Building Practices Reduces Infiltration Potential in Urban Environments and Subsequent Effects of Stormwater in Kitsap County

by

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ABSTRACT

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Jonathan Pavy

Our building practices have been dominated by impervious surfaces and stormwater infrastructure through the ages. Our approach has been to channel stormwater away from the built environment as quickly as possible. Conventional stormwater management has focused on complex and costly infrastructures that have not totally delivered on reduced environmental impacts to aquatic habitats through scouring of stream banks and streambeds, and the movement of pollutants from the landscape to receiving water bodies.

Kitsap County receives 80% of its potable water from ground sources. Future population growth will foster a larger urban foot print and an increasing irrigation need will exert greater demands on the water supply. Climate change presents an uncertain future of its effects on the Pacific Northwest's weather patterns. In light of this, we must start treating stormwater as a resource instead of waste. By reducing impervious surfaces and managing rainwater at the impact site, we will reduce the amount of stormwater produced and mimic the natural hydrology within urban spaces. By modifying how we manage stormwater we will retain a larger percentage of the water budget within the landscape, allowing for infiltration to the ground water system. Base flow in streams and rivers will be maintained during periods of low precipitation and aquifer recharge rates will be maintained.

Low impact development techniques minimize impervious surfaces and manage rainwater at the impact site before it turns into runoff. It is a proven approach to onsite infiltration that can mimic the natural hydrology of the landscape.

I conducted a trending analysis on ground water in Kitsap County using the Washington Active Water Level Network. Conducted a t-test: Paired two sample for means using initial well measurements and the most recent measurements. The calculated t critical two-tailed value is 1.9860 and is less than the tabled value of t indicating no significance.

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Chapter 1

Introduction: Defining the Problem

One of the enemies of the built environment is water. Therefore, the age old standing premise of channeling and expelling stormwater away from the built environment is a hard habit to break. Current building practices encourage stormwater production with the impervious surfaces that result from it. Building densities within the urban/suburban land use areas provide limited opportunity for rainwater to contact the ground and replenish ground water. There is an elaborate stormwater infrastructure designed to move water away from the built environment as soon as it runs off of impervious surfaces. The top soil and vegetation, well beyond the building envelope, are stripped away, reducing the ability of the soil to delay the movement of water across the landscape and the potential to infiltrate to the ground water system.

Traditional urban development primarily focuses on enhancing human life and prosperity (Frey, 1999) and does not necessarily take into consideration the part cities play in the ecological processes of the region. In short, cities are part of nature (they are the site of complex, socially organized relationships between “social” and natural” processes), but it is precisely their ecologies that are often most difficult to see (since urbanization distances people both spatially and perceptually from the larger bio-physical processes in which cities occur) (Braun & Castree, 1998). The Puget Sound Regional Council (PSRC) in updating its *VISION 2020 Growth Management Economic and Transportation Strategy for the Central Puget Sound* has identified a regional environmental vision that maintains and restores ecological connectivity, decreases fragmentation of natural systems, and protects critical areas and resources (Council, 2005).

1.1.1 Building Practices

The Kitsap County Code authorizes a maximum density of 30 dwellings per acre in the urban high residential zone (County K. , http://www.codepublishing.com/wa/kitsapcounty/, 2010) which allows rain water very little chance of contacting the ground and infiltrate to ground water. All rainfall that falls on these impervious surfaces are channeled to an elaborate stormwater collector system that conveys it to a waste water treatment plant(s) and then out to a receiving water body. This water is summarily removed from the water budget for the watershed.

The Washington State Growth Management Act (GMA) of 1990 was developed to control uncoordinated and unplanned growth that posed a threat to the environment, sustainable economic development and quality of life (State, 1990). Though mandated by the state, local governments manage growth and growth areas and in protecting the environment to enhance the state's high quality of life, including air and water quality, and the availability of water (State, 1990).

A Comprehensive Plan developed on the local scale to guide the vision of what county legislatures, with citizen input, would like the county to look like 20 years in the future. The plan seeks to demonstrate the ability to accommodate the projected population and employment growth to 2025.

Urban development modifies hydrologic processes when vegetation and soil are cleared from the land surface, the surface is graded, depressions (e.g. wetlands) are filled, remaining soils are compacted, and buildings, roads, and drainage systems are constructed. Replacing natural vegetation with development strips the land of its ability to trap and slow the movement of rainwater. The loss of vegetation reduces the watershed's ability to naturally remove large quantities of rainfall through interception and evapotranspiration. Rainfall that does reach the forest floor is absorbed by the spongy material that is the top soil. This is the perfect medium that traps and slows the movement of rainwater, allowing it to infiltrate to the ground water system that feeds rivers, streams and aquifer recharge.

1.2 Regulatory

Understandably, the density within the urban area is designed to maximize the utilization of building space, although these particular zonings bring with it a myriad of environmental problems that have manifested over time. With up to 95 percent of the urban area covered with impervious surfaces, a tremendous amount of stormwater is produced by a minimal amount of rainfall. Stormwater moves through the built environment quite rapidly and can be measured in minutes versus the days or weeks it takes for rainwater to move through the natural environment.

Critical aquifer recharge areas (CARAs) are defined by the GMA as "areas with a critical recharging effect on aquifers used for potable water" (State, 1990). To this end, Kitsap County has developed regulations for land use activity within identified CARAs:

a. Retain existing list of operations that potentially threaten groundwater.

b. Update the list of operations that potentially threaten groundwater using the latest EPA

list modified for the county.

c. Continue to allow any activity based on results of a geo-hydrologic report.

d. Prohibit certain activities outright (e.g. landfills, mining, wood treatment facilities)

within CARAs.

e. In addition to regulating land use for groundwater quality concerns, regulate land use

within CARAs for groundwater quantity concerns.

f. Regulate land use to achieve an acceptable density of septic systems (County K. , Critical Aquifer Recharge Areas - Potential Next Steps, 2004).

Figure ## shows the location and variation of the Critical Aquifer Areas in Kitsap County.

1.3 Objective

The focus of this paper is primarily to explore how the built environment influences the removal of a large percentage of the water budget from the watershed that is Kitsap County. Kitsap County receives approximately 80% of its potable water through various aquifer systems and by removing such a large percentage of the water budget from the system, the recharge rate of underlying aquifers and baseflow in rivers and streams will be severely affected, jeopardizing long term viability. The primary means of addressing aquifer recharge will be to examine the trending analysis of Kitsap County wells in the Washington Active Water Level Network.

Secondly, I will evaluate Stormwater management as it relates to pollution entering Puget Sound from non-point sources. Conventional stormwater management techniques have continuously evolved as problems with the “current” design becomes, apparent normally long after the problem(s) have manifested themselves. Despite land development regulations, including stormwater management with best management practices (BMPs), have not had much success in reducing the amount of pollution entering surface water bodies. Low impact development techniques, though not widely accepted, have proven to manage rainwater/stormwater at the impact site, without exporting large quantities of water to receiving water bodies.

Stormwater rushing off of impervious surfaces reduces the resident time on the landscape producing earlier peaks and higher flow volumes. Stream beds and stream banks are scoured, compromising aquatic habitats. By incorporating LID techniques in new development and redevelopment projects, the natural hydrology of the site will be maintained, allowing rainwater to be detained, infiltrate and evaporate before it becomes runoff.

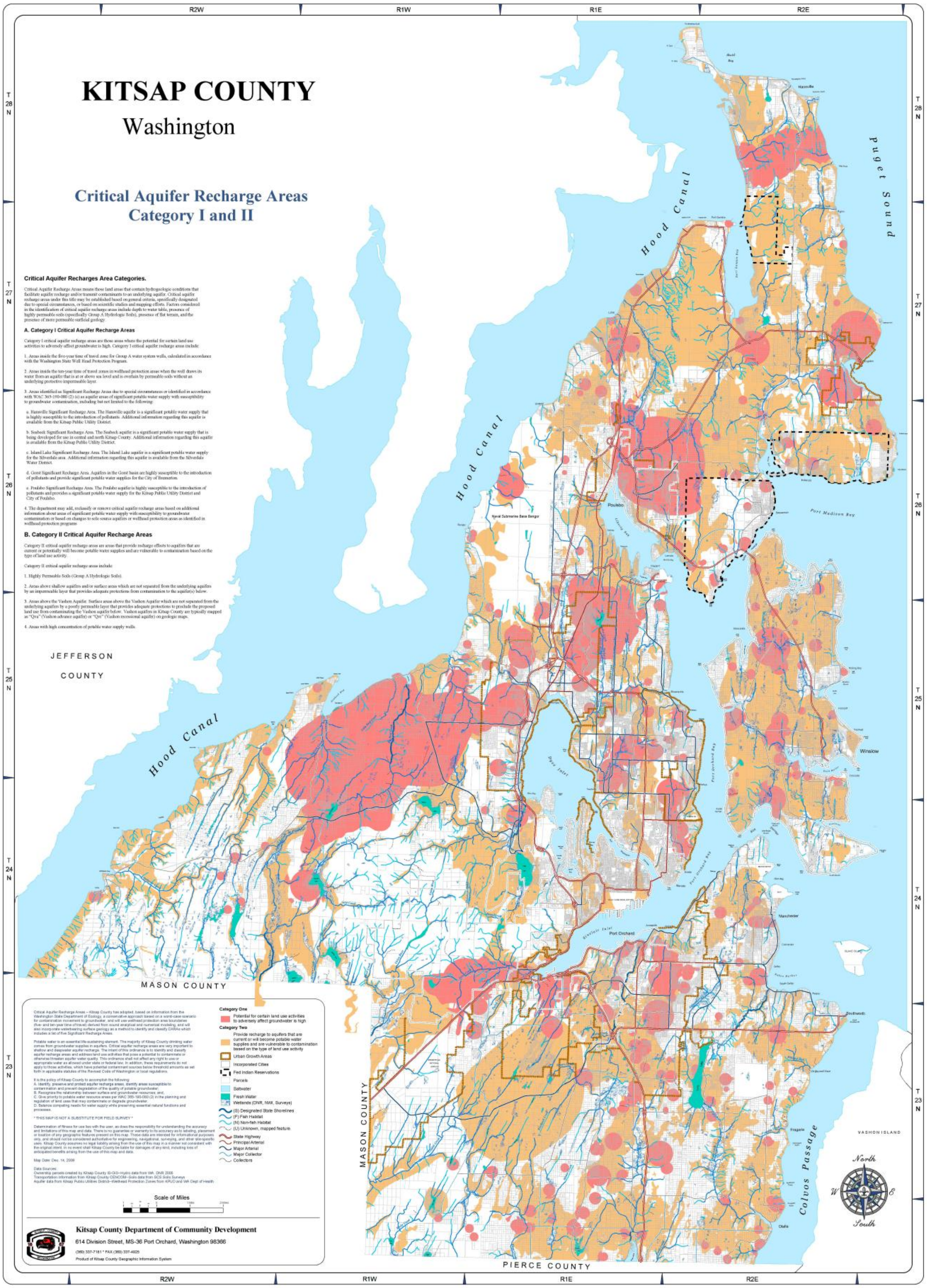

Figure 3 Kitsap County Critical Aquifer Recharge Areas

Chapter 2

Kitsap County

The availability of ground water has always been the essential commodity for the establishment and continued prosperity of an urban environment. Most aquifers in the urban environment, or from nearby watersheds, supply most or all the water the area needs for residential, industrial and irrigation purposes. As the urban area grows, due to increases in population and industrial activities, more of the natural environment is replaced with impermeable surfaces. Runoff increases and infiltration decreases. At some point in time, the rate of withdrawal from the aquifer(s) in Kitsap County will exceed the rate at which the aquifers are being recharged if this problem is not mitigated. Stormwater runoff has a limited chance of being infiltrated since it typically runs off of impermeable surfaces to storm water conveyances then to detention ponds or wastewater treatment plants, or is channeled to the roadside ditch, makes its way to the nearest stream or river and then out to sea.

> Historically, urban drainage was designed with a single objective in mind—to provide hydraulically and economically effective transport of surface runoff from urban areas into local receiving waters and thereby to protect urban dwellers against flooding and provide for their convenience by controlling runoff ponding in urban areas. (Ellis & Marsalek, 1996)

Stormwater is often viewed as an enemy to the built environment especially when there is more than the man-made conveyances can handle. As an area becomes more developed, stormwaters increase to the point of overwhelming designed infrastructure. Sewage treatment plants cannot handle the increased load and, therefore, introduces the excess, including raw sewage, into nearby streams and coastal waterways. I shall focus on the Kitsap County peninsula in Washington State and look at alternative ways to reduce the volume of stormwater produced and new avenues for excess stormwater in an urban environment.

There are few if any suitable sites for expanded surface water storage in Kitsap County. Coordinated land use strategies will be necessary to accommodate water needs of future population growth. An expanding industrial base and an increasing irrigation need will exert even more pressure on existing water resources. Water diverted from infiltrating into the soil and occurring as runoff to surface water will result in more rapid depletion of aquifers and more contaminated surface waters (Levin, Epstein, Ford, Harrington, Olson, & and Reichard, 2002). Levin, et al. (2002) cited a recent survey that found a variety of pesticides in both surface water and groundwater in all basins with appreciable agricultural activities or urbanized development (as mentioned in the U.S. Geological Survey, 1999). He also mentioned that in these circumstances, competition among sources (drinking water, agriculture, fish and wildlife habitats, residential development, energy production, leisure, etc.) is likely to increase (as mentioned in U.S. EPA SAB report, 1995).

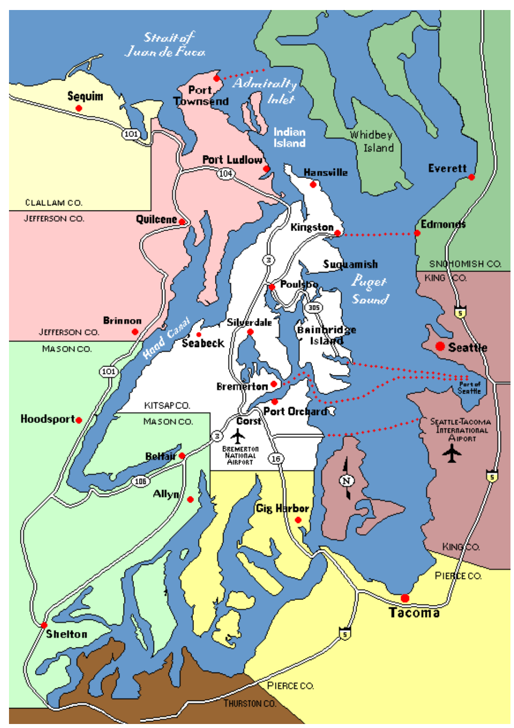

Figure 4 Kitsap County

2.1 Area Description

The Kitsap Peninsula is located west of Seattle and northwest of Tacoma, the two most populous areas in Washington State. Situated in the middle of Puget Sound, it is connected to the Olympic Peninsula by a narrow land mass. It is bordered by the Puget Sound to the east, the Hood Canal to the west and Admiralty Inlet to the north. Almost completely surround by water, it has a land mass of approximately 393 square miles and 265 miles of shoreline. Kitsap County is approximately 0.6 percent of the state's land mass, ranked 36^{th} in size of all counties and is the 2^{nd} most densely populated county in the state. In 2000, the population was 231,969 and is projected to grow to 345,674 by 2030 (Transportation, 2003).

The county's built environment consist of medium to high density urban and suburban dwellings, 5 to 10 dwellings per acre, with commercial and industrial facilities throughout. There are four military installations on the coast and adjacent to highly populated urban areas. A good portion of the county is in its natural state dominated by coniferous trees, and to a lesser extent, a variety of deciduous trees. The densities in rural areas are one dwelling per 5 acres and one dwelling per 10 acres.

The landscape of the Puget Sound lowland was carved out by the Vashon glaciations (15,000 – 20,000 BP). As the ice advanced, it carried large amounts of glacial sediment, shaping the landscape. The glacial landscape was subsequently modified during the Holocene period by fluvial erosion and deposition, coastal processes and hillslope masswasting along the steeper slopes bounding streams and the coastline (Shipman, 2008) The Kitsap topography is undulating with rolling hills and valleys rising to heights between 400 to 600 feet above sea level. The Gold and Green Mountains are the most prominent peaks rising to approximately 1700 feet above sea level. Much of the upland areas terminate at the shoreline in steep cliffs and bluffs (Kitsap Public Utility District, 1997) allowing concentration of human activity in the lowlands to the eastern side of the county.

Although the county has the second highest density of the state, a significant portion of the county is in an undeveloped forested state with numerous single family acreage units, farms and small scattered communities throughout. Kitsap County's Growth Management Act (GMA) was developed to facilitate an organized plan for development and minimize sprawl to all corners of the county. The plan would allow for increased development of urban areas and restrict waterfront development to one dwelling per acre (Kitsap Public Utility District, 1997). Further concepts within the plan provide stipulations aimed at reducing anthropogenic impacts on water quality.

2.2 Building Practices

Land use planning can prevent ecological degradation and maintain environmental services that the human species has come to take for granted. Surface water contamination is a direct result of runoff from the landscape that we have engineered to serve our needs. In our attempt to protect the built environment, we have neglected to account for the needs of the natural environment.

The Kitsap County Code is the governing regulation for development within the county, in satisfaction of the GMA. Land use designations prescribe how much, what type and where development takes place within the county. Within the urban designation the density ranges from 10 to 30 dwelling units per acre (Community Development, 2010). At these densities there are few opportunities for rainfall to contact the earth and infiltrate to ground water systems. Impervious surfaces such as rooftops, driveways, roads and pavements dominate the landscape, producing increasing amounts of stormwater that is removed from the landscape and conveyed to receiving water bodies.

There is a reduction in density the further away from the urban growth area one goes and the incidence of natural vegetation is more regular. Consequently, there is a continual reduction in the amount of impervious surfaces that reduces the amount of stormwater produced.

2.3 Climate

The Pacific Northwest is characterized by a mild marine climate in relation to other locations at the same latitude in the United States. Temperatures rarely fall below freezing and rarely rise above 80° F due to the influence of the Pacific Ocean. Summers are dry with minimal rainfall and receives a significant amount of rainfall from early fall to late spring (Kitsap Public Utility District, 1997).

Winter storms generally approach from the southwestern Pacific Ocean, bringing winds and clouds saturated with moisture. The southwestern section of the Kitsap peninsula receives much more rainfall than the northern section due to the rain shadow effect of the Olympic Mountains. The average rainfall in the northern section of the county is approximately 30” compared to approximately 70” in the southwestern portion (Kitsap Public Utility District, 1997)

Of the few studies conducted on the urban environment as it affects aquifer recharge, none depict a formula or technique that quantifies the recharge rate (Lerner, 2002). This paper cannot to attempt to develop such a strategy. It is beyond the scope of this study. It will attempt to show that the urban environment does affect ground water and suggest ways in which the urban environment can be a negligible factor on the recharge rate of underlying aquifers.

Kitsap County receives an average of 127mm of rainfall per year of which 7% results in groundwater recharge. Evapotranspiration accounts for 44%, surface runoff 35% and baseflow14% (Inc., 2005). The basic formula for the water balance is:

Precipitation = Evapotranspiration + Runoff + Recharge (Lerner, 2002).

We must remember that these allocations are averages for the entire county and are not a representation of only the urban environment. It is anticipated that evapotranspiration is much lower and runoff is much higher in areas where impervious surfaces dominate. Increased runoff leads to increased stream flow during storm events but may not sustain base stream flow during periods of reduced precipitation (Platt, 2006).

Urbanization drastically alters the hydraulic regime of an area is severely altered when it is replaced by an urban landscape. The hydraulic connection of rainwater infiltrating to the ground water is severed if steps are not taken to allow water to reach the ground. County officials and water purveyors must plan for the growth in future demands on water resources and the unforeseen effects climate change will have on the amount of rainfall that is delivered to the region annually.

2.4 Climate Change

Climate change is occurring and it will have global implications on weather patterns (Kevin, Epstein, Ford, Harrington, Olson, & Reichard, 2002). As seen in fig. 3, the temperature rose as much as 2.0° C across most of the Pacific Northwest between 1920 to 1999 (Mote, 1999). This temperature increase has serious implications for Kitsap County but is not yet clearly understood. The snow pack that delivers a reliable water supply when it melts during the summer months, a time of reduced precipitation, may melt before the need arises as reflected in Fig 4.

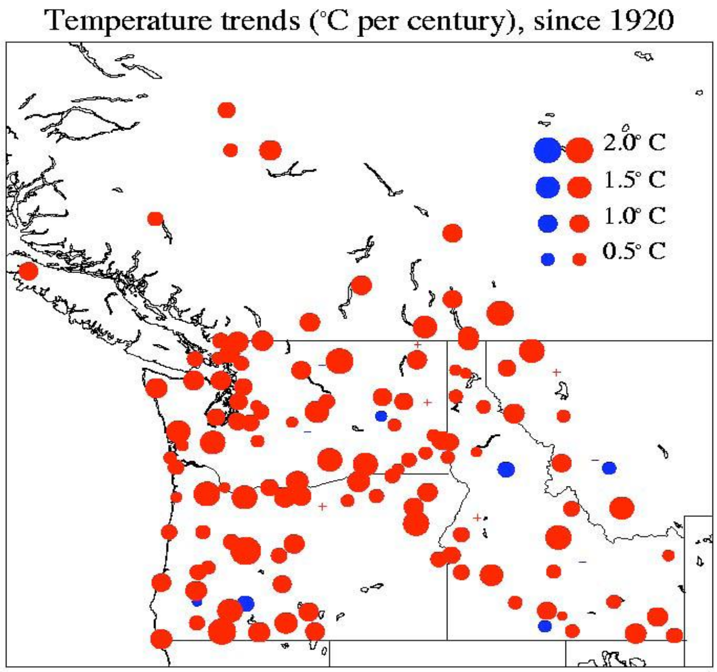

Figure 3 Temperature trends in the Puget Sound Region since 1920. (Mote, 1999)

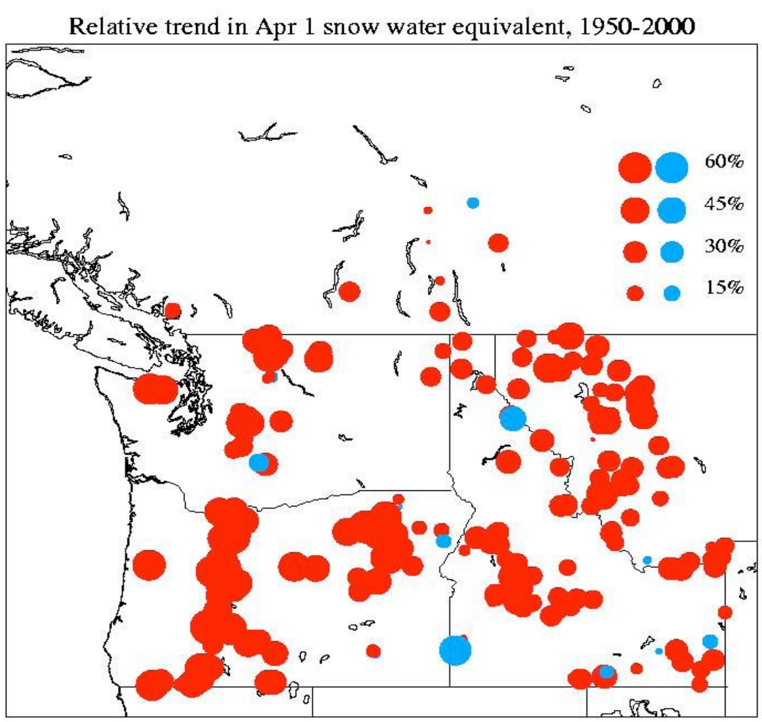

Figure 4 Relative trend in April 1st snow water equivalent in Puget Sound 1920-2000. (Mote, 1999)

This reduces the amount of water available during drier months and the growing season for crops needing irrigation. The implications are clear. Early snow melt results in increased stream flow during the wetter months and is reduced during the dryer months of the year. Maintaining base flow is essential for ecological viability within water courses. Water input from springs and seeps, and connection to ground water will decrease as the dry period advances, possibly compromising the ecological integrity of stream(s). Groundwater extraction may reduce natural aquifer discharge to the aquatic environment in some cases, seriously, and resource development involving consumptive use of groundwater (or export from the sub-basin concerned) has the greater impact (Chilton, 2003). Global warming has caused the retreat of the majority of the earth's glaciers. The melting of these glaciers has promoted sea level rise which will increase the hydraulic pressure on exploited aquifers. This could lead to salt water intrusion and compromise the viability of the aquifer(s).

Water in aquifers has residence time in the order of thousands of years. The U.S. Geological Survey, in corporation with the U.S. Navy, estimates the age of water in aquifers in the vicinity of Bangor Submarine Base ranges from recent to 4,500 years. Carbon dating indicates age descriptions ranged from recent in the shallow aquifers which were, of course, from recent recharge. Longer residence times are in water from wells either deeper in the ground-water flow system or near the area of ground-water discharge (Cox, 2003)

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Chapter 3

Stormwater

The Clean Water Act (CWA) of 1977, an upgrade of the Federal Water Pollution Control Amendments Act of 1972, was enacted to eliminate point source contamination of the nation's waterways and achieve suitable water quality in surface waters for human sports and recreation by 1983. The ultimate goal was to eliminate point source pollution of these waterways by 1985. It was further revised by the Water Quality Act of 1987 to include pollution from nonpoint source pollution activities.

The command and control approach of the CWA was necessary to address the rampant discharges of pollution to the nation's waterways that rendered the vast majority of surface waters unusable by both humans and aquatic creatures. After years of regulatory control of point source pollution, nonpoint sources now cause the greatest pollution that introduces contaminants to our surface waters.

The Pacific Northwest is an area that does not, as a matter of course, receive torrential downpours that results in flash floods, but does receive steady rainfall that delivers a lot of precipitation over a longer period of time. This temporal dispersal of rainfall, together with soils and vegetation, allows for the storage and infiltration of rainfall to the ground water before runoff turns into stormwater. The storage potential and subsequent release of water as a continuous flow to rivers and streams help to maintain the base flow in these waterways. The predominance of subsurface flow in the Pacific Northwest leaves the area particularly susceptible to negative hydrologic effects associated with urbanization. A typical suburban neighborhood in this region contains approximately 90% less storage capacity than would be found under naturally forested conditions (Wigmosta, Burgess & Meena, 1994).

As the population increases, so does the amount of impervious surfaces. As development is regulated under the GMA to prevent sprawl, planned growth extends outwards from the urban growth areas (UGA) and so do capital facilities to serve these areas. Conventional building practices are still used; therefore, there are increasing amounts of impervious surfaces producing more stormwater and thus vital water resources are removed from the water budget for the watershed.

Urbanization causes dramatic changes to the water regime within a watershed promoting flooding, erosion, sediment transport and ultimately channel morphology. (Booth, Hartley, & Jackson, 2002). Hydrologic change also influences the whole range of environmental features that affect aquatic biota – flow regime, aquatic habitat structure, water quality, biotic interactions, and food sources (Karr, 1991). These effects are quite evident in the Illahee Creek Watershed through scour and sedimentation in the stream channel, near-shore sediment deposition from stormwater runoff, and temperature and other water quality issues related to stormwater (Massmann & Waters, 2006).

3.1 Stormwater Contaminants

Stormwater runoff, including runoff from agricultural activities, constitutes approximately 80% of the pollution that enters Puget Sound surface waters, despite the employment of best management practices (BMP). Human societies engaging in activities that create the pollutants in urban stormwater runoff are the same cultural systems that must manage stormwater runoff (Owen, 2004) to which additional techniques must be employed to minimize transporting pollutants off of the landscape.

Land development, with the installation of impervious surfaces, ultimately changes and disrupts surface water runoff and restricts input to ground water. Typically, urbanized watersheds have impervious surface areas and drainage systems designed for efficient removal of surface water (Winter, 1990). Overland runoff is an excellent medium to transport dissolved, suspended, and sediment adsorbed materials into receiving water bodies (Corbett, Wahl, Porter, Edwards, & Moise, 1997). Surface water and stormwater runoff in urban and rural areas are now recognized as the primary, unaddressed transporters of toxic, nutrient, and pathogen pollutants to surface and groundwater resources throughout the Puget Sound Basin (Crowser, 2007). Kitsap County, with its many rivers and streams that empty into Puget Sound and Hood Canal, transport the principal contaminants of non-point source pollutants to the receiving water bodies.

Categories of Principal Contaminants in Stormwater

Category	**Examples**
Metals	zinc, cadmium, copper, chromium, arsenic, lead
Organic chemicals	pesticides, oil, gasoline, grease
Pathogens	viruses, bacteria, protozoa
Nutrients	nitrogen, phosphorus
Biochemical oxygen demand (BOD)	grass clippings, fallen leaves, hydrocarbons, human, and animal waste
Sediment	sand, soil, and silt

Salts	sodium chloride, calcium chloride

Table 1 Categories of Principal Contaminants in Stormwater ((NRDC), 1999)

3.2 Stormwater Runoff

There is a noticeable effect on the volume and flow of stormwater in the urban landscape due to the absence of vegetative cover that intercepts and retards the movement of rainwater once it hits the ground. Impervious surfaces like rooftops, driveways and parking lots offer little resistance to water flowing across its surface, particularly on a sloped surface. This water moves faster and faster, transporting a greater amount of sediments and pollutants with increasing erosive power once it leaves the impervious surfaces and enters rivers and streams.

Natural landscapes have the ability to absorb and infiltrate rain water to the ground water system and slowly release it through lateral and downward movement to streams, creeks, seeps and underlying aquifers. This absorption and release slows and meters the volume of stormwater that is present in the system at any one time. Precipitation runoff from a developed area reaches the stream channel with a typical delay of just a few minutes, instead of what had been a lag of hours, days, or even weeks. The result is a dramatic change in flow patterns in the downstream channel, with the largest flood peaks doubled or more and more frequent storm discharges increased by as much as tenfold (Booth, Hartley, & Jackson, 2002). The implications of stormwater runoff are multiple in that in addition to introducing pollutants to receiving water bodies, it also causes erosion and destroys aquatic habitats.

In stream habitat is severely altered and compromised through extensive changes in basin hydrologic regime, channel morphology, and the physicochemical water quality associated with modified rainfall-runoff patterns and anthropogenic sources of water pollutants. The cumulative effects of these alterations produce an in-stream habitat considerably different from that in which native fauna evolved (Horner, et al., 2002). Increased flow patterns erodes stream banks in the process of undercutting riparian vegetation, wash away gravel beds that provide habitat for in stream micro and macro invertebrates, or is buried under large deposit of sediment leading to a decline of in stream species (Recreation, 2009). In 1997 and 1998 a salmon rearing project in the Illahee Creek watershed failed due to high sedimentation from stream bank erosion, and the inability to maintain minimum base flow during months of low precipitation (Massmann & Waters, 2006).

3.3 Regulation of Stormwater

The Clean Water Act (CWA) established the basic structure for regulating discharges of pollutants into the waters of the United States. It provides EPA and the States with a variety of programs and tools to protect and restore the Nation's waters. These programs and tools generally rely either on water quality-based controls, such as water quality standards and water quality-based permit limitations, or technology-based controls such as effluent guidelines and technology-based permit limitations (EPA), Water: Laws and Regulatory Development, 2009). In 1987 Congress amended the CWA authorizing the EPA to develop phased requirements for the National Pollutant Discharge Elimination System (NPDES) for stormwater discharges. Phase I was promulgated in 1990.

Under Phase 1, the NPDES set forth guidelines for stormwater discharges from industrial activity and for discharges from municipal separate storm sewer systems serving a population in excess of 100,000 people. These permits served as a mechanism to monitor the discharges from these entities (EPA), Overview of the Storm Water Program. EPA 833-R-96-008, 1996). Stormwater Phase II Final Rule was adopted in 2003 in the EPA's effort to preserve, protect, and improve the Nation's water resources from polluted stormwater runoff. It is intended to further reduce adverse impacts to water quality and aquatic habitat by instituting the use of controls on the unregulated sources of stormwater discharges that have the greatest likelihood of causing continued environmental degradation (EPA), Stormwater Phase II Final Rule, 2000).

Phase II Final Rule provides nationwide direction for cities and counties operating a municipal separate storm sewer system (MS4), serving an urbanized area with less than 100,000 people with densities of 1,000 people per square mile, and also applies to construction activities disturbing 5 acres or more of land. Kitsap County was designated as a Phase II location and the Washington State Department of Ecology issued a Phase II permit in January 2007 which became effective in February 2007 (Public Works & Utlities).

All municipalities that fall into this category must develop and implement a Stormwater Management Program (SWMP) that addresses the following program elements that collectively results in a significant reduction of pollutants entering surface waters. The six program elements are: 1) Public Education and Outreach; 2) Public involvement and participation; 3) Illicit Discharge Detection and Elimination; 4) Construction Site Runoff; 5) Operation and Maintenance of Post Construction Stormwater Facilities; and 6) Pollution Prevention and Good Housekeeping (Public Works & Utlities). This multipronged approach is designed to produce the greatest reduction in non-point source pollution entering surface water bodies.

Section 319 of the CWA mandates that states rank their surface waters on susceptibility of non-point source pollution and to develop and implement management programs that directly addresses a reduction in this type of pollution when implemented. Washington Administrative Code 400-12-210, Puget Sound Water Quality Action Team, establishes criteria and procedures in ranking watersheds and implementing corrective or preventative action where needed. This is expected to reduce pollutant loading, prevent unforeseen or new pollutant loading avenues, enhance water quality and protect beneficial uses. This approach will require a collaborative problem solving approach from all stakeholders – local, state, tribal and federal interest (Code, 1996).

3.4 Puget Sound Partnership

The Puget Sound Partnership, under the same statutory authority as the Puget Sound Water Quality Action Team, was designed to combine individual groups within Washington State that were working on environmental issues plaguing Puget Sound. Individual research was being duplicated several times over as organizations worked to identify problems and ways in which to fix them. This was a waste of resources and money. In 2008 The Puget Sound Partnership was formed to maximize the efforts of all entities and streamline the processes in a more collaborative manner.

Within this partnership, there is a strong conviction for a scientific approach in addressing the pollution problems of Puget Sound. The Partnership Science Panel worked with a broad-base of leading scientists, professionals and other interested parties that developed 20 indicators that would allow for a manageable and measureable list of scientifically valid, socially relevant elements by which to gauge the progress of the Puget Sound restoration and protection work. The executive director of The Puget Sound Partnership, David Dicks, said "these indicators are the ‘vital signs’ of Puget Sound that will allow us to measure key elements of the general health of the Puget Sound natural system”.

These indicators address both marine and fresh water quality and the fauna and biota in both environments. The abundance of salmon, forage fish and orca species are monitored as well as are the abundance and breeding patterns of birds in the region. The extent of ell grass beds, degree of shoreline armament and the various types of land use and the extent of impervious surfaces are also being monitored. Toxins in marine organisms and in sediments are also being addressed. The social science aspect is not ignored in that the quality of life index is monitored and the extent to which Puget Sound-friendly practices are being practiced. The percentage of core swimming beaches meeting water quality targets, shellfish beds being affected by degraded water quality and the harvest of commercial fisheries, both tribal and non-tribal are recorded as well.

This collaborative approach ideal could relegate the adversarial model to history in the Puget Sound region. New leadership techniques realize that society, technology, and communication have all changed in ways that make historic leadership approaches increasingly obsolete (Gordon & Berry, 2006). The historic leadership model revolved around a central figure with absolute decision making authority whereas the collaborative model is centered on a team of diverse professionals from different disciplines. The diverse nature of the makeup of the Puget Sound Partnership brings people of varying backgrounds and skills together to address and propose solutions to specific problems. Complex problems require diversity of thought to be solved; often differences in personal characteristics and background produce different views of the same problem (Gordon & Berry, 2006).

The command and control approach to solving environmental problems was a necessary approach in bringing the Nation's surface waters back from the brink of total disaster. Point source pollution entering surface water bodies has been reduced to a minimum but non-source pollution is much harder to eliminate due to the wide array of contributing sources. The more complex problems remain that would require a more scientific approach. We are now in a phase where interconnected environmental problems are much more difficult to identify. Gunderson et al demonstrates, through a wide-ranging array of environmental management cases, that there are no simple, consistent, widely accepted answers to environmental problems, and that an adaptive, place-based approach, requiring broad yet fine-grained local leadership, is the only one likely to pay off (Gordon & Berry, 2006).

Existing stormwater management employs both expedited removal of stormwater runoff through stormwater infrastructure, and also the detention and slow release through non-structural BMPs like infiltration ponds, filters, and constructed wetlands. These approaches in dealing with stormwater have proven ineffective in eliminating or preventing the introduction of non-point source pollution into surface water bodies, and they have not addressed or made allowances for the natural hydrologic function of ground water. The Construction Stormwater Pollution Prevention Plan discussed in the *Stormwater Management Manual for Western Washington* (2005), monitored by the Washington State Department of Ecology, must consist of and make provisions for erosion prevention, sediment control and for the control of other pollutants (Washinton State Department of Ecology, 2005). I am not proposing a "silver bullet" to reduce pollution entering surface water bodies but must look to new techniques to work with existing technologies as we address this problem. The City of Bremerton has taken the lead in adopting Low Impact Development techniques as a stormwater management strategy.

3.5 Low Impact Development

The limitations of conventional stormwater management techniques have continuously evolved as problems with the “current” design become apparent, which is normally long after the problem(s) have manifested themselves (Debo & Reese, 1995). Treating all stormwater before discharging to receiving water bodies is an unrealistic endeavor and is not being suggested as a goal. Minimizing the amount of stormwater generated might prove to be a more effective measure in reducing the amount of pollution washing off of the landscape to receiving water bodies. An integrated approach to stormwater management appears to be the most effective use of BMPs. When multiple layers of structural and nonstructural BMPs are used in unison, the watershed will reap the largest benefit (Muthukrishnan, Mardge, Selvakumar, Field, & Sullivan, 2004).

The volume of stormwater runoff generated in a development can be greatly reduced by minimizing the amount of impervious surfaces. Reductions in impervious area can be undertaken by reducing the overall size of the developed area, and/or by reducing the amount of impervious surface created within the developed area. Reductions in impervious area can also be achieved through cluster developments that maximize open (undeveloped) space and minimize the required length of roadway and other infrastructure. Clustering concentrates development on smaller lots leaving relatively large areas undeveloped with reduced impervious surfaces.
This approach will help address peak flow control, stream bank erosion protection, removal of drainage path obstruction, water quality enhancement, and groundwater recharge and community enhancement (Muthukrishnan, Mardge, Selvakumar, Field, & Sullivan, 2004).

Low impact development (LID) techniques are a proven approach to onsite infiltration that can mimic the natural hydrology of the landscape. Instead of large, centrally located detention ponds, LID applications uses small site specific designs that store, filter and infiltrate to ground water recharge while minimizing peak volume flows and maintaining normal hydrologic discharges. Basic LID techniques involve conservation of natural features, minimizing impervious surfaces, hydraulic disconnects, disbursement of runoff and phytoremediation (Muthukrishnan, Mardge, Selvakumar, Field, & Sullivan, 2004). Phytoremediation, as defined in Encarta, is the process of decontaminating soil by using plants to absorb heavy metals or other pollutants.

Specific LID controls referred to as Integrated Management Practices (IMPs) reduces runoff by integrating stormwater controls in small, discrete units near the source of impacts reducing or eliminating the need for a centrally located BMP. These micromanagement techniques break up a site into micro-watersheds allowing for many smaller systems instead of one large system (Griffin, 2007).

Four major hydrologically based planning elements go into the site planning and design approach that affect hydrology:

- Curve Number (CN)- A factor that accounts for the effects of soils and land cover on amount of runoff generated. Minimizing the change in the post development CN by reducing impervious areas and preserving more trees and meadows to reduce runoff storage requirements all to maintain the predevelopment runoff volume.
- Time of Concentration (Tc) - This is related to the time runoff travels through the watershed. Maintaining the predevelopment Tc reduces peak runoff rates after

development by lengthening flow paths and reducing the use of pipe conveyance systems.

- Permanent storage areas (Retention) - Retention storage is needed for volume and peak control, water quality control and to maintain the same CN as the predevelopment condition.
- Temporary storage areas (Detention) - Detention storage may be needed to maintain the peak runoff rate and/or prevent flooding (Coffman, 2000).

Maintaining predevelopment Time of Concentration (Tc) requires the inclusion of several micro-scale retention and detention LID practices at the impact site. Micro-scale features include redirecting flows to vegetated swales, rain gardens, preserving woodlands, avoiding soil compaction the elimination of curbs/gutters and disconnecting down spouts. Impervious surfaces such as driveways, parking lots and streets that are exposed to light traffic can be replaced with pervious concrete and asphalt that will allow rainwater to pass through and infiltrate to the ground water system.

Multi-functional LID features such as rain gardens, vegetated swales and bioretention cells have built in storage to detain runoff that will either filter into the soil or evaporate while trapping suspended solids and pollutants before they are carried to the receiving water bodies. These LID features provide infiltration for ground water recharge to mimic site pre-development hydrology, filter out pollution and detain the runoff long enough that evaporation may take place. As the retention storage increases there is a reduction in the runoff volume and peak discharge rate. More storage volume may result in a reduction in runoff that is less than predevelopment runoff rate (Coffman, 2000).

Tables 2 provides a level of reference of how effectively different LID practice removes different pollutants.

Reported Pollutant Removal Efficiency of LID Practices							
LID Practice	***TSS***	***Total P***	***Total N***	***Zinc***	***Lead***	***BOD***	***Bacteria***
Bio-retention	-	81	43	99	99	-	-
Dry Well	80-100	40-40	40-60	80-100	80-100	60-80	60-80
Infiltration Trench	80-100	40-60	40-60	80-100	80-100	60-80	60-80
Filter/Buffer Strip	20-100	0-60	0-60	20-100	20-100	0-80	-
Vegetated Swale	30-65	10-25	0-15	20-50	20-50	-	-
Infiltration Swale	90	65	50	80-90	80-90	-	-
Wet Swale	80	20	40	40-70	40-70	-	-

Table 2 Pollution Removal Efficiencies, Mason County (County M. , 2008)

Table 3 illustrates the effectiveness of LID practices over conventional stormwater management technologies as it affects the hydrologic cycle in a watershed.

Comparison of Conventional and LID Stormwater Management Impacts on the Hydrologic Cycle		
Hydrologic Parameter	***Conventional***	***LID***
Vegetation/Natural Cover	typically not incorporated into drainage designs.	used to maintain pre-development hydrology
Time of Concentration	shortened, reduced as a by-product of drainage efficiency	increased where possible to approximate predevelopment conditions
Runoff Volume	increases in runoff volume	controlled to predevelopment conditions
Peak Discharge	controlled to predeveloped design criteria	controlled to predeveloped conditions for all storms
Runoff Frequency	increased, especially for small, more frequent storms	controlled to predeveloped conditions for all storms
Rainfall Abstractions (Interception, Infiltration, Depression Storage)	large reduction in all elements	maintained to predevelopment conditions
Groundwater Recharge	reduction in recharge	maintained to predevelopment conditions

Table 3 Comparison of Conventional and LID Stormwater Management Impact on the Hydrological Cycle

(County M. , 2008)

3.6 LID Cost

Installing multiple micro-scale site specific LID features that reduces runoff consequently negates the need for more costly stormwater infrastructure. A major reduction in stormwater infrastructure cost can be realized when LID techniques are employed in site development designs. The elimination of pipes, pond, curbs and pavers greatly reduces the cost of site development resulting in substantial saving to the developer. LID techniques can reduce the cost of flood control structures by infiltrating and evaporating runoff (EPA), Fact Sheet: Reducing StormwaterCost Throught Low Impact Development (LID) Strategies and Practices. EPA Publication number 841-F-07-006, 2007).

The following table provides cost comparison between conventional development costs versus LID cost. There is a tremendous cost savings when LID techniques are employed to manage stormwater reducing or negating the need for stormwater infrastructure.

Table 1. Cost Comparisons Between Conventional and LID Approaches

Project [a]	Conventional Development Cost	LID Cost	Cost Difference[b]	Percent Differnce[b]
2nd Avenue SEA Street	$868,803	$651,548	$217,255	25%
Auburn Hills	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	$27,600	$5,600	$22,000	80%
Bellingham Bloedel Donovan Park	$52,800	$12,800	$40,000	76%
Gap Creek	$4,620,600	$3,942,100	$678,500	15%
Garden Valley	$324,400	$260,700	$63,700	20%
Kensington Estates	$765,700	$1,502,900	-$737,200	-96%
Laurel Springs	$1,654,021	$1,149,552	$504,469	30%
Mill Creek[c]	$12,510	$9,099	$3,411	27%
Prairie Glen	$1,004,848	$599,536	$405,312	40%
Somerset	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corporate Campus	$3,162,160	$2,700,650	$461,510	15%

Table **4 Cost Comparisons Between Conventional and LID Approaches**

(EPA), Fact Sheet: Reducing StormwaterCost Throught Low Impact Development (LID) Strategies and Practices. EPA Publication number 841-F-07-006, 2007).

LID techniques not only mimic natural hydrology of the watershed and filter out pollutants, they also provide substantial cost savings when compared to traditional development costs.

Chapter 4

Analysis of Effectiveness

When the natural landscape is replaced by impervious surfaces, the natural hydrology of the area is disrupted by removing a large portion of the water budget from the watershed. Stormwater infrastructure collects and transports waters sheeting off impervious surfaces away from the built environment to receiving water bodies. Not only is the hydrology disrupted but pollutants are carried from the landscape, roads and parking lots to receiving water bodies that degrade water quality and compromises aquatic habitats.

The City of Bremerton is taking steps to mitigate stormwater production and the resulting effects of stormwater to rivers and streams, and the introduction of pollutants to receiving surface waters. They have formally adopted LID techniques in the city's code as a stormwater management and development strategy, being applied at the parcel and sub-division scale to closely mimic predevelopment hydrologic functions (Bremerton, 2011).

Throughout Kitsap County, there are 110 wells out of 344 that are part of the Washington State Active Water Level Network, used to monitor the levels of ground water resources throughout the state. Figure 5 provides a visual representation of their locations, randomly dispersed throughout the county. Initial measurements of the sampled wells began in approximately 1988 with the most recent as early as 2002. I was unable to determine when these wells were drilled. The most recent measurement of the water level in the wells was recorded late in 2010 and early 2011.

The measurements represent the static level of the water level below land surface. Data is collected and maintained by the US Geological Survey. Out of the 110 wells in Kitsap County, seventeen with only one measurement have been removed from the analysis.

Kitsap County, Washington. Part of Washington Active Water Level Network

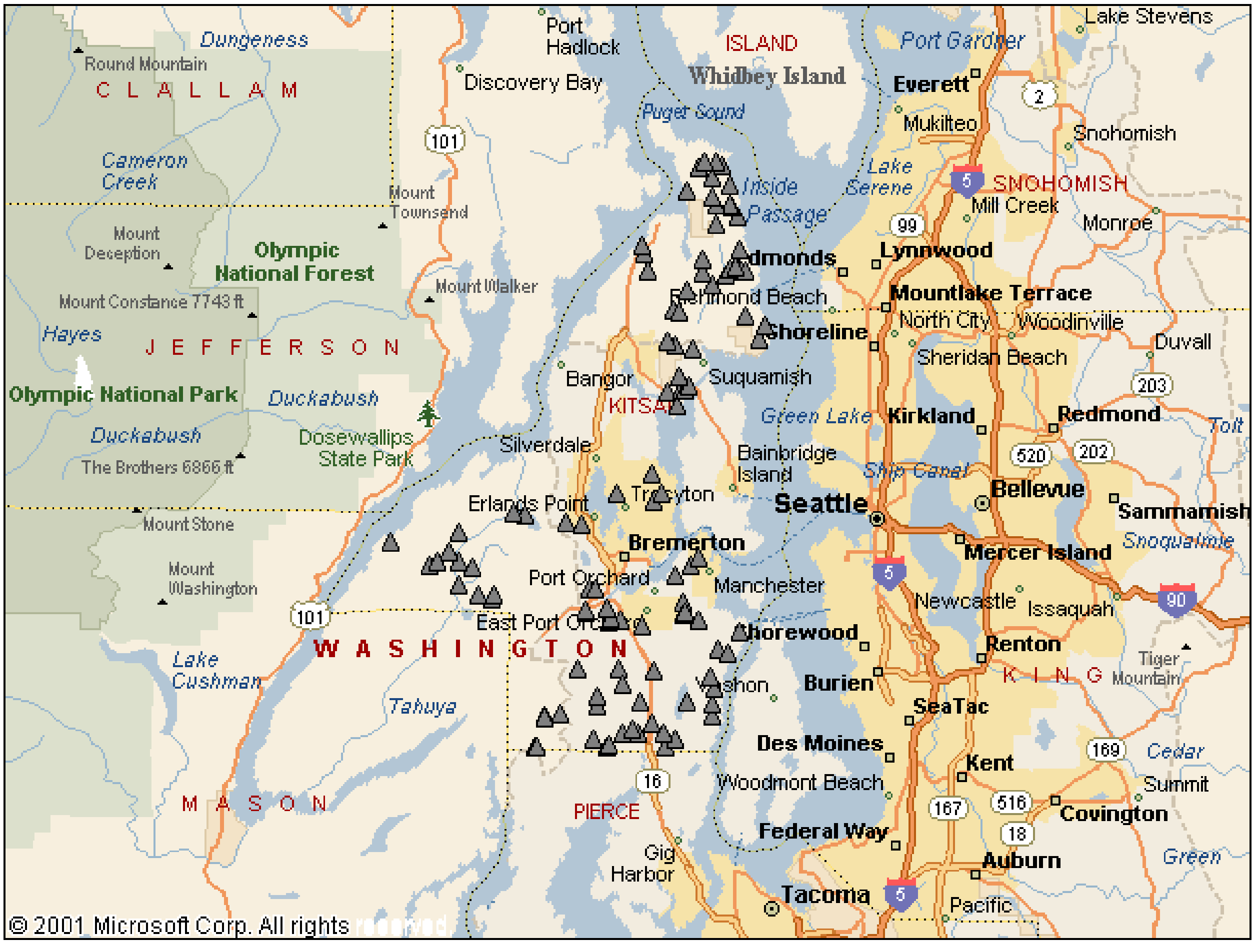

Figure 5 Kitsap County, Washington Active Water Level Network

Wells are at varying depths and water levels may have either decreased or increased from the initial measurement and the latest measurement. The difference in measured levels ranged from less than an inch to approximately 100 feet. The well with the difference of approximately 100 feet was a gain in water level. (I can only report on the data and make no claim to the veracity of said data).

The data, subjected to a t-test, suggests that building practices have not significantly affected aquifer recharge. See Table ##

t-Test: Paired Two Sample for Means

	Initial Measure	*Second Measure*
Mean	124.3188172	122.3790323
Variance	9596.487984	8954.800881
Observations	93	93
Pearson Correlation	0.969496876	
Hypothesized Mean Difference	**0**	
df	92	
t Stat	0.779012796	
P(T<=t) one-tail	0.218985696	
t Critical one-tail	1.661585397	
P(T<=t) two-tail	**0.437971392**	
t Critical two-tail	1.986086272	

Table 3 Results of t-test.

Using a probability of 0.05, degrees of freedom (df) of 92, the tabled critical t value is 1.9861 (two tailed). The calculated t Critical two-tailed value is 1.9860 and is less than the tabled value of t. There is no significant difference between the initial measurement and the most recent measurement of the sampled wells. Therefore, the null hypothesis that building practices does not affect aquifer recharge has not being repudiated.

4.1 Discussion

Water resources, and the continued supply of these resources, are one of the most important ingredients of the human habitat. The larger the population grows, the greater the need will be for an increase in the water supply. Population growth drives urban expansion, commercial activity and irrigation needs. All of these increases water demand. Urban expansion also increases impervious surfaces prompting additional quantities of the water budget being expelled from the watershed. These impervious surfaces will also contribute to the degradation of surface water bodies with the introduction of additional pollution from non-point sources.

Regulating urban growth is an orderly path to controlled development which will minimize sprawl. We recognize our current stormwater management practices are not enough to minimize the amount of pollution being carried from the landscape to surface water bodies. The EPA adopted a phased approach in addressing pollution entering surface water bodies through regulation and expensive stormwater treatment. A shift in our approach to dealing with stormwater will not only maintain the hydrology of the watershed that allows rainfall to infiltrate to the ground water system, but it also filters out pollution before entering surface water bodies.

Incorporating LID techniques as a stormwater management strategy reduces runoff by managing rainfall at the impact site. Land Use Planners and Landscape Designers must adopt a new paradigm in addressing stormwater. The goal must be to minimize stormwater volume by managing it at the impact site. LID techniques can complement existing stormwater management strategies as we address surface water pollution.

Expected population growth in Kitsap County will continue to increase the demands on the water supply. The future is uncertain as to climate change impacts on the region's hydrologic cycle. It is imperative that we retain as much of the rainfall on the landscape as possible to maintain base flow in rivers and streams, and recharge of underlying aquifers. LID techniques are an effective means in mimicking natural hydrology. Although the t-test did not indicate significance in declining water levels in the county's wells, it was on the far end of the acceptable spectrum.

Developers must recognize the benefits of adopting LID techniques as they transform the natural landscape, and redevelopment projects, into residential spaces. If the environmental benefit is not a concern, the cost savings from not having to install stormwater infrastructure, larger roads and the prospect of enhanced property values may provide some incentive. We will never totally eliminate the impacts development has on water quality and the hydrology within the developed landscape but human beings can mitigate their impacts.

Throughout history, we have consistently integrated new technologies into development projects as the need arises. Today we have another need. We need to minimize the transport of pollutants from the landscape to surface water bodies that compromises aquatic habitat. We need to maximize the infiltration potential within the urban area to provide for the long term viability of underlying aquifers.

Kitsap County is right in the middle of the Puget Sound Lowland, seemingly isolated, surrounded by water. Our water source is totally dependent on rainfall that falls within its watershed. This is a resource that must be utilized and not expelled to receiving water bodies. Being self-sufficient and maintaining a reliable water supply well into the future will depend on how we make allowances for its continued replenishment. Employing LID techniques as we transform the landscape is a step in the right direction.

Chapter 5

Moving Forward

The Bremerton Housing District is redeveloping the Bay Vista Complex, formally known as West Park constructed shortly after World War II, with a new vision moving forward. Previous stormwater infrastructure made no provision for water quality with direct release to Sinclair Inlet, Oyster Bay and Ostrich Bay. The 83 acre site sits on Glacial till determined to be Type C soil. This soil type has a moderately high runoff potential. As quoted in the *Hydrologic Soil Series for Selected Soils in Washington State:*

> *Soils having low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine textures. These soils have a low rate of water transmission (0.05-0.15 in/hr.).*

The designs call for a reduction in traditional impervious surfaces through pervious roads, driveways and sidewalks. Stormwater infrastructure consists of multiple subterranean chambers that detain the water onsite for infiltration or evaporation. Porous concrete and asphalt provide enormous surface area that allow for faster evaporation, reducing the amount of water entering the stormwater system (Dort & Johnson, 2009).

The landscape is divided into three distinct watersheds that drain to three separate locations in Puget Sound – Sinclair Inlet, Oyster Bay and Ostrich Bay. Within each watershed are micro-watersheds that employ LID techniques that detain water for infiltration and evaporation (Dort & Johnson, 2009). It is expected that upon completion, a light rain will produce zero stormwater entering Puget Sound from the Bay Vista Complex. This is just one area in which the City of Bremerton is addressing water quality problems in Puget Sound.

The Kitsap Conservation District (KCD) has instituted a Rain Garden Cost Share Program with over 63 property owners taking advantage of this financial incentive to install rain gardens on their property. The program provides half of the cost to install a rain garden up to $500. The average cost of installing a rain garden is $1,000 to $1,500. Kitsap County Surface and Stormwater Management (SSWM) provide funding for the program through stormwater fees from property owners in unincorporated parts of the county. $50,000 is allotted to the program on a yearly basis. Technical assistance is provided by trained Conservation staff or Master Gardeners from Washington State University (WSU) (Works, 2011).

In the 1980s, non-point source fecal pollution was instrumental in the closure of shellfish beds within Puget Sound. Due to intensive development in rural watersheds and the marine shoreline, large amounts of fecal coli form was introduced to the marine environment. Shellfish growing areas in Dyes Inlet watershed are situated among rural, urban and commercial activities. Potential fecal pollution sources include failed onsite sewage systems, waste from farm animals, combined stormwater-sewer overflows (CSOs), and contaminated stormwater runoff. Numerous fecal pollution sources were identified and resolved through the efforts of Kitsap County, City of Bremerton and the U.S. Navy to the point where water quality has shown significant improvement. After decades of closure, shellfish beds in Dyes Inlet are once again open for consumption (Health, 2010).

These continued efforts throughout the county indicate that watershed specific approach to controlling environmental problems associated with stormwater runoff are effective in reducing pollution entering surface waters.

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