fall.

The most pressing of these issues is the occurrence of algae blooms. There are a number of algae types common to Black Lake including: diatoms, and green and blue-green algae. The blue-green algae *Aphanizomenon sp.* or *Anabaena sp.* are considered to be the dominant algae in Black Lake. (Thurston County Department of Environmental Health, 2005) The dominance of blue-green algae is generally considered a sign of nutrient-rich conditions and poor water quality. (Thurston County Department of Environmental Health, 2005) Blue-green algae growth has been responsible for algae blooms in Black Lake on multiple occasions. In September 2000, much of the western shore of Black Lake was covered by a spectacular blue-green algae bloom, which at the point of algae die-off, resembled a turquoise-blue paint spill. (Thurston County Department of

Environmental Health, 2005) Another smaller bloom occurred in August of 2004 and resulted in the closure of the County's swimming area at Kenneydell Park. (Thurston County Department of Environmental Health, 2005) Recreational use is frequent for Black Lake. There are numerous private access points to Black Lake, including private residences, one church camp, two private resorts, and three small private community accesses. (Thurston County Department of Environmental Health, 2005) There are also two public accesses: the Washington Department of Fish and Wildlife public boat launch and Kenneydell County Park. (Thurston County Department of Environmental Health, 2005)

The south, west and north portions of Black Lake's shorelands are within unincorporated Thurston County. The eastern portion falls within the City of Tumwater's Urban Growth Area, thus urban growth will move into this part of the basin as the city expands. As this portion of the shoreland area is regulated by a Joint Plan crafted collaboratively by Thurston County and the City of Tumwater; this section of shoreland is subject to specialized regulations that reflect the anticipated transition within the UGA from rural to urban development.

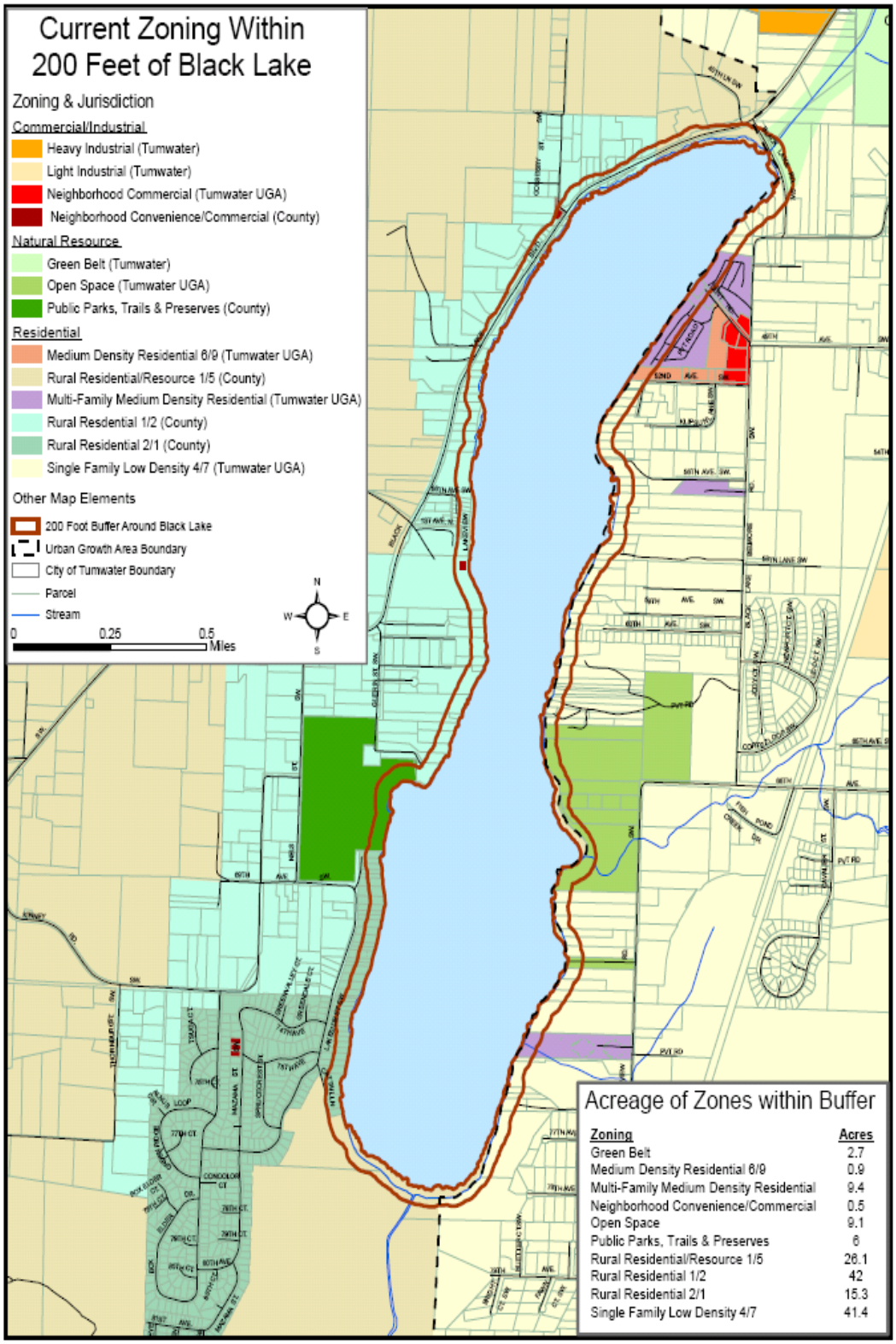
A description of the primary land-uses surrounding Black Lake is provided by Thurston County Waste and Water Management Staff: "A large percentage of the lake shore is moderate density residential. There are two large mobile home parks on the east shoreline and two RV commercial resorts on the west side of the lake." (Thurston County Department of Environmental Health, 2005) The south end of the lake is primarily undeveloped land due largely to its proximity to the Black River wetland system.

There are multiple zoning designations within the Black Lake shoreland area. A zoning designation determines the density (number of dwelling units, etc…) allowed in a particular area, as well as the types of uses and the amount of lot coverage allowed, and is represented by an abbreviation of the full designation's name, and a ratio representing the number of dwelling units allowed per a certain number of acres. This density ratio can be represented via one of the following notations: a) 1/5, b) 1:5, or c) 1du per 5 ac. The zoning designations for the shoreland areas surrounding Black Lake are as follows: Rural Residential Resource (RRR) 1/5, Rural Residential (RR) 1/2, Single Family Low-density (SFL) 4/7, Green Belt (GB), Tumwater Urban Growth Area Open Space (OS), Multi-Family Medium Density Residential (MFM) 9/15, Rural Residential (RR) 2/1, Parks, Trails, and Preserves (PP), and Neighborhood Convenience (NC). Figure 2 gives the distribution of these zoning districts, and the embedded table provides information on the number of acres that fall within each zoning district within the study area's boundaries.

Each of these zoning designations has specific standards restricting lot coverage by impervious surfaces, and allowed development densities. The allowed impervious surface or lot coverage standards range from 60% to 85% of the individual lot for the zoning districts listed above with the exception of the PP, GB, and OS zoning districts. This thesis did not perform parcel-level analysis so an evaluation of how consistently and effectively these standards have been applied is not possible; however, the cumulative effects can be measured by

looking at the rate of change in impervious surface before and after the implementation of these districts.

Figure 2. Zoning District Map for Black Lake's 200 foot Shoreland Area



Created by: Amy Calahan, GIS Analyst – Thurston County Geodata Center

Chapter 5: Case-Study – Methods

Overview

The data used for this case-study were gathered from aerial photographs of the Black Lake region spanning the time period from 1937 to 2005. These photographs were scanned, geo-rectified, and when necessary, mosaics were created. The boundary for Black Lake was then digitized and a 200 foot buffer established to create the study area. Finally, land-cover types were delineated and digitized.

After completing the aerial photography processing and land-cover classification, the percent of impervious surface for each land-cover type was calculated. Those data were then used to calculate the total impervious area for each year of photo coverage. Four main analytical steps were then taken:

1) The change in total impervious area was calculated to determine how the study area has changed over the 68 year time span.
2) Regulations that limit impervious surfaces within the study area were identified, and an adoption and implementation timeline was created to determine when regulatory changes took effect.
3) The regulatory adoption and implementation timeline created in step 2 was used as a guide to divide the total impervious area data into specific timeframes. The overall change in the percent of total impervious surfaces and the corresponding rate of change were then calculated within these timeframes, in order to evaluate how

effectively regulations have limited increases in impervious surfaces within the study area.

4) The benefits and limitations associated with using total impervious area data as a tool were identified to evaluate how effectively implementation of regulations limit impervious surfaces.

Restrictions to the Scope of Analysis Performed in Steps 1-4

Due to the nature of the data used for this particular case-study, there were some restrictions on the scope of this evaluation. The resolution of the photo sets available was not precise enough to allow for parcel-level analysis of the study region. The lack of parcel data for all the years that aerial photos were available also prevented parcel-level analysis within the study area. Therefore, an evaluation of changes in impervious surfaces was done for the whole study area, and the goals, intents, and general policy guidelines for the regulations were analyzed instead of the specific parcel-level standards.

It is also important to note that analysis of the effectiveness of the regulations at achieving their intended goals was done using only the change in impervious surface variable. Although other variables (economic, social, and political) may influence the effectiveness of regulations, this analysis focuses on whether there is a quantifiable relationship between the implementation of regulations and changes in the amount of impervious area present within the study region.

Aerial Photographs

Aerial photos from 1937 and 1944 were used to calculate a baseline for impervious surface prior to the implementation of the Shoreline Management Act (SMA). Photo sets from 1977, 1980, 1992, 1996, 2000, and 2005 were used to calculate the amount of total impervious surface present after the adoption of the SMA. The rate of change in total impervious area was calculated using these photos for the pre-SMA and post-SMA time periods.

Aerial photos from 1937, 1944, 1977, 1980 and 1992 were used to calculate a baseline for impervious surfaces prior to the implementation of the Growth Management Act (GMA). Photo sets from 1996, 2000, and 2005 were used to calculate the amount of impervious surface present after the adoption of the GMA. The rate of change in total impervious area was calculated for these time periods using the same photo sets.

The aerial photos were processed using geographic information systems software from ESRI. Specifically the software used was ESRI's 9.1 ArcGIS suite of products. The land-cover data files were created using this same ESRI software, and the total impervious area calculations were done by exporting attribute table data from the ArcGIS software to Microsoft's Excel program.

1937

These black and white aerial photos were obtained from Thurston County's Roads and Right-of-way Department. The scale of the photos is 1:12,000. These photos were saved as image files, and imported into ArcGIS software. Then the images were geo-rectified and placed into a mosaic.

1944

These black and white aerials were taken by the Army Corp of Engineers at a scale of 1:20,000, as part of a wartime reconnaissance effort. They are housed at the Evergreen State College Library–maps section. These photos were scanned, geo-rectified, and clipped to achieve proper alignment.

1977

The aerial photos taken in 1977 are referred to as the Thurston Block and were obtained from the University of Washington Library's map and photo collection. They are black and white, taken at a scale of 1:20,000, and were originally from the Washington State Department of Transportation. These photos were scanned, geo-rectified, clipped, and tiled.

1980

The 1980 aerial photos are referred to as Thurston Met, and are in color and have a scale of 1 to 24,000. They were originally taken by the Washington State Department of Transportation, but are now housed in the University of Washington Library's map and photo collection. After scanning these images, they were geo-rectified, clipped and tiled to remove blank data spaces automatically added during the geo-rectification process.

1992, 1996, 2000, and 2005

The aerial photos from 1992, 1996, 2000, and 2005 came from Thurston County's Geodata Department. They were already geo-rectified and in some cases tiled. The scale of the photos is 1: 20,000.

Delineation of The Study Area

The study area was defined for each set of aerial photos by loading the datasets into ArcMap and using ArcToolbox to create a 200 foot buffer around the digitized boundaries of Black Lake. A polygon defining the boundaries for Black Lake was created for each of the photo sets, since the boundaries change over time. Likewise, the 200 foot buffer was defined separately for each data set.

Digitization/Delineation of Land-cover Types

The selection of a land-cover classification system is required in order to perform a total impervious area analysis. The National Land-cover Type project's classification system (NLCD) was selected due to its use in other research that is similar in nature, in an effort to ensure that the data created could be used for other inquiries. Land-cover coefficients were then chosen to reflect the area's ecosystem characteristics. These selections incorporate the main assumptions made when identifying methods for analyzing the change in impervious surfaces within the study region.

Land-cover types were delineated using the NLCD guidelines for the land-cover classifications (Appendix 4). The land-cover categories were then digitized

using the following steps: 1) import into ArcMap; 2) create a geodatabase to house feature class datasets for that photo set using ArcCatalog; and 3) use on-screen digitization to create feature classes for each land-cover category. These steps were repeated for each of the photo sets listed above.

Calculation of Total Impervious Area

The percent of total impervious area within the Black Lake 200 foot shoreland area was calculated for the years 1937, 1944, 1977, 1980, 1992, 1996, 2000, and 2005 using the following methods. The 200 foot Black Lake shoreland study area was determined for each year analyzed. Within the established study area land-cover types were delineated and digitized into polygons. The percentage of impervious surface for each polygon of land-cover type was then estimated. The coefficients in the calculation of percentage of impervious surface for each land-cover type are presented below in Table 1, and are based on values determined by Karr 1998 and Booth et al. 2001. From these data, an estimate of the total impervious area within the shoreland area surrounding Black Lake was calculated.

Table 1. Estimated percent impervious values for land-cover types

Land-cover Type	Percent Impervious	Source
Agriculture	0	Karr (1998)
Forest	3	Booth et al. (2001)
Grasslands: grass, pasture, bare earth, recent clear cuts, scrub/shrub, herbaceous	5	Booth et al. (2001) & Karr (1998)
Low Intensity Residential	30	Karr (1998)
High Intensity Residential	44	Karr (1998)
Commercial/Industrial/Transportation	80	Karr (1998)

Time Periods Used

The following time frames were used, based on years that regulations were actually implemented in the study area: 1) pre-SMP: using the 1937 and 1944 datasets; 2) post-SMP and pre-GMA (the 1995 date is used to reflect the actual implementation within the study area): using the 1977, 1980, and 1992 datasets; and 3) post-SMP and post-GMA: using the 1996, 2000, and 2005 datasets.

Method Used to Calculate the Rate of Change for Impervious Surfaces

The rate of change for total impervious area was determined for the timeframes discussed above, which correspond with the adoption of impervious surface regulations. The rate of change in total impervious area was calculated using the following equation: $(X_1-X_2)/Y$ Where, X_1 and X_2 represent total

impervious acreages for two different data sets, and Y equals the number of years between the two data sets.

Chapter 6: Results, Conclusions, and Recommendations

Overview

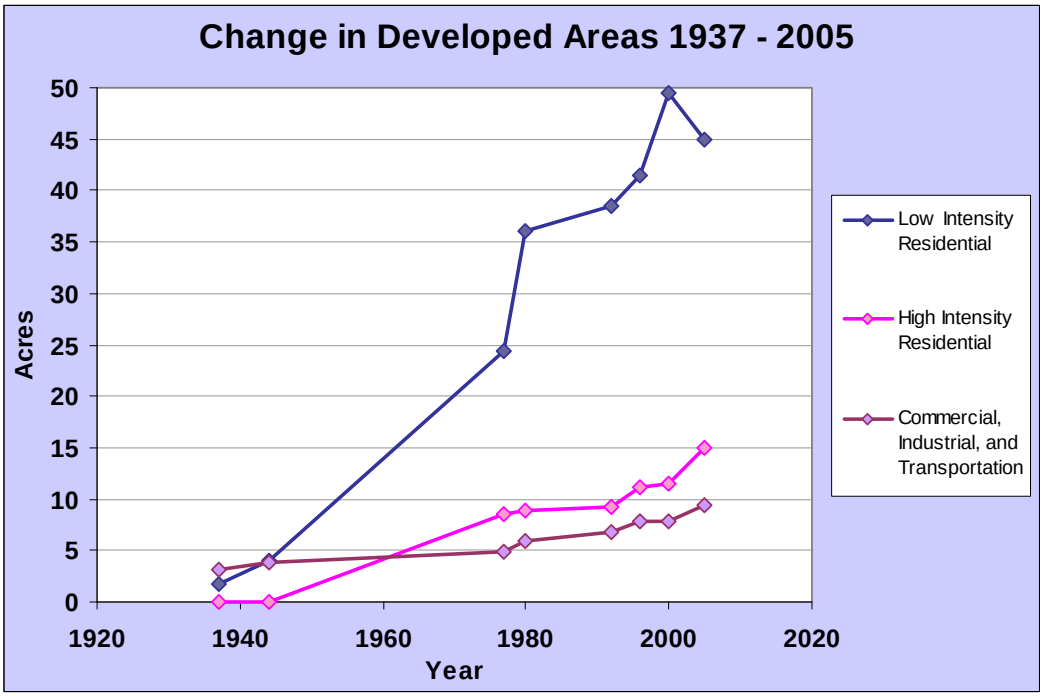
The results of the total impervious area analysis and policy analysis for the case study area are detailed below. Information regarding specific land-cover types provides a look at how the landscape has changed over time, and the rate of change data illustrates how fast the alteration occurred. The research done for this thesis indicates that total impervious area analysis data can be used to evaluate how effective regulations have been at limiting increases in impervious surfaces within the study area. This is primarily done by looking at the rate of change data in combination with the regulatory implementation timeline.

Results for Step 1: Change in Land-Cover Categories and Total Impervious Area Over Time

Change in Land-Cover Categories

Changes in individual land-cover types were assessed over the time span of available data. Within Black Lake's 200 foot shoreland area, the following land-cover types were identified: forest, grassland, low intensity residential, high intensity residential, and commercial/industrial/transportation. No agricultural lands were identified. This type of specific land-cover type change information is necessary to perform the total impervious area analysis for this thesis. These data are also worth examining for their potential to answer a variety of specific land-use questions regarding the study area.

Figure 3. Change in Development within Black Lake's 200 foot Shoreland Area 1937 - 2005

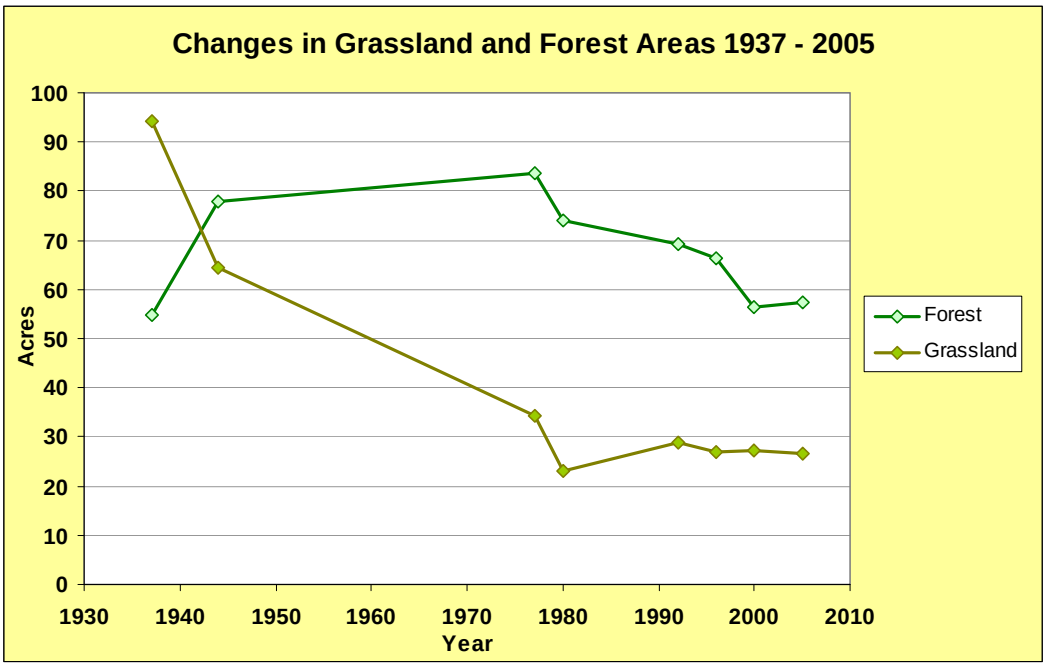


As shown in Figure 3, high intensity residential, and commercial/industrial/transportation land-cover types continually increased over the last 68 years. Low intensity residential development increased up until 2000. Between 2000 and 2005 it decreased by 5 acres. The cause for this decrease is unknown; however, my assumption is that some low intensity residential acreage was converted to high intensity residential or commercial/industrial/transportation acreage during that time period. High intensity residential development was nonexistant in 1937 and 1944. It wasn't until 1977 that approximately 8 acres of this type of development was recorded. In comparison, commercial/industrial/transportation land-cover areas had the smallest increase, only 6 acres between 1937 and 2005. It is interesting to note that 3 acres of this

type of land-cover was present in 1937, which is more than the combined total for the two land-cover types associated with development. One possible explanation is that clear-cutting was occurring extensively within the study area in 1937, and the predominant type of development was the infrastructure supporting logging activities.

The logging or clear-cutting that occurred prior to 1937 is likely also responsible for the small amount of forested land within the study area in 1937, only 55 acres. Figure 4 shows that the amount of forested land increased up to 84 acres from 1937 to 1977, likely due to re-growth. Then from 1977 to 2005 the number of forested acres steadily declined to 57 acres in 2005, ironically quite close to the amount found in 1937. By 2005, the forested acres had been largely replaced by development, rather than clear-cutting activities. Therefore, the possibility of re-growth or a repeat of the increase in forested land like the one experienced between 1937 and 1977 is highly unlikely. In general, forestlands fluctuated over the 68 year time span covered by this thesis, as did grasslands.

Figure 4. Change in Grassland and Forest Areas within Black Lake's 200 foot Shoreland Area 1937 - 2005

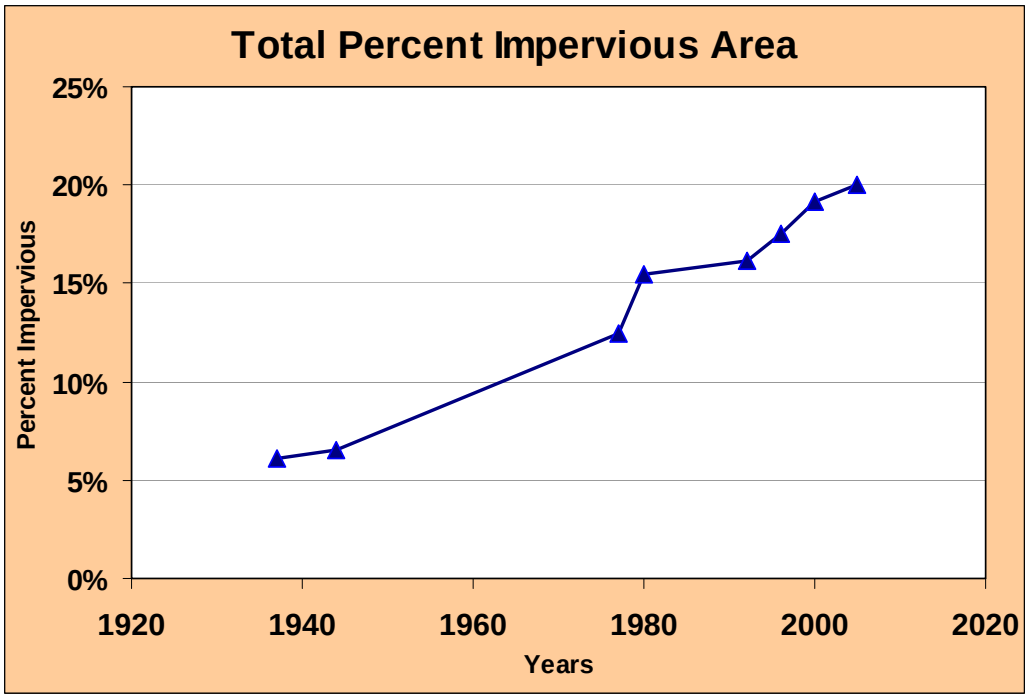


The number of acres covered by grasslands decreased from 94 acres in 1937 to approximately 27 acres in 2005. Yet from 1980 to 2005 grasslands increased from a low of 23 acres in 1980 to 29 acres in 1992 and then back down to 27 acres in 2005. This change over 25 years may be attributable to forestlands being cleared, which created more grasslands. This is uncertain speculation, however, and needs verification from a more in-depth investigation, which was outside the scope of this thesis. Overall, grasslands experienced the most significant change with close to 70 acres being converted to other land-cover types over this study's time span.

Change in Total Impervious Area

The quantity of each land-cover type was determined and used to calculate the total impervious area present for each aerial photo set. The changes in the amount of total impervious area within the study region are given in Figure 5.

Figure 5. Change in Total Percent Impervious Area for Black Lake's 200 foot Shoreland Area 1937 - 2005



From 1937 to 2005, the total impervious area found within the study area increased from 6% to 20%. The amount of impervious area steadily increased between 1944 and 1977, from 6.5% to 12.5% over that 33 year time period. However the greatest increase over a short time span occurred from 1977 to 1980. During this time period the total impervious area increased from 12% to 15% for a 3% increase in just three years. In general the 14% increase in total impervious

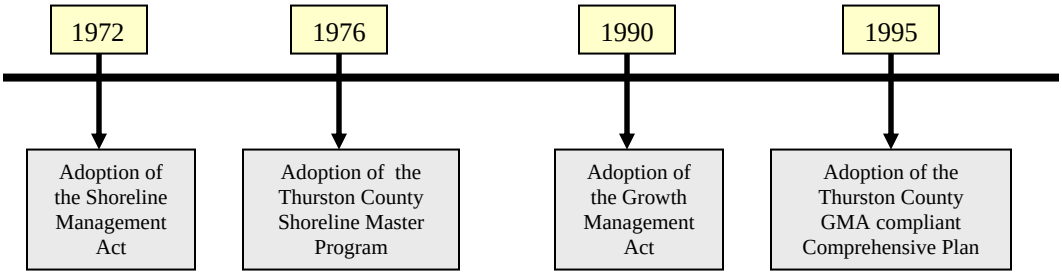
area is a concern for the study area, as is the total of 20% impervious area present in 2005.

The threshold for the amount of impervious surface coverage that leads to ecosystem degradation in a drainage basin is thought to be 10%. (Booth and Jackson, 1997; Alberti et. al., 2006) Although the study area is not an entire drainage basin, the threshold is still a relevant measure for concern, as Black Lake is a closed system and the shoreland area is a small region directly connected to the water's edge. Based on this assumption, the 20% total impervious area found within the study area in 2005 implies that ecosystem degradation is occurring due to the effects of impervious surface coverage. The data also indicate that the amount of total impervious area is continually increasing and therefore, any existing ecosystem degradation is likely to continue.

Results for Step 2: Timeline for the Adoption and Implementation of Land-Use Regulations

The policy analysis performed for this thesis yielded two state laws that mandate the majority of Thurston County's land-use regulation policies pertaining to impervious surface limitations. These two are the Shoreline Management Act and the Growth Management, which were described in detail in Chapter 3. Thurston County adopted a Shoreline Master Program to comply with the SMA and a Comprehensive Plan to comply with the GMA. The implementation dates for these two sets of regulations were used for the regulatory evaluation process undertaken in Step 3. Figure 6 provides the complete timeline and specific adoption dates.

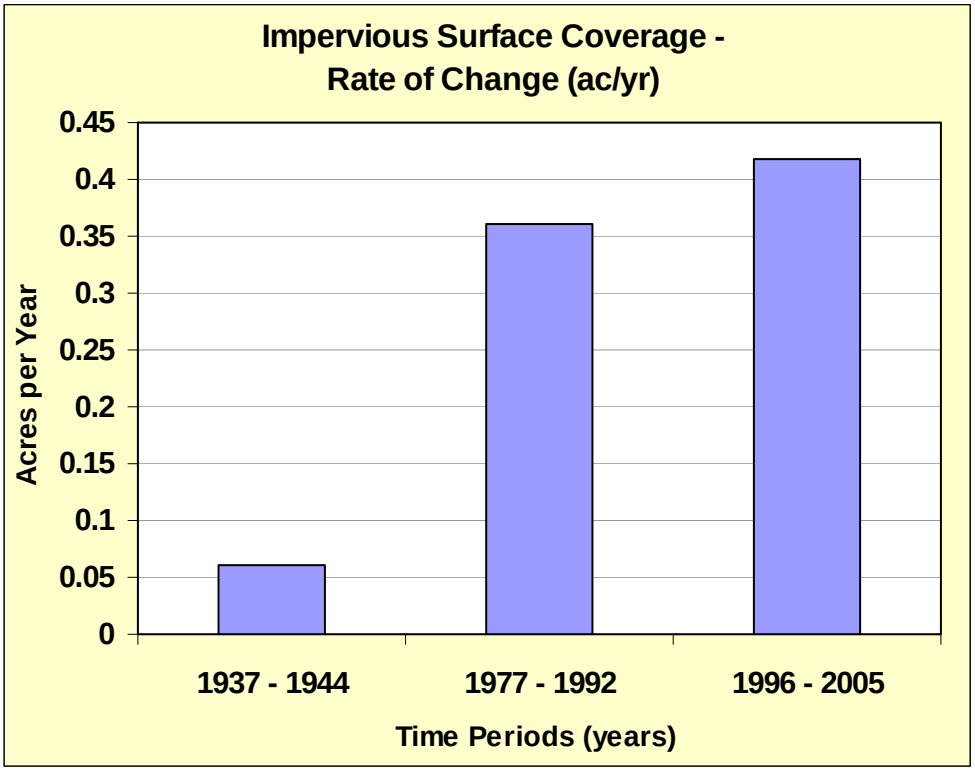
Figure 6. Regulatory Implementation Timeline



Results for Step 3: Evaluation of Thurston County's Effectiveness at Regulating Impervious Surfaces

Figure 7 shows how the rate of change for impervious surfaces has varied over the 68 year time span were categorized by the dates for adoption and implementation of the applicable regulations analyzed in this thesis.

Figure 7. Rate of Change in Impervious Surface Coverage within Black Lake's 200 foot Shoreland Area



The time periods represented in Figure 7 were established to show the rate of increase in impervious area before and after the implementation of specific regulations. Analyzing the rate of change in the percent of total impervious surface in combination with the dates that key regulations were implemented, provides a way to evaluate regulatory effectiveness. When looking at Figure 7 it is important to remember that although the Shoreline Management Act was adopted in 1972, Thurston County did not adopt its first Shoreline Master Program until 1976. Similarly, although the Growth Management Act was adopted in 1990, Thurston County did not update its comprehensive plan to come into compliance with the GMA until 1995.

The results of the analysis performed in this thesis indicate that neither the implementation of the Shoreline Management Act or the Growth Management Act halted the rate of increase in impervious area within the study region. The rate of change from 1937 – 1944 was 0.06 acres/year and this increased for the years 1977 – 1992 to 0.36 acres/year. The rate increased further for the years 1996 – 2005 to 0.42 acres per year. Therefore, the implementation of these regulations did not slow the rate at which landscapes are being covered by impervious surfaces. The rate of increase in impervious surfaces is still increasing after the implementation of both of these regulations. Therefore, it is clear that additional regulations or alternative efforts are needed to counter this trend.

Results for Step 4: Summary of Benefits and Limitations

There are multiple benefits to the use of total-impervious-area analysis as a tool for evaluating the effectiveness of regulations that limit impervious surfaces. For example, the data gathered as part of a total-impervious-area analysis can be used to set benchmarks for specific areas. The ability to set benchmarks allows for the effectiveness of regulations to be evaluated. In terms of the use of aerial photos, it should be noted that they can be regularly acquired via a relatively inexpensive data-gathering exercise. These photographs provide information that can be used in conjunction with other temporally collected data. This type of analysis also yields useful land-cover data, as shown in Chapter 5, which can detect changes in a specific type of land-cover. In other words, it can provide information relevant to other inquiries besides changes in impervious area.

These benefits aside, there were some restrictions on the depth of the evaluation that was possible for this thesis using the available data. The parcel-specific standards outlined in Thurston County's regulations pertaining to impervious surfaces could not be evaluated for their consistent application. Therefore, no determination regarding whether they have been effectively implemented was made as a part of this research effort. Yet, although this study does not investigate the question at the parcel-scale, a more comprehensive study that considers implications of permit conditions could be undertaken with access to higher resolution photographs and multi-spectral imagery over a finite time period. A study that normalizes for other variables (economic, social, and

political) would more closely evaluate the regulatory effects on increases in impervious surfaces. (Cinde Donoghue: Personal Communication, 2007)

Recommendations

The existing regulations have not prevented the amount or rate of impervious surfaces from increasing, which suggests that additional measures are necessary to at least reduce the rate at which land is being converted to impervious surfaces within the study area. One option is the creation of specific zoning districts that further restrict the amount of impervious surface allowed for each parcel. These districts could be applied to drainage basins containing environmentally sensitive areas, in order to limit the amount of development or impervious surfaces allowed within those areas. Another option is the adoption of more restrictive environmental designation areas via the adoption of amendments to the Thurston County Shoreline Master Program. Either of these options could require specific caps on the amount of impervious area allowed, either on each parcel or on a cumulative basis for the entire area. To further increase the protection of ecosystems throughout Thurston County, the environmental designation areas mentioned above could be incorporated into the County's Comprehensive Plan or Critical Areas Ordinance, in order to extend their range to lands outside of Thurston County's shoreline regions.

In addition to the adoption of more restrictive regulations, Thurston County should explore partnerships with other organizations and government agencies. Through these partnerships, resources could be pooled to support a

combined effort aimed at informing the general public of the reasons behind the need for impervious surface limitations. A public education and outreach campaign would help build support for more restrictive regulations. This type of support is vital, as the County attempts to balances the Growth Management Act's planning goals, and the economic and private property interests of its citizens.

The County also needs to invest in staff, data, and technology that will allow for the parcel-level research mentioned above to take place. This type of information is vital to policy makers and citizens so that they can evaluate how successfully regulations have fulfilled their objectives. Improvements to data availability and storage techniques should also be sought, in order to improve the sharing of data from one department to another. In general, there is a need for a central location for Thurston County's physical and environmental condition data that could house information used by State Agencies, Non-Governmental Organizations and Thurston County's individual departments.

Conclusion

The results of this thesis' research indicate that: 1) the amount of impervious surface present within Black Lake's 200 foot shoreland area has steadily increased from 1937 to 2005; 2) The primary regulations utilized by Thurston County to limit impervious surfaces are those mandated by the Shoreline Management Act (implemented in 1976) and the Growth Management Act (implemented in 1995); 3) Thurston County's regulations have not lowered the growth rate of impervious surfaces within the study area; and 4) Total

impervious area analysis data can be used to successfully evaluate how effectively regulations limit increases in impervious surfaces. This thesis found that additional regulations need to be adopted by Thurston County, or at the very least existing regulations need to be made more restrictive in order to prevent the continued increase in impervious surfaces within the study area. In conclusion, additional analysis needs to be done on a County-wide basis to determine how effectively Thurston County's regulations are limiting increases in impervious surfaces. Efforts to inform the public regarding the hazards associated with increases in impervious surfaces also need to be implemented.

References

Alberti, M., et al. 2006. The impact of urban patterns on aquatic ecosystems: An empirical analysis in Puget lowland sub-basins. Journal of Landscape and Urban Planning, date of issue: 10.1016/j.landurbplan.2006.08.001.

Arnold, C.L., and C. J. Gibbons. 1996. Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American Planning Association 62(2): 243-258.

Booth, D.B. 1991. Urbanization and the natural drainage system – impacts, solutions, and prognosis. The Northwest Environmental Journal 7:93-118.

Booth, D.B., and C. R. Jackson. 1997. Urbanization of Aquatic System-Degradation Thresholds, Stormwater Detention, and the Limits of Mitigation. Journal of the American Water Resources Association 22: 1-18.

Booth, D.B. 2000. Forest Cover, Impervious-Surface Area, and the Mitigation of Urbanization Impacts in King County, Washington: Prepared for King County Water and Land Resources Division. Seattle, Washington.

Booth, D. B., et al. 2001. Urban Stream Rehabilitation in the Pacific Northwest: Final Report to U.S. EPA. Center for Urban Water Resources, University of Washington, Seattle Washington.

Donoghue, C. 2007. Thurston County Long Range Planning Department. Personal Communication.

Gates, Tim. 2003. Introduction to the Shoreline Management Act. Washington State Department of Ecology, PUB 99-113, Lacey, Washington.

Grant, J., W. Schroeer, B. Petersen, and M. O'Neill. 2000. Our built and natural environments: A technical review of the interactions between land use, transportation, and environmental quality. U.S. Environmental Protection Agency, EPA 231-R-00-005, Washington D.C.

Hinman, Curtis. 2005. Low Impact Development: Technical guidance manual for Puget Sound. Puget Sound Action Team, 05-03, Olympia, Washington. Washington State University Pierce County Extension, Tacoma, Washington.

Karr, J.R. 1998. Rivers as sentinels: using biology of rivers to guide landscape management. In: Naiman, R.J., Bilby. R. (Eds.). River Ecology and management: Lessons from the Pacific Coastal Ecoregion. Springer, New York, pp. 502-528.

May, C.W., E. B. Welch, R.R. Horner, J.R. Karr, and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams: Final Report for the Washington State Department of Ecology. Department of Civil Engineering, Environmental Engineering and Science Water Resources Series Technical Report No. 154, University of Washington, Seattle, Washington.

Municipal Research and Services Center of Washington. Comprehensive Planning/Growth Management. [updated April 2007; cited August 2007]. Available from http://www.mrsc.org/subjects/planning/compplan.aspx.

National Water Quality Inventory: 1996 Report to Congress. 1998. U.S. Environmental Protection Agency, Washington D.C.

NLCD Land Cover Classification System Key. 1999. United States Geologic Survey.

Watershed Protection Research Monograph No.1: Impacts of Impervious Cover on Aquatic Systems. 2003. The Center for Watershed Protection, Elliot City, Maryland.

Thurston County. 1995a. Comprehensive Plan. Thurston County Planning Department, Olympia, Washington.

Thurston County. 1995b. Comprehensive Plan: The City of Tumwater and Thurston County Joint Plan. Thurston County Long Range Planning Department, Olympia, Washington.

Thurston County. 1997. Development Code: Critical Areas Ordinance, Chapter 17.15. Thurston County Planning Department, Olympia, Washington.

Thurston County. 1994. Drainage Design and Erosion Control Manual. Thurston County Waste and Water Management Department, Olympia, Washington.

Thurston County Geodata Center. Thurston County GIS data files. [updated August 2007; cited August 2007]. Available from http://www.geodata.org

Thurston County. 1976. Shoreline Master Program. Thurston Regional Planning Council, Olympia, Washington.

Thurston County. 2005. Water Resources: Annual Monitoring Report 2003 – 2005 Water Years. Thurston County Department of Environmental Health, Olympia, Washington.

The Relationship of Land-Cover to Total and Effective Impervious Area: Building input files for the hydrological simulation program – FORTRAN

(HSPF) model. 2003. Thurston Regional Planning Council, Olympia, Washington.

Urbanization and Streams: Studies of Hydrologic Impacts. 1997. U.S. Environmental Protection Agency, EPA 20460 841-R-97-009, Washington D.C.

Washington State History Link. Washington Legislature enacts Growth Management Act on April 1, 1990. [updated 2007; cited August 2007] Available from http://www.historylink.org/essays/printer_friendly/index.cfm?file_id=7759.

Washington State. 1990. The Growth Management Act, RCW 36.70A Washington State Legislature, Olympia, Washington.

Washington State. 1972. The Shoreline Management Act, RCW 90.58. Washington State Legislature, Olympia, Washington.

Wissmar, R.C. 1993. The Need for Long-Term Stream Monitoring Programs in Forest Ecosystems of the Pacific Northwest. Journal of Environmental Monitoring and Assessment. 26:219-234.

Appendices

Appendix 1. Thurston County Comprehensive Plan: Chapter 9 – Natural Environment

III. GOALS, OBJECTIVES AND POLICIES

A. GEOLOGIC HAZARD AREAS

GOAL: MINIMIZE THE LOSS OF LIFE AND PROPERTY FROM LANDSLIDES AND SEISMIC, VOLCANIC, OR OTHER NATURALLY OCCURRING EVENTS, AND MINIMIZE OR ELIMINATE LAND-USE IMPACTS ON GEOLOGICALLY HAZARDOUS AREAS.

OBJECTIVE: To designate and manage geologic hazard areas to avoid loss of life and damage to structures by guiding development away from geologic hazard areas and by regulating uses and activities that occur within or near such areas in a manner that minimizes the potential for damage or loss of life.

POLICIES:

1. The county should designate and provide for the protection and management of geologic hazard areas based on best available science and cumulative impact assessments of existing and planned land and resource uses within and near geologic hazard areas.

2. The county should restrict development and resource use within or near areas susceptible to significant damage from erosion, landslides, earthquakes or lahar flows, as necessary to protect life, property, and wildlife habitats (e.g., streams and marine waters downslope).

3. The county should cooperate with other jurisdictions and agencies to implement the "Natural Hazards Mitigation Plan for the Thurston Region," TRPC 2003, or as hereafter amended**.**

4. The county should protect the public from natural hazards, minimize the need for emergency rescues and replacement of public facilities damaged by natural forces, and avoid public subsidy of private development located in areas vulnerable to damage from natural events by minimizing the amount of development at risk.

5. The county should delineate landslide hazards, the path of potential lahar flows, and other natural hazard areas with the greatest degree of accuracy possible. Reevaluate land-use regulations in light of the refined mapping and make changes as warranted, consistent with public safety and best available science.

6. The county should collaborate with other jurisdictions and agencies to gain a better understanding of earthquake hazards in the county and devise appropriate mitigative measures to minimize the loss of life and property.

B. GROUNDWATER AND AQUIFER RECHARGE AREAS

GOAL: PROTECT Groundwater QUALITY AND QUANTITY.

OBJECTIVE: To provide for the identification and protection of sensitive aquifer recharge areas, protect groundwater quality, and prudently conserve groundwater resources.

POLICIES:

1. The county should designate and provide for the protection and management of groundwater and aquifer recharge areas based on best available science and cumulative impact assessments of existing and planned future land and resource uses within and near aquifer recharge areas.

2. The county should protect groundwater quality and prevent aquifer contamination, degradation, and depletion through the comprehensive management of groundwater in conformance with the Clean Water Act, the Northern Thurston County Ground Water Management Plan, the South Thurston County Aquifer Protection Strategy, and all other applicable federal, state and local water quality regulations.

3. The county should determine, based on watershed plans, if there are areas where low summer stream flows or elevated instream water temperature may, now or in the future, imperil anadromous or native resident fish. If such areas are identified, the county should devise and implement development restrictions and management practices as necessary to sustain the fish.

4. The county should reduce allowed land-use densities, in areas where the supply of groundwater is limited, to the extent necessary to preserve sufficient water for existing uses, unless alternative domestic water supplies are available from other sources. Special consideration should be given to areas where additional groundwater withdrawals would diminish summer stream flows and elevate instream water temperatures and thereby jeopardize the survival of anadromous or native resident fish.

5. The county should regulate land-uses within designated wellhead protection areas to prevent degradation of groundwater quality.

6. The county should strive to develop and fully implement regional wellhead protection policies and locally developed wellhead protection plans. Support efforts by water utilities to acquire or provide long-term management of wellhead protection areas.

7. The county should encourage that coordinated, reliable water systems be used to provide water in the urban growth areas. Urge jurisdictions to develop

compatible, coordinated water system design standards for their growth areas.

8. The county should discourage construction and use of individual private wells in urban growth areas where community or public water sources are reasonably and economically available.

9. The county should encourage the use of community or public water in unsewered areas where residential density is in excess of one unit per acre. Community or public water systems should also be provided in residential developments with densities in excess of one unit per two acres and excessive soil permeability.

10. The county should ensure that community and public water systems and supplies are managed to meet state and local health standards.

11. The county should regularly monitor and protect the water quality of watersheds feeding into water bodies used for drinking water (e.g., Summit Lake). If pollution is identified, the county should devise and implement programs to improve water quality.

12. The county should encourage the safe recycling and reuse of water and treated wastewater in order to recharge aquifers, conserve groundwater supplies, and reduce contamination of receiving waters.

13. The county should encourage the use of no- and low-water use appliances and fixtures, particularly in conjunction with septic systems, to reduce the potential for groundwater contamination.

14. The county should promote the use of integrated pest management and the reduction of pesticide and fertilizer use by residents, businesses, and governmental agencies in designated wellhead protection areas and in areas identified as a source of contamination to important wildlife habitats and shellfish beds.

C. SURFACE WATER

GOAL: PROTECT AND IMPROVE THE WATER QUALITY AND BIOLOGICAL HEALTH OF LAKES, WETLANDS, RIVERS, STREAMS, AND PUGET SOUND.

OBJECTIVE 1: To manage surface water in a manner that will protect or improve the quality of water sustaining human use, wildlife, and aquatic life.

POLICIES:

1. The county should provide for the protection and management of surface water, consistent with the Clean Water Act, based on best available science and

cumulative impact assessments of existing and planned future land and resource uses within the watersheds**.**

2. The county should retain substantially in their natural condition: ponds, wetlands, rivers, lakes and streams, and their associated buffers and riparian areas.

3. The county should protect streams from the adverse impacts of activities occurring within their watersheds to avoid degradation of their water quality and biological health. These impacts include, but are not limit to, elevation of stream water temperature and low flows in summer and stream channel damage and sedimentation from excessive flows during winter.

4. The county should protect and maintain the valuable natural functions of wetlands by maintaining an undisturbed or restored native vegetation buffer around the wetland and by prohibiting filling, draining, and clearing within wetlands and their associated buffers.

5. The county should designate and protect riparian habitat areas to help maintain water quality consistent with best available science. (Also see related policies under Section E, Important Fish, Wildlife, and Plant Habitat).

6. The county should prevent development and activities in streams, riparian areas, and wetlands and any associated buffers that would damage water quality or habitat functions, except to the minimum extent necessary when there is no reasonable alternative for accommodating an essential use (e.g., an essential road or utility crossing).

7. The county should consider establishing a wetland mitigation bank to provide an alternative to individual stream and wetland mitigation projects associated with essential public projects. Enhancement of degraded wetlands is preferred over creation of new wetlands.

8. The county should require, to the extent legally permissible, restoration of degraded buffers and wetlands associated with lakes, streams, rivers, and Puget Sound as a part of new land-uses and development activity.

9. The county should cooperate with adjoining jurisdictions to develop complementary regulations pertaining to streams, upland wildlife habitat, and other Critical Areas that span jurisdictional boundaries.

10. The county should evaluate the performance of county regulations in maintaining surface water and monitor the performance of restoration and enhancement projects to provide a basis for periodic refinement of county regulations and management practices.

11. The county should promote the use of integrated pest management, reduction of pesticide and fertilizer use, and best management practices for animal waste by residents, businesses, and governmental agencies in areas identified as a source of contamination of surface water, particularly if it affects the harvest of shellfish.

12. The county should provide technical assistance and education, to the extent resources allow, to operators of small businesses and industrial uses, and residents located near surface water bodies regarding proper storage, handling and disposal of hazardous materials.

13. The county should encourage the Thurston Conservation District Board to continue their voluntary efforts regarding education, conservation planning, and use of best management practices on existing farms, golf courses, parks, schools, residences, and other facilities that use pesticides and fertilizers near surface water bodies.

OBJECTIVE 2: *Lake Management* - To provide for a comprehensive, long-term approach to lake management that accommodates all appropriate uses and benefits, consistent with the maintenance or enhancement of water quality.

POLICIES:

1. The county should work with property owners and interested parties to develop an integrated aquatic management plan for lakes, consistent with best available science and the Clean Water Act, that addresses pollution sources, such as stormwater runoff and on-site disposal system effluent, and the cumulative impacts of existing and planned future land and resource uses within the watersheds.

2. The county should strive to reduce the spread of Eurasian milfoil and other exotic aquatic weeds through monitoring, public information and other means.

OBJECTIVE 3: *Marine Waters and Shoreline Management* - To preserve and protect marine shorelines and near shore areas as valuable natural resources and habitats, consistent with state and federal law.

POLICIES:

1. The county should regulate uses and activities along the marine shoreline and within the waters of Puget Sound, consistent with the State Shoreline Management Act and the Clean Water Act, based on best available science and cumulative impact assessments of existing and planned future land and resource uses in upland watersheds.

2. The county should identify and protect, consistent with best available science, important, sensitive marine habitats, such as juvenile salmon migration corridors, kelp and eelgrass beds, shellfish beds, and herring and smelt spawning areas.

3. The county should protect special shoreline features, such as dry accretion beaches, and undeveloped bays and lagoons.

4. The county should provide information to property owners regarding various protection options for their marine shoreline consistent with the State Shoreline Management Act and the Shoreline Master Program for the Thurston Region. Encourage the use of "bioengineered" shoreline stabilization as an alternative to bulkheading or other forms of shoreline armoring where necessary to protect existing structures from erosion.

D. FREQUENTLY FLOODED AREAS

GOAL: PROTECT LIFE AND STRUCTURES FROM FLOOD HAZARDS AND RETAIN THE FLOOD STORAGE, TRANSMISSION CAPACITY, AND HABITAT VALUE OF FLOODPLAINS.

OBJECTIVE: To provide the highest degree of flood protection at the least cost.

POLICIES:

1. The county should provide the highest degree of flood protection at the least cost through identification and accommodation of natural flooding and channel migration processes that pose hazards to life or property. Protection and management should be based on best available science and cumulative impact assessments of existing and planned future land and resource uses within the floodplains, channel migration zones, and watersheds.

2. The county should prohibit development and emplacement of fill in floodways and floodplains, except to the minimum extent necessary to accommodate public infrastructure and utilities that cannot be accommodated elsewhere and to stabilize channels against erosion in order to protect existing agricultural lands, public roads and bridges, public infrastructure, utilities and significant private structures, and to achieve habitat enhancement. Any development in the floodways should be designed to avoid habitat degradation. Stream bank stabilization, if necessary, should be of a type that maintains or enhances habitat functions. Rip-rap and other hard armoring should only be used if there is no effective alternative, based on sound engineering principles, to protect existing structures or public facilities.

3. The county should provide for land-uses such as forestry, open space, public recreation, existing agriculture and water-dependent uses in areas subject to river flooding to minimize risks to life and structures and help retain or enhance habitat functions**.** Other uses and development in the floodplain should be restricted to minimize public safety risks (e.g., through compensating design features) and loss of habitat function.

4. The county should minimize disruption of long-term stream channel migration processes that allow formation of essential habitat features by prohibiting construction of new structures in channel migration zones and minimizing streambank stabilization.

5. The county should actively participate in the multi-jurisdictional flood hazard reduction efforts within the Chehalis River Basin.

6. The county should regulate uses in and around areas where groundwater periodically surfaces as necessary to avoid property damage and protect groundwater quality.

7. The county should maintain the county's enrollment in the Community Rating System through the National Flood Insurance Program.

E. IMPORTANT FISH, WILDLIFE, AND PLANT HABITAT

GOAL: PROTECT, CONSERVE, AND ENHANCE THE ECOLOGICAL FUNCTIONS OF IMPORTANT FISH, WILDLIFE, AND PLANT HABITATS.

OBJECTIVE: Identify important fish, wildlife, and plant habitats and develop strategies for protecting or restoring important habitats, particularly if they are at risk of significant degradation.

POLICIES:

1. The county should protect fish and wildlife habitats that are important to the long-term viability of locally important species in Thurston County, which are unique or rare, or which contain state priority species or species listed under the federal Endangered Species Act.

2. The county should identify and protect (e.g., through easements, fee acquisition, or regulations) land providing essential connections between riparian habitat areas, open spaces, and significant wildlife habitats sustaining state priority, federally listed, or locally important wildlife species. Include wildlife corridors that lead away from riparian areas to facilitate wildlife migration to upland habitats and minimize the potential for increased fecal contamination of streams from wildlife sources.

3. The county should encourage protection of areas containing special plants and special plant communities listed by the state Department of Natural Resources Heritage Program.

4. The county should establish and protect riparian habitat areas to maintain or enhance the functions sustaining aquatic life and terrestrial wildlife, consistent with best available science.

5. The county should establish priorities for performing stream/subwatershed assessments to tailor and refine riparian habitat widths, consistent with best available science, to provide appropriate water quality and habitat protection while minimizing the burden on affected property owners. Priority should be given to those areas at greatest risk of degradation, for example, due to potential impacts from existing and planned development, the sensitivity of dependent species, or the sensitivity of the watershed's hydrology to development.

6. The county should evaluate streams/riparian areas supporting anadromous fish, sensitive native resident fish, or state priority wildlife species to determine their long-term viability to sustain such fish and wildlife at buildout of the drainage basin under current regulations, consistent with best available science. The county should build upon the information and analysis produced through the Watershed Resource Inventory Area projects as necessary to assess current and projected stream and riparian conditions. In performing the assessments, consider factors such as stream gradient, channel dimensions, valley configurations, historical conditions, current stream conditions, the width, continuity and quality of riparian areas, the presence of any associated wetlands, aquatic and terrestrial habitat utilization and sensitivity, the intensity of adjacent uses, current zoning, the cumulative impacts of existing and planned future land and resource use, subwatershed hydrology (e.g., based on soil characteristics, tree cover, land-use types and characteristics, impervious surface coverage, and the performance of existing stormwater facilities), and water quality.

   If any streams/riparian areas that currently support anadromous fish, sensitive native resident fish, or state priority wildlife species would not be expected to sustain such fish and wildlife at buildout of the subwatershed under current zoning and development regulations, the county should identify and pursue viable remedial actions to preserve or enhance the habitat functions (e.g., maintaining water quality). Remedial actions may include, for example, limits on effective impervious surface coverage and retention of substantial tree cover in the subwatershed, higher stormwater standards, reduced housing density, limits on stream crossings by roads or utility lines to maintain the continuity of riparian areas, expanded riparian areas, and restoration.

7. The county should identify priorities for fish and wildlife habitat protection/acquisition and other remedial actions necessary to maintain or restore the riparian or important upland habitat. Consider giving highest priority for habitat protection/acquisition to the following:

   a. streams/riparian areas with sensitive fish or wildlife species in watersheds with existing or planned levels of development that threaten fish and wildlife survival;

b. streams/riparian areas that support significant numbers of anadromous or sensitive native resident fish in drainages with moderate levels of development which, based on best available science, have potential to be maintained or restored if prompt action is taken;

c. streams/riparian areas largely in a natural condition that support the county's largest or most sensitive populations of Chinook, coho or chum salmon, steelhead, cutthroat trout or other native fish, particularly if they are listed as endangered or threatened species; and

d. streams/riparian areas that support sensitive populations of priority wildlife species or significantly affect shellfish beds subject to harvest restrictions or closures.

8. The county should provide for removal of existing "man made" barriers to anadromous fish migration in streams (e.g., impassible culverts) and prohibit installation of new barriers.

9. The county should preserve adequate water quantity and quality for fish migration, spawning, incubation and rearing, including peak and summer flow levels, dissolved oxygen and chemical content, sediment load, and temperature.

10. The county should maintain and improve surface water quality, consistent with the Clean Water Act, such that pollution does not imperil public health or the survival of fish, shellfish, or other aquatic life or prevent the harvest of shellfish. Surface waters within the drainage basins of Geological Sensitive Areas, and areas of significant recreational or commercial shellfish harvesting should be maintained or restored to the highest quality possible.

11. The county should prohibit uses and activities that degrade lakes, streams and shellfish beds or result in the loss of the natural functions of waterbodies, wetlands, and groundwater aquifers.

12. The county should require that sewage treatment plant owners explore opportunities for the beneficial use of treated wastewater before any new point discharges are authorized. The county should prohibit any new wastewater discharges, including those from sewage treatment plants, into waters where shellfish are harvested, if the discharges would significantly harm the shellfish or their harvest potential.

13. The county should cooperate with adjoining jurisdictions to develop complementary regulations pertaining to streams, fish, wildlife, plant habitats, and other Critical Areas that span jurisdictional boundaries.

14. The county should prevent development and activities in streams, riparian areas, wetlands, other protected wildlife habitats and any associated

buffers that would damage their functions, except to the minimum extent necessary when there is no reasonable alternative for accommodating an essential use (e.g., an essential road or utility crossing).

15. The county should encourage stream and wetland restoration activities consistent with best available science through partnerships between the county, conservation district, other agencies, and landowners. Provide incentives for landowners to retain, enhance, or restore important wildlife habitat such as reduced permit fees, expedited permit review, and reduction in property taxes.

F. GREENSPACES

GOAL: IDENTIFY AND PROTECT IMPORTANT GREENSPACES USEFUL FOR RECREATION, TRAILS, WATER RESOURCE PROTECTION OR WHICH CONTAIN IMPORTANT WILDLIFE HABITATS.

OBJECTIVE 1: *Important Greenspaces Designation* – To provide for identification of important greenspaces within and adjacent to Thurston County, consistent with state law.

POLICIES:

1. The county should periodically update the Important Greenspaces Map (Map 31) to accurately reflect current conditions and knowledge regarding sites, open space corridors (including corridors within and between urban growth areas), and ecological units which are useful for recreation, trails, or water resource protection, contain important wildlife habitats and species, or provide connections to Critical Areas that would be useful for wildlife travel or dispersal.

2. The county should coordinate greenspaces planning with important greenspaces stakeholders (e.g., tribes, federal agencies, state departments, county departments, adjacent jurisdictions, private conservation organizations, local land trusts, resource land owners, county residents and other interested parties.)

3. The county should support greenspaces planning efforts by important greenspaces stakeholders within or adjacent to Thurston County.

4. The county should provide for extensions of urban trails that have been identified by an adjacent jurisdiction, consistent with the Important Greenspaces Map (Map 31). However, important wildlife habitats, including riparian areas, should have priority over trails. Therefore, locate, design, and construct trails to avoid significantly degrading important wildlife habitats or disrupting their use by state priority or federally protected wildlife species.

OBJECTIVE 2: *Protection Options* - Use a variety of protection options in order to protect the greatest number of priority greenspaces.

POLICIES:

1. The county should establish a system for identifying and prioritizing greenspaces for acquisition or other form of protection in order to maximize public benefits. The following types of lands should be considered for acquisition:

    a. lands important to public health and safety, such as critical aquifer recharge areas for public drinking water supplies, wellhead protection areas, flood prone areas, geologically hazardous areas, and sensitive and priority watersheds defined in adopted basin plans;

    b. lands containing environmental features with significant educational, scientific, wildlife habitat (especially areas important to the preservation of anadromous fish), natural or historic values;

    c. lands that provide access to fresh and marine waters;

    d. lands with recreational values, such as sites with potential to accommodate picnicking, boating, fishing, swimming, camping, trail use, nature observation, play areas and sports fields, or open space corridors within and between urban growth areas, consistent with the Important Greenspaces Map (Map 31); and

    e. lands that provide scenic amenity or community identity.

2. The county should identify and evaluate the protection options for each important greenspace. Preservation options should include, but not be limited to: critical area designation (where appropriate), clustered development, enrollment in the open space tax program, conservation easements, purchase or transfer of development rights, and public acquisition.

3. The county should provide for identification and preservation of important greenspaces in coordination with the acquisition and development of future county parks, trails, preserves, and water resource protection areas.

4. The county should encourage private property owners to protect important greenspaces through the clustering of development on the least sensitive portion of the property.

5. The county should encourage private property owners with priority resources, according to the Public Benefit Rating System, to enroll their properties in the Open Space Tax Program.

6. The county should support efforts by land trusts and conservation organizations to acquire either fee simple property for preserves or conservation easements on private lands serving important habitat or water quality functions, protecting critical areas, or identified on the Important Greenspaces Map (Map 31).

7. The county should support efforts to protect lands identified in the Washington Department of Natural Resources Natural Heritage Data Base, through either private initiatives or public acquisition.

8. The county should support efforts by other governmental agencies to acquire and develop parks, trails or preserves within or adjacent to Thurston County, consistent with adopted park plans, the Important Greenspaces Map (Map 31), and the preservation of important wildlife habitat.

9. The county should examine, and act on as appropriate, opportunities to develop operating agreements and/or leases for land in proximity to urbanizing areas that are appropriate for preservation as open space, nature study areas or conservation areas.

10. The county should develop liaison with the Nature Conservancy, land trusts and other organizations and agencies interested in acquisition of lands for conservation and preservation.

11. The county should require, to the extent legally permissible, that areas for active recreation or open space be dedicated as part of the development approval process for residential developments containing ten or more acres that are zoned for more than one residential dwelling unit per acre, based on the demand expected to be generated by the developments for such areas.

12. The county should consider amending the open space program enrollment criteria to enable enrollment of parcels of less than five acres that contain important wildlife habitat, consistent with Chapter 84.34 RCW.

13. The county should encourage the use of special incentives to preserve and protect high quality or sensitive environmental resources that regulations do not adequately protect or to minimize the burden of affected private property owners. The means to be used (in order of priority) include: open space taxation, the assistance of federal or state resource agencies, the initiatives of private conservation organizations and local land trusts, or public acquisition.

G. AIR QUALITY

GOAL: protect and improve the county's air quality and minimize OR ELIMINATE ODOR AND noise from new land-uses that would reduce the livability of residential areas OR SIGNIFICANTLY DEGRADE IMPORTANT WILDLIIFE HABITAT.

OBJECTIVE: To protect the livability of established neighborhoods and to protect sensitive wildlife habitats.

POLICIES:

1. The county should support federal, state, and regional clean air policies and air quality standards and regulations.

2. The county should assess the impacts of new land-uses and activities on air quality, including pollution, particulate matter, odor and noise. The county should direct those uses that are likely to generate health or nuisance problems away from residential neighborhoods, schools, hospitals, and facilities housing residents who are particularly susceptible to air quality problems (e.g., long-term health care centers), and wildlife refuges.

3. The county should maintain the peace and quiet of residential neighborhoods by:

    a. limiting noisy, polluting, or heavy traffic generating land-uses and activities in close proximity to such areas;

    b. through the use of screens, open space, or other buffers; and

    c. through enforcement of noise and air emission standards.

4. The county should minimize the noise impacts from noise-producing sources, such as airports and military firing ranges, by designating noise impacted lands for use as forestry, agriculture, public reserves, industrial and, as a last priority, low density residential. Require that the deed, title, or covenants for lots in new residential subdivisions contain statements notifying prospective purchasers that the property will be affected by noise.

5. The county should continue to coordinate with local and regional government agencies to reduce air pollution by adopting land-use and transportation plans that help reduce the amount of vehicle emissions.

6. The county should provide education and information to the public to promote reduction of air pollutants and particulate matter.

H. MANAGEMENT APPROACHES

GOAL: ENCOURAGE COMPREHENSIVE, SCALE-APPROPRIATE APPROACHES TO ENVIRONMENTAL RESOURCE MANAGEMENT AND COORDINATION OF MANAGEMENT ACTIONS.

OBJECTIVE 1: *Management Approaches*- To encourage and facilitate coordination of resource management to enable efficient use of public funds, maximize environmental and public benefits through coordinated and complementary actions, and to facilitate work at the appropriate scale (e.g., subwatershed).

POLICIES:

1. The county should establish management approaches that reflect our dependence on natural systems and maintain a balance between human uses and the natural environment.

2. The county should establish a pattern and intensity of land and resource use that are consistent with the limitations imposed by natural constraints (e.g., flooding, steep slopes prone to landslides, and saturated soil conditions), sustain environmental functions (e.g., aquifer recharge, water storage and cleansing performed by wetlands), and minimize public safety risks.

3. The county should assess the cumulative impacts of past, current, and planned future land and resource uses on the county's natural environment and implement management and protection programs that address these impacts.

4. The county should incorporate in management approaches, education programs; the use of incentives; regulation; restoration; construction; maintenance; county or land trust acquisition; and adaptive management, including establishing performance goals and monitoring programs, to enable evaluation of the effectiveness of implemented regulations and programs.

5. The county should provide for management at the appropriate scale (e.g., subwatershed), take into account the many factors and interests involved, and draw upon best available science.

6. The county should select a management approach that best addresses the degree of risks or hazards to the public, the uniqueness and sensitivity of the resource, and the long-term public benefit and the cost and financing feasibility.

7. The county should designate and manage Critical Areas in a manner that will sustain dependent human and wildlife use and avoid loss of life and damage to structures.

OBJECTIVE 2: *Water Resource Management Approaches* – To coordinate water resources planning, funding and implementation within Thurston County to ensure high quality surface and groundwater, preserve the functions of water resources, ensure compatibility between land and water uses and minimize the costs of parallel programs.

POLICIES:

1. The county should manage county-wide water resources through a coordinated water resources program that integrates county groundwater, stormwater, lakes, stream and wetland programs related to water quantity and quality.

2. The county should consider the hydrologic continuity between ground and surface water when managing water resources.

3. The county should address water resource concerns by the appropriate scale, such as a catchment, subwatershed or sub-basin for surface waters and by aquifers for groundwater.

4. The county should support watershed planning processes conducted under RCW 90.82 as a framework for comprehensive water resource management.

5. The county should involve affected stakeholders in groundwater, watershed and stormwater basin planning.

6. The county should support and implement the county-adopted water resource plans addressing watersheds, stormwater, sewerage, groundwater, water supply and solid waste, including the Northern Thurston County Ground Water Management Plan and the South Thurston County Aquifer Protection Strategy.

7. The county should protect public water supplies from contamination to avoid the cost of developing new water sources.

8. The county should manage water resources for multiple beneficial uses. Use for one purpose should preserve opportunities for other uses, while maintaining overall water quality. When conflicts arise, the natural system should be given priority, particularly if the use would be detrimental to anadromous fish or public safety.

9. The county should monitor both surface water and groundwater to evaluate program effectiveness, establish long-term trends for both water quality and water quantity, and provide for the early detection of pollution, to minimize the damage and the cost of resource restoration, and to provide a basis for adaptive management.

8. The county should identify and designate in the Critical Areas regulations geographic areas with unusual physical features or high sensitivity to human impacts that require management approaches specially designed for each area.

Appendix 2. The City of Tumwater and Thurston County Joint Plan: Goal #6 Policy Objectives

Policy Objective

6.1 Ensure that new development is in conformance with the requirements and standards of the North Thurston Groundwater Protection Plan.

6.2 Ensure that new development is in conformance with the requirements and standards of the City of Tumwater's Master Storm Drainage Plan.

6.3 Ensure that new development meets the quality and quantity control requirements contained in the Drainage Design and Erosion Control Manual for the Thurston Region.

6.4 Ordinances meeting applicable legal standards should be adopted by the City of Tumwater and Thurston County regulating land-uses within wellhead protection areas to ensure that negative effects on groundwater quality are avoided or mitigated.

6.5 Ensure that future land-use and development is in conformance with regional wellhead protection policies and adopted wellhead protection programs of Thurston County and the City of Tumwater.

6.6 Ensure coordination with the Percival Creek Comprehensive Drainage Basin Plan.

6.7 Ensure that new development is in conformance with aquifer protection standards of the City's Conservation Plan.

6.8 Prohibit new residential development in the 100-year floodplain.

Appendix 3. The City of Tumwater and Thurston County Joint Plan: Goal #8 Policy Objectives

8.1 Ensure that new development is in conformance with the applicable standards and requirements for critical areas

8.1.1 Conduct a geological study and mapping program for the urban growth area.

8.2 Prohibit or set conditions on development based on anticipated adverse environmental impact.

8.3 Inventory the hillside areas to determine which areas, because of known hazards, topographic formations and unstable soils, should be limited to extent of development.

8.3.1 Conduct a geological study and mapping program for the urban growth area.

8.4 Development within the Shoreline Management Jurisdiction shall adhere to the flood control policies, land-use controls and regulations of the applicable environmental designation as described in the Thurston Region Shoreline Master Program adopted by the City of Tumwater and Thurston County.

8.5 Consider applying the standards of the City's Tree Protection Ordinance to the unincorporated urban growth area through an intergovernmental agreement.

Appendix 4. NLCD Land-Cover Classification System Land-Cover Class Definitions

Water – All areas of open water or permanent ice/snow cover.

11. Open Water – All areas of open water; typically 25 percent or greater cover of water (per pixel).

12. Perennial Ice/Snow – All areas characterized by year-long cover of ice and/or snow.

Developed – Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g. asphalt, concrete, buildings, etc).

21. Low Intensity Residential – Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.

22. High Intensity Residential – Includes highly developed areas where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80 to 100 percent of the cover.

23. Commercial/Industrial/Transportation – Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

Barren – Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive.

31. Bare Rock/Sand/Clay – Perennially barren areas of bedrock, desert, pavement, scarps, talus, slides, volcanic material, glacial debris, beaches, and other accumulations of earthen material.

32. Quarries/Strip Mines/Gravel Pits – Areas of extractive mining activities with significant surface expression.

33. Transitional – Areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land-cover to another, often because of land-use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

Forested Upland – Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover.

41. Deciduous Forest – Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.

42. Evergreen Forest – Areas dominated by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. Mixed Forest – Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.

Shrubland – Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included.

51. Shrubland – Areas dominated by shrubs; shrub canopy accounts for 25-100 percent of the cover. Shrub cover is generally greater than 25 percent when tree cover is less than 25 percent. Shrub cover may be less than 25 percent in cases when the cover of other life forms (e.g. herbaceous or tree) is less than 25 percent and shrubs cover exceeds the cover of the other life forms.

Non-natural Woody – Areas dominated by non-natural woody vegetation; non-natural woody vegetative canopy accounts for 25-100 percent of the cover. The non-natural woody classification is subject to the availability of sufficient ancillary data to differentiate non-natural woody vegetation from natural woody vegetation.

61. Orchards/Vineyards/Other – Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals.

Herbaceous Upland – Upland areas characterized by natural or semi-natural herbaceous vegetation; herbaceous vegetation accounts for 75-100 percent of the cover.

71. Grasslands/Herbaceous – Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing.

Planted/Cultivated – Areas characterized by herbaceous vegetation that has been planted or is intensively managed for the production of food, feed, or fiber; or is

maintained in developed settings for specific purposes. Herbaceous vegetation accounts for 75-100 percent of the cover.

81. Pasture/Hay – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.

82. Row Crops – Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.

83. Small Grains – Areas used for the production of graminoid crops such as wheat, barley, oats, and rice.

84. Fallow – Areas used for the production of crops that are temporarily barren or with sparse vegetative cover as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

85. Urban/Recreational Grasses – Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Wetlands – Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al.

91. Woody Wetlands – Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.

92. Emergent Herbaceous Wetlands – Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.