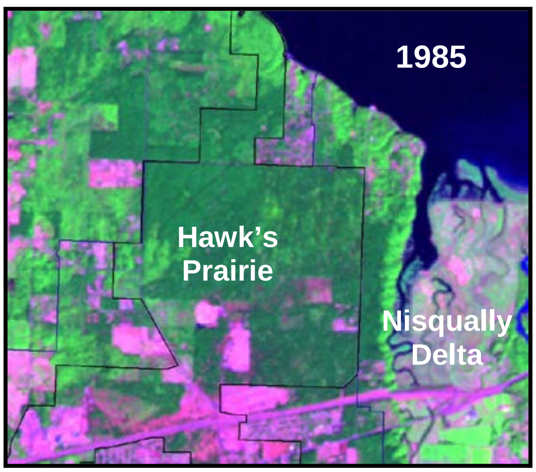
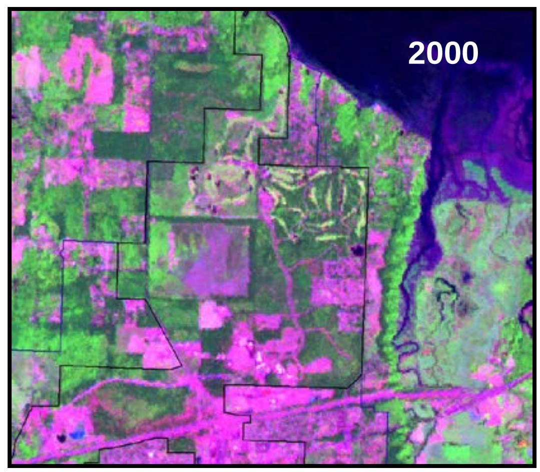
THE RATE OF URBANIZATION AND FOREST HARVEST IN THURSTON COUNTY 1985-2000





A Land Cover and Change Detection Satellite Remote Sensing Study

FINAL REPORT

JANUARY 2002

Prepared By: Thurston Regional Planning Council

THURSTON REGIONAL PLANNING COUNCIL (TRPC) is a 16-member intergovernmental board made up of local governmental jurisdictions within Thurston County plus the Nisqually Indian Tribe and the Confederated Tribes of the Chehalis Reservation. The Council was established in 1967 under RCW 36.70.060 which authorized creation of regional planning councils.

TRPC's mission is to **"Provide Visionary Leadership on Regional Plans, Policies and Issues."** The primary functions of TRPC are to develop regional plans and policies for **transportation** (as the federally recognized Metropolitan Planning Organization and state recognized Regional Transportation Planning Organization), **growth management, environmental quality** and other topics determined by the Council; provide **data and analysis to support local and regional decision making;** act as a **"convener"** to build **community consensus** on regional issues, through information and citizen involvement; build **intergovernmental consensus** on regional plans, policies and issues, and advocate local implementation; and provide **planning, historic preservation and technical services** on a contractual basis.

This report was prepared as part of the Thurston Regional Planning Council's 2001 regional work program.

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Cover: Satellite images (1985 and 2000) of Hawks Prairie Region of Lacey with city and urban growth area boundaries overlaid. Vegetation is shown in green; built features and bare soils are shown in pink.

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EXECUTIVE SUMMARY

The Rate of Urbanization and Forest Harvest in Thurston County

Thurston County, Washington is located at the southern end of the Puget Sound Basin. Home to the State Capital (Olympia), and six other cities and towns, it currently has a population of just over 210,000 people. In the last 30 years the population of the county has more than doubled. Much of the growth occurred in the 1970s, when the county experienced a growth rate of almost 5 percent annually. In the 1980s and 1990s, the growth rate dropped somewhat, to a relatively steady 2.5 percent annually.

Results from a satellite imagery-based study show that more than 32,000 acres of lands were converted from intact forest lands, agricultural lands, or large expanses of shrubby vegetation to urban lands between 1985 and 2000. The majority (57 percent) of urban conversions took place on previously forested lands. Thirty percent took place on lands previously in agricultural activity, and an additional 13 percent took place on shrubby lands. More than 9,000 acres were converted to urban usage within designated urban growth areas, which include the cities and towns of Thurston County and those areas that the county has identified as likely to be annexed and provided with city services within the next 20 years. In the rural county, 23,000 acres of land were converted to urban usage, representing 70 percent of the total conversions.

Urbanization has resulted in changes in the urban land cover, or built land cover, of the county. Total land area covered by built or urban features has increased by 1 percent as a whole over the last 15 years. The change in urban land cover was not spread uniformly across the landscape. In the cities and towns, the amount of land covered by built features increased by 2,000 acres, or 29 percent of the total land area. In the rural county, an additional 2,300 acres were covered by built features. Watersheds that experienced rapid changes in urban land cover included Budd Deschutes, Henderson Inlet, and Nisqually River.

Increased urbanization often comes at the expense of intact forest cover. Thurston County's forest cover was reduced by almost 13,000 acres, or 3 percent of the total land area, over the last 15 years as a result of urbanization of forest lands. Five thousand acres of forest cover loss occurred in the cities, towns, and designated urban growth areas of the county. A further loss of 8,000 acres occurred in the rural county.

Thurston County's forests are in a constant state of flux. In addition to being subject to urbanization, most of the commercial forest lands also undergo cycles of harvest and replanting. It is estimated that between 1985 and 2000, almost 56,000 acres of land were in the forest harvest cycle, for an average annual rate of approximately 4,000 acres per year. Forest lands account for 282,000 acres of public and private forests, as well as parks, reserves, and other forested lands in Thurston County. Ninety eight percent of the forest harvest activity occurred in the rural county. Within 15 years of harvest, almost half of the area undergoing harvest activity was identifiably reforested.

Understanding the changes that take place in land cover in Thurston County provides an important tool to understanding the health of our natural systems, including streams, wetlands, and marine shorelines. Recent scientific evidence has found a direct correlation between forest cover, urban cover (impervious area), and stream conditions. Mapping land cover change can help planners in Thurston County understand recent trends in stream, wetland, and marine shoreline health decline.

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I. INTRODUCTION

Thurston County, Washington is located at the southern end of the Puget Sound Basin. Home to the State Capital (Olympia), and six other cities and towns, it currently has a population of just over 210,000 people. In the last 30 years the population of the county has more than doubled. Much of the growth occurred in the 1970s, when the county experienced a growth rate of almost 5 percent annually. In the 1980s and 1990s, the growth rate dropped somewhat, to a relatively steady 2.5 percent annually. The distribution of where people were choosing to live has also changed throughout the last 30 years. In 1970, 53 percent of the population of the county lived in urbanized areas, within city and town boundaries. Ten years later, this number had dropped to 45 percent, as many people were choosing to live on the urban fringe just outside of city limits, in an area that was rapidly succumbing to urban sprawl. By 1988, most of the incorporated jurisdictions had defined an Urban Growth Area (UGA) around existing city or town limits. This identified the area that each jurisdiction plans to incorporate into its city limits and provide city services within the next 20 years. After the passage of the state Growth Management Act (GMA) in 1990, the county "downzoned" large portions of the unincorporated rural county in a further effort to curb urban sprawl and retain the rural characteristics of large portions of the county. By the time the post-GMA County Comprehensive Plan was passed, the county had identified a variety of strategies aimed at preserving farm and forest lands from urban infringement, and encouraging new growth to locate in urban areas.

The addition of approximately 32,000 new dwelling units to the county between 1985 and 2000, to accommodate the growth in population, has resulted in changes in land cover throughout the county. Land cover categorizes the vegetation, water, natural surface, and cultural features on the land surface, and is distinct from land use. For instance, a stand of trees would be categorized as a forest with a land cover classification. That same stand of trees could be categorized as part of a park, a commercial forest, or someone's back yard in a land use classification. Additional land has been modified to accommodate new commercial and industrial uses to support the growing economy of the region. Changes can take many forms. In some cases, existing urban land is redeveloped and used more efficiently, or small lots of vacant land within existing urban areas are developed. This type of development can be tracked through monitoring of building permit activity. In other cases, land that was previously in use for forestry or agricultural activity is converted to urban uses. These changes can be assessed by looking for differences between satellite images captured over time.

Another large scale change that occurs over the landscape is the harvest of forest lands. Forest lands are extremely important to our community, both in terms of economic stability, and the long-term environmental and quality-of-life benefits forest lands provide. If forest lands in timber production are managed correctly, long term benefits ensue, such as a reduction in soil erosion, protection of wildlife habitat, maintenance of water quantity and quality, mitigation of the effects of storm water runoff and flood damage, enhancement of air quality, and opportunities for recreation. It is not only important to monitor when forest harvest activity occurs, but also where it occurs, especially in relationship to established water basin and watershed boundaries. It is also important to gain an understanding of the timing of the cycle of change in a forest, and how many years it takes to reforest a clear cut.

This report summarizes the results of a change analysis performed using satellite data collected in 1985, 1990, 1995, and 2000 for Thurston County. Change is separated into two categories: urbanization and forest harvest. Both provide insight into the dynamic nature of Thurston County's landscape.

II. BACKGROUND

A. Overview

In 2000 the Thurston Regional Planning Council (TRPC) received a grant from the Washington State Office of Community Development, Growth Management Program to create a digital land cover data layer for Thurston County using satellite data. This project was concluded in June of 2001. The results of the project are available on the TRPC website (www.trpc.org) or by calling (360) 786-5480 and requesting the document: <u>Land Cover Mapping of Thurston County, Methodology and Applications, June 2001.</u>

As a second phase to this project, TRPC acquired additional satellite data for the years 1985, 1990, and 1995. The intent was to monitor change in forested land cover over time. Landsat Thematic Mapper satellite data were obtained for this phase of the project.

B. Landsat Thematic Mapper

Landsat Thematic Mapper (TM) data are acquired from the Landsat series of commercial satellites operated by NASA. Since first available in 1984, data have been used to map a variety of land cover types, including forested lands, agriculture, snow packs, and geologic formations and structure. The spatial resolution of TM data is 30 meters by 30 meters.

The spectral resolution of Landsat TM data refers to the positioning of the sensor's seven spectral bands in relation to the reflected visible and infrared wavelengths of the electromagnetic spectrum. Table 1 lists the positioning of each band, in addition to a brief summary of the intended principal applications of each. Band six, designed to capture data reflected from the thermal wavelengths of the electromagnetic spectrum, was not used in this study.

For additional information on the Landsat satellite, please refer to the Land Cover Mapping Report, referenced above.

C. Time Frame

Data used in this study were collected between May and September for the years 1985, 1990, 1995, and 2000 (Table 2). The screening mechanism for selecting data was 1) minimum cloud cover; 2) maximum data quality; and 3) summer growing season. Often, only one suitable scene was available for a given year.

TABLE 1: THEMATIC MAPPER SPECTRAL BANDS AND THEIR PRINCIPAL APPLICATIONS.

Band	Wavelength (μm)	Nominal Spectral Location	Principle Applications
1	0.45-0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest type mapping, and cultural feature identification.
2	0.52-0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63-0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76-0.90	Near infrared	Useful for determining vegetation types, vigor and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55-1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6	10.4-12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08-2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

SOURCE: FROM LILLESAND AND KEIFER, 1994.

TABLE 2. DATES OF SATELLITE DATA USED IN THIS STUDY.

Path	Row	Date of Acquisition	Description
46	27/28	07/15/2000	Landsat 5 TM data. Zero percent cloud cover.
46	27/28	05/31/1995	Landsat 5 TM data. Zero percent cloud cover.
46	27/28	09/22/1990	Landsat 5 TM data. Zero percent cloud cover.
46	27/28	08/23/1985	Landsat 5 TM data. Zero percent cloud cover.

III. PROCESSING

A. Data Preparation

All satellite data were placed into the same geographic coordinate system as existing geographic information system (GIS) data at Thurston Regional Planning Council, using a process called georectification. This required selecting at least 40 ground control points on each image and matching them to the same points on existing one foot resolution aerial photography. The final data are available in the Stateplane coordinate system, NAD 83, FIPSZONE 4602 with a spheroid of GRS 1980.

B. Change Detection

The change detections were performed in a series of five year time slices. For instance, the satellite data from 1985 was compared only to the data from 1990. The data from 1990 in turn was compared to 1995. The five year time slices were thought to be adequate time intervals to identify areas that had undergone change from vegetation to non-vegetation.

Two computer algorithms were used for the change detection, the first to identify clear cuts in forest lands, and the second to identify more subtle changes in vegetation such as those associated with urbanization. In addition, hand screening was utilized to detect changes on agricultural lands.

Clear Cuts:

Clear cuts were identified by looking at the difference in brightness values between one spectral band of data in one time period, compared to the same spectral band in the previous time period. The spectral band most useful in identifying clear cuts was band 5. The output was an image of difference values. The values that showed the most difference between time periods were clear cuts and changes in crop lands.

Urbanization:

Urbanized areas were identified by first applying a tassle cap transformation algorithm to each set of satellite data, then identifying the difference between the resulting image for two subsequent time periods. The tassle cap transformation is a way of combining information in all 6 bands of Landsat Thematic Mapper data into discrete themes. In this case, the data that was output in theme 2, which is designed to represent vegetation, was used in the change detection. This algorithm is useful for pulling out subtle changes in vegetation such as those found when the change is from immature forests to lawns and roads. Urbanization could only be identified when the pre-urban land cover was forest or shrubs. Hand digitizing was utilized to isolate changes on agricultural lands.

C. Post Processing

The primary difficulty with change detections is that they result in a great deal of artifacts or noise that is not useful for the analysis. The first phase in noise reduction was to filter out individual pixels. The data were then transferred into a GIS, where polygons were further screened based on their size. Any polygons smaller than 5 acres for clear cuts, or 3 acres for urbanization, were screened out of the data set.

D. Change Analysis

The final step in the analysis was to visually screen each data set to remove artifact polygons. Artifact polygons included changes attributed to agriculture (one crop versus another or a tilled field), changes along the shoreline due to differing tide levels, and any other changes not associated with either urbanization or harvest activity. During the visual screening phase, it was determined that there was significant overlap between the two methods of change detection. For this reason, data sets for each time interval were merged into one data set, and polygons were tagged with the date of vegetative cover removal.

Change between land clearing (shrubs to soils to shrubs again) was difficult to distinguish from urbanization in the urban environment. For this reason, the boundaries of subdivisions platted between 1970 and 2000 were overlain on the change polygons as an additional screening mechanism.

Results of each time interval (1985-1990, 1990-1995, and 1995-2000) were then merged in a master file. Additional screening was performed on those areas that were identified as showing change in more than one time interval.

The final phase in the change analysis was to compare each polygon that defined change with 1985 and 2000 land cover characteristics. Land cover characteristics in 1985 were derived from an unsupervised classification of the 1985 satellite data. Classes developed in the classification were: urban, forest, water, and other. Using the classifications, polygons were defined as either having forest, shrubs, or agriculture as their original vegetative cover.

2000 land cover characteristics were developed in Phase 1 of this project. The results of the project are available on the TRPC website (www.trpc.org) or by calling (360) 786-5480 and requesting the document: Land Cover Mapping of Thurston County, Methodology and Applications, June 2001. Using the 2000 classification, change polygons were defined as either urban or harvest polygons depending on the percentage of urban land cover present in 2000 (see above report for 2000 land cover classes). Visual discrimination was necessary to separate those harvest parcels with a small urban component attributable to logging roads, from other urban parcels.

IV. RATE OF FOREST HARVEST

Thurston County's forests are in a constant state of flux. Much of our forest lands are in commercial forest production, and undergo regular cycles of harvest, replanting, and eventual reforestation. Of the 197,800 acres of commercial forest lands, approximately 132,900 acres are held by private forest companies and small forest land owners. The remainder, 64,900 are held in public ownership, most of which is in the State Capital Forest. But this is just one component of the total forest cover in Thurston County. Much of the almost 17,000 acres of the Fort Lewis Military Base, located in the eastern portion of the county, are forested. In addition, forests are present in parks, preserves, along riparian corridors, on agricultural lands, and in urban areas. All of this adds up to over 282,000 acres of forest lands in Thurston County, covering almost 60 percent of the land area (Table 3).

Between 1985 and 2000, almost 56,000 acres of land were in the forest harvest cycle in Thurston County, which amounts to an annual rate of approximately 4,000 acres a year. Almost all (98 percent) of forest harvest activity occurred in the rural regions of Thurston County. The remainder took place within existing city or town limits, or in the urban growth areas. These areas are likely to convert to urban usage in the future.

Forest lands have been harvested at a rate of approximately 1.4 percent annually, which translates to 20 percent of the county's forest lands being harvested over the last 15 years. The rate of harvest is significantly higher in the rural county where most of the commercial forest lands are found.

Of the 56,000 acres of forest lands that have been subjected to harvest activity over the last 15 years, approximately 29,000, or just over half, have not yet re-grown an identifiable forest cover of young trees. These lands are identified as forest lands currently in the harvest cycle, or forest lands in flux. Some of these lands may convert to urban uses in the future (Table 3).

TABLE 3: ESTIMATE OF FOREST LANDS IN THURSTON COUNTY, 2000.

	2000 (acres)				1985-2000	
Jurisdiction	Total Land	Forest Land Cover	Forest Lands Currently in Harvest Cycle	Estimate of Total Forest Lands	Total Harvest (acres)	% of Total Forest Lands
Cities	33,296	8,331	178	8,509	627	7%
Urban Growth Areas	29,015	7,301	443	7,744	701	9%
Rural County	407,562	237,831	28,362	266,193	54,638	21%
Total	**469,873**	**253,463**	**28,982**	**282,445**	**55,966**	**20%**

The rate of harvest has dropped steadily over the last 15 years, from almost 25,000 acres between 1985 and 1990 to 12,000 acres between 1995 and 2000 (Table 4). Forest harvests are cyclical in nature, and trends in Thurston County are consistent with statewide trends (Larson, 2001).

TABLE 4: RATE OF REFORESTATION OF THURSTON COUNTY FOREST HARVESTS, 1985-2000.

	2000 Land Cover of Harvested Areas					
Period of Harvest	Urban	Forest	Young Forest	Non-Forest Vegetation	Other	Total
1985-1990	115	9,231	8,914	6,135	227	24,622
1990-1995	180	4,516	3,627	10,559	6	18,888
1995-2000	278	614	82	11,480	1	12,456
Total	**572**	**14,361**	**12,623**	**28,174**	**235**	**55,966**

Within 10-15 years of harvest activity, approximately 75 percent of harvest areas have regenerated to young forests or forest lands. Young forests are characterized by tree plantations with an open canopy. Trees identified as young forests are generally between 8 and 25 years old. Within 10 years of harvest activity, harvest areas remain in a state of flux, with more than half of the land cover characterized by non-forest vegetation, which can include shrubs, saplings, and grasses. The remainder remains forested, such as in areas of partial harvest, or are beginning to regenerate to a new generation of forest cover.

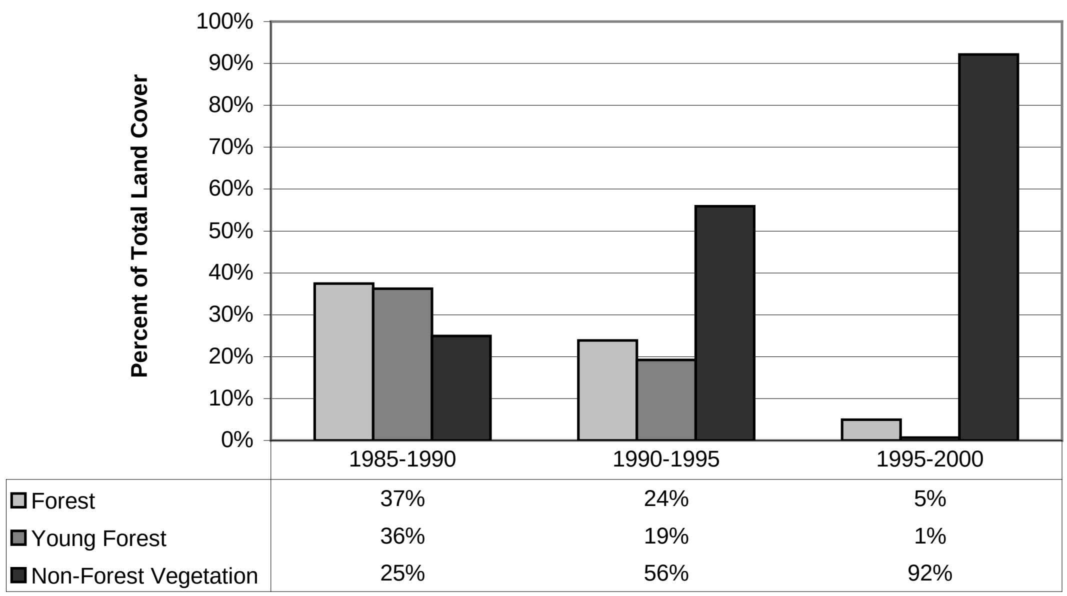

FIGURE 1: RATE OF REFORESTATION OF THURSTON COUNTY FOREST HARVESTS, 1985-2000.

V. URBANIZATION

A. Overview

Since 1985 the population of Thurston County has increased by almost 70,000 people, and the total number of jobs has increased by more than 48,000 (Table 5). During the same period of time, building permits were issued for approximately 32,000 residential dwelling units, and over 15 million square feet of commercial or industrial space. While some of the urbanization occurred on underdeveloped or vacant urban lots, or was scattered across rural areas, a large component resulted in the urbanization of lands that were previously forested, in agricultural use, or covered by shrub vegetation.

Large-scale change detectable from satellite imagery indicates that approximately 32,000 acres of land were converted from intact forest stands, agricultural lands, or large expanses of shrub vegetation to urban landscapes over the last fifteen years in Thurston County. Infill of existing subdivisions and urban areas was not considered a conversion, nor were the placement of individual homes in the rural landscape. Conversely, large tracts of vacant land developed into urban subdivisions were considered conversions, even if the conversion occurred within existing city limits and was surrounded by earlier development. These conversions resulted in a change in both land use and land cover in Thurston County.

TABLE 5: CHANGES IN EMPLOYMENT, POPULATION, AND URBAN LAND, 1985-2000.

Change 1985-2000	Change in Employment (Total Jobs)	Change in Population	Urbanization (Acres)
Total	48,106	67,855	32,617
Annual Average	3,436	4,847	2,330

NOTE: EMPLOYMENT FOR 2000 IS AN ESTIMATE BASED ON 1999 FIGURES. 2000 DATA WILL NOT BE AVAILABLE UNTIL JUNE 2002.

Land use is often confused with land cover, although they differ in many significantly ways. Land cover categorizes the vegetation, water, natural surface, and cultural features on the land surface. In comparison, land use evaluates the human uses for the land. For instance, a stand of trees would be categorized as a forest or trees with a land cover classification. That same stand of trees could be categorized as part of a park, a commercial forest, or someone's back yard as part of the urban landscape in a land use classification.

The urban component of the change analysis measures changes in land use (Figure 2; Figure 3).

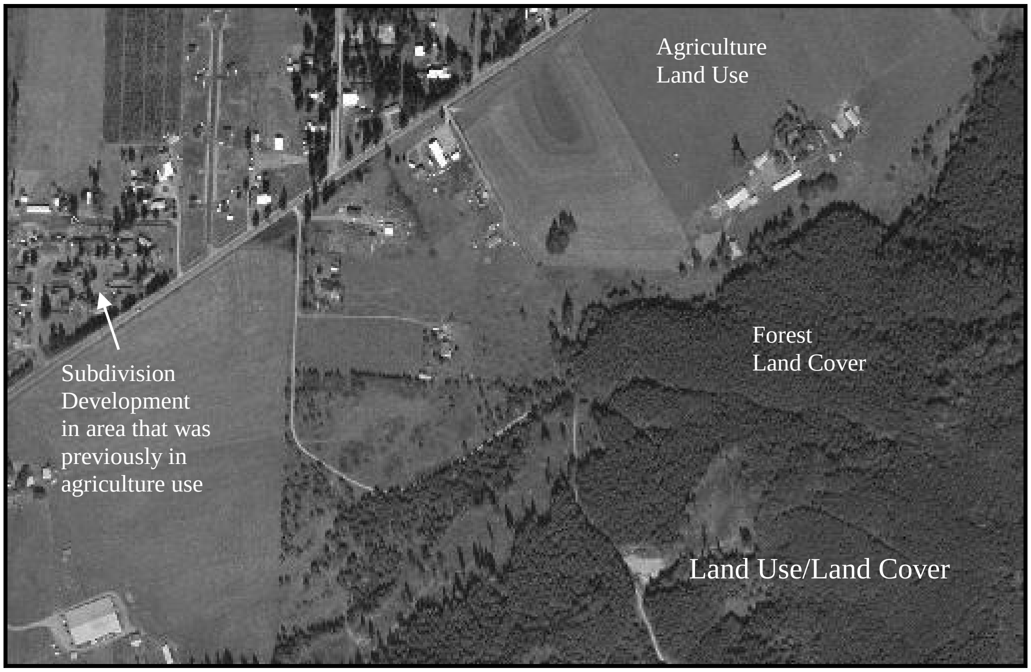

FIGURE 2: CURRENT LAND COVER/LAND USE PATTERNS IN SOUTHERN THURSTON COUNTY.
FOREST COVER, AGRICULTURE, AND URBAN LANDS COEXIST IN RURAL LANDSCAPES. SCALE IS APPROXIMATE 1 INCH TO 1000 FEET.

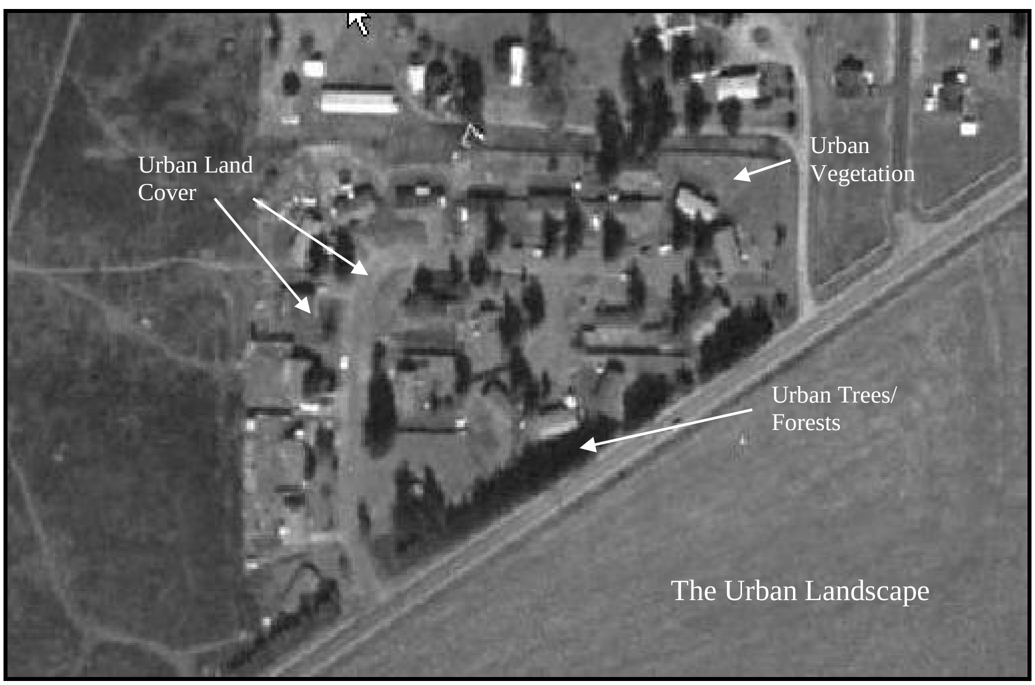

FIGURE 3: ENLARGEMENT OF SUBDIVISION SHOWN IN FIGURE ABOVE.
NOTE THAT URBAN LANDSCAPE INCLUDE BUILT FEATURES SUCH AS ROADS AND HOMES, AS WELL AS URBAN VEGETATION SUCH AS SHRUBS AND GRASSES. THESE COMBINE TO CREATE URBAN LANDSCAPES. SCALE IS APPROXIMATELY 1 INCH TO 300 FEET.

B. The Urban Landscape

The urban landscape consists of a large variety of land cover types. Predominant on the urban landscape are the man-made or built features, which can include roads, buildings, parking lots, and sidewalks. These features are readily identifiable on high resolution satellite data due to their often unique characteristics, and have been grouped into a category called urban. Another component of the urban landscape is urban trees and forests. Trees are often found on urban lots, in open space buffers, or in park lands. A third component of the urban landscape are the lawns, shrubs, bare soils, and water. It is not surprising that urban landscapes that were originally forested have a larger component of trees or forests (31 percent) than those lands that were originally in agriculture or shrubs (Table 6). Despite that difference, data from the last fifteen years of change show that new urban environments are composed of approximately 17 percent built features, and 83 percent vegetation.

While the percent of built features (urban features) in new urban environments remains relatively constant despite original land cover, it does vary significantly depending on the distance away from existing urban areas. New urban development that occurs within existing city limits is composed of a large component of built features (42 percent), and a relatively small component of trees (9 percent). In the urban growth areas, areas adjacent to existing city limits where it is efficient to provide urban services in a reasonable planning horizon (20 years), urbanization is occurring at lower densities. Built features account for only 27 percent of the land cover after urbanization, forest or tree cover accounts for an additional 13 percent, and the remainder, 60 percent consists of lawns, shrubs, and soils. In the rural county, or those areas where development is encouraged to occur at densities that maintain the rural characteristics of the land, built features account for 10 percent of new urban development. Forests and trees are more likely to be found, and account, on average, for 25 percent of the land cover in newly urbanized areas.

TABLE 6: LAND COVER CHARACTERIZATION OF THE URBAN LANDSCAPE BASED ON ORIGINAL LAND USE/LAND COVER.

	Urban Land Cover in 2000 of Areas Urbanized between 1985 and 2000				
Original Land Use/ Land Cover	Urban (roads, buildings, parking lots)	Forest (conifers and hardwoods)	Other (lawns, shrubs, soil, water)	Total Acres	Total Percent
Forested Lands	2,882 16%	5,667 31%	10,016 54%	18,565 100%	57%
Agricultural Lands	1,867 19%	464 5%	7,562 76%	9,893 100%	30%
Shrub Lands	791 19%	627 15%	2,740 66%	4,159 100%	13%
Total	**5,541** **17%**	**6,758** **21%**	**20,320** **62%**	**32,619** **100%**	**100%**

NOTE: UNIT OF MEASUREMENT IS ACRES.

C. *The Land Susceptible to Urbanization*

The expansion of the urban environment in Thurston County is accompanied by an associated loss in forested lands, agricultural lands, and other types of open lands with mixed vegetation cover such as shrubs. In the interval between 1985 and 2000, it is estimated that approximately 57 percent of the land converted to urban land use was originally forested. Another 30 percent was in agricultural use, and the final 13 percent was originally covered in mixed vegetation (Table 6).

Thirty percent of the new urbanization occurred with urban areas and urban growth areas. The remainder, 70 percent, occurred in the rural regions of the county (Table 7). Infill and redevelopment of existing urban areas are not accounted for in this analysis. Building permit activity in Thurston County has indicated that approximately 40 percent of new dwelling units have been placed into the rural county. Due to differences in density of development in the urban and rural environment, significantly more land is consumed for rural development than urban.

Another interesting approach is to examine the amount of urbanization in acres, as compared to the total land area. Overall, Thurston County is urbanizing at a rate of 7 percent in 15 years, or approximately one half of 1 percent per year. Land is being consumed at the greatest rate in the urban growth areas, at 17 percent over the last 15 years. In the cities and towns, 14 percent of the total land area was urbanized in the last 15 years. It is presumed that the rate of urbanization in the cities is less than that of the urban growth area as there is less land supply available for urbanization. The rural county is being converted at a rate of 6 percent over 15 years (Table 8).

Watersheds experiencing the greatest percent of urbanization over the last 15 years were Henderson Inlet with 14 percent, and Black River with 10 percent.

TABLE 7: LAND COVER CHARACTERIZATION OF THE URBAN LANDSCAPE BASED ON LOCATION OF URBANIZATION.

	Urban Land Cover in 2000 of Areas Urbanized between 1985 and 2000				
	Urban (roads, buildings, parking lots)	Forest (conifers and hardwoods)	Other (lawns, shrubs, soil, water)	Total	
Jurisdiction				Acres	Percent
Cities	1,975 42%	435 9%	2,322 49%	4,732 100%	15%
Urban Growth Areas	1,299 27%	626 13%	2,941 60%	4,867 100%	15%
Rural County	2,266 10%	5,697 25%	15,055 65%	23,018 100%	71%
Total	**5,542** **17%**	**6,758** **21%**	**20,320** **62%**	**32,619** **100%**	**100%**

NOTE: UNIT OF MEASUREMENT IS ACRES.

TABLE 8: URBANIZATION BETWEEN 1985 AND 2000 BY VARIOUS GEOGRAPHIES.

		1985-2000 Conversion from:				
Jurisdiction	Total Land Area	Forested Lands	Agriculture Lands	Shrub Lands	Total	Percent of Total
Cities	33,296	3,007	1,138	587	4,732	14%
Urban Growth Areas	29,015	2,689	1,353	824	4,867	17%
Rural County	407,562	12,869	7,402	2,747	23,018	6%
Total	**469,873**	**18,565**	**9,893**	**4,159**	**32,617**	**7%**

		1985-2000 Conversion from:				
WRIA	Total Land Area	Forested Lands	Agriculture Lands	Shrub Lands	Total	Percent of Total
WRIA 11	83,978	3,666	1,275	49	4,990	6%
WRIA 13	149,136	8,076	2,938	1,588	12,602	8%
WRIA 14	30,781	923	39	66	1,028	3%
WRIA 23	205,978	5,888	5,641	2,456	13,985	7%
TOTAL	**469,873**	**18,553**	**9,893**	**4,159**	**32,605**	**7%**

		1985-2000 Conversion from:				
WATERSHED	Total Land Area	Forested Lands	Agriculture Lands	Shrub Lands	Total	Percent of Total
BLACK RIVER	78,971	4,248	2,110	1,551	7,908	10%
BUDD/DESCHUTES	104,019	4,422	1,427	1,299	7,149	7%
CHEHALIS RIVER	47,034	699	3,264	505	4,468	9%
ELD INLET	23,534	1,193	73	199	1,464	6%
HENDERSON INLET	31,832	2,547	1,470	445	4,462	14%
NISQUALLY RIVER	88,640	4,890	1,275	73	6,239	7%
SKOOKUMCHUCK RIVER	55,163	35	236	20	291	1%
TOTTEN INLET	21,401	519	39	66	623	3%
WEST CAPITOL FOREST	19,272	0	0	0	0	0%
TOTAL	**469,867**	**18,553**	**9,893**	**4,159**	**32,605**	**7%**

		1985-2000 Conversion from:				
BASIN	Total Land Area	Forested Lands	Agriculture Lands	Shrub Lands	Total	Percent of Total
ALDER LAKE	2,656	0	0	0	0	0%
ALLEN CREEK	3,418	0	65	236	301	9%
BALD HILL LAKE	794	0	0	0	0	0%
BEAVER CREEK	13,166	898	194	453	1,546	12%
BLACK LAKE	5,526	906	31	376	1,313	24%
BLACK RIVER	25,092	1,306	1,540	395	3,241	13%
BLOODY RUN	2,062	0	0	0	0	0%
BLOOM DITCH	5,010	677	80	21	778	16%
BURNS	166	130	8	0	138	84%
CAPITOL LAKE	1,663	67	0	34	101	6%
CHAMBERS	8,416	810	532	278	1,620	19%
CLEAR LAKE	1,850	409	0	0	409	22%
DANA PASSAGE	1,146	12	0	0	12	1%
DEMPSEY CREEK	5,844	245	9	0	255	4%
DESCHUTES RIVER	56,284	1,201	555	306	2,062	4%
EAST BAY	2,761	196	0	18	214	8%
EAST FORK INDEPENDENCE CR	1,551	15	0	0	15	1%

NOTE: UNIT OF MEASUREMENT IS ACRES.

TABLE 8 (CONTINUED): URBANIZATION BETWEEN 1985 AND 2000 BY VARIOUS GEOGRAPHIES.

		1985-2000 Conversion from:				
BASIN (CONTINUED)	Total Land Area	Forested Lands	Agriculture Lands	Shrub Lands	Total	Percent of Total
ELBOW LAKE	1,163	23	0	0	23	2%
ELD INLET	9,061	342	73	48	462	5%
ELLIS CREEK	1,472	4	22	1	27	2%
FALL CREEK	1,443	0	0	0	0	0%
FROST PRAIRIE	1,844	9	0	0	9	1%
GREEN COVE CREEK	2,636	219	0	51	269	10%
HANAFORD CREEK	6,095	0	0	0	0	0%
HENDERSON	7,335	446	55	14	514	7%
INDIAN CREEK	1,500	27	62	36	125	8%
JOHNSON CREEK	6,495	0	3	0	3	0%
KENNEDY CREEK	9,876	0	0	0	0	0%
LAKE LAWRENCE	1,687	129	0	0	129	8%
LINCOLN CREEK	1,879	0	0	0	0	0%
LOST VALLEY	1,143	0	0	0	0	0%
MCALLISTER CREEK	19,818	1,395	293	36	1,725	9%
MCINTOSH LAKE	1,486	123	0	0	123	8%
MCLANE CREEK	7,305	446	0	101	546	7%
MICHIGAN	2,630	0	0	0	0	0%
MIMA CREEK	7,941	0	20	0	20	0%
MISSION CREEK	359	12	0	18	30	8%
MONROE CREEK	1,072	0	0	0	0	0%
MOXLIE CREEK	1,463	51	11	15	77	5%
NISQUALLY	31,736	1,001	455	6	1,462	5%
NISQUALLY REACH	4,662	1,225	0	25	1,249	27%
O'CONNOR	2,189	0	0	0	0	0%
OFFUT LAKE	1,532	139	0	0	139	9%
PERCIVAL CREEK	4,712	405	0	143	547	12%
PERRY CREEK	4,047	178	0	0	178	4%
PIERRE	103	0	2	0	2	2%
PORTER CREEK	9,427	0	0	0	0	0%
PRAIRIE CREEK	13,551	73	804	50	927	7%
REICHEL LAKE	5,147	0	0	0	0	0%
SALMON CREEK	7,318	854	200	401	1,455	20%
SALMON CREEK (SK)	2,831	0	0	0	0	0%
SCATTER CREEK	27,423	612	2,460	454	3,526	13%
SCHNEIDER	680	9	26	36	72	11%
SCHNEIDER CREEK	5,243	74	28	29	131	3%
SHERMAN CREEK	6,187	0	0	0	0	0%
SKOOKUMCHUCK	9,472	25	233	1	259	3%
SPURGEON CREEK	6,662	305	179	11	495	7%
SQUAXIN PASSAGE	485	9	0	0	9	2%
SUMMIT LAKE	1,900	31	0	0	31	2%
TEMPO LAKE	749	16	0	0	16	2%
THOMPSON CREEK	10,295	484	173	7	663	6%
THOMPSON CREEK (SK)	21,174	0	0	19	19	0%
TOTTEN INLET	4,113	283	0	37	320	8%
WADDELL CREEK	11,182	267	0	46	313	3%
WEST BAY	1,918	23	8	27	58	3%
WOODARD	4,479	229	66	77	372	8%
WOODLAND	18,873	1,860	1,349	355	3,564	19%
YELM CREEK	15,667	355	354	0	709	5%
ZENKNER	3,002	0	0	0	0	0%
TOTAL	**469,867**	**18,553**	**9,893**	**4,159**	**32,605**	**7%**

NOTE: UNIT OF MEASUREMENT IS ACRES.

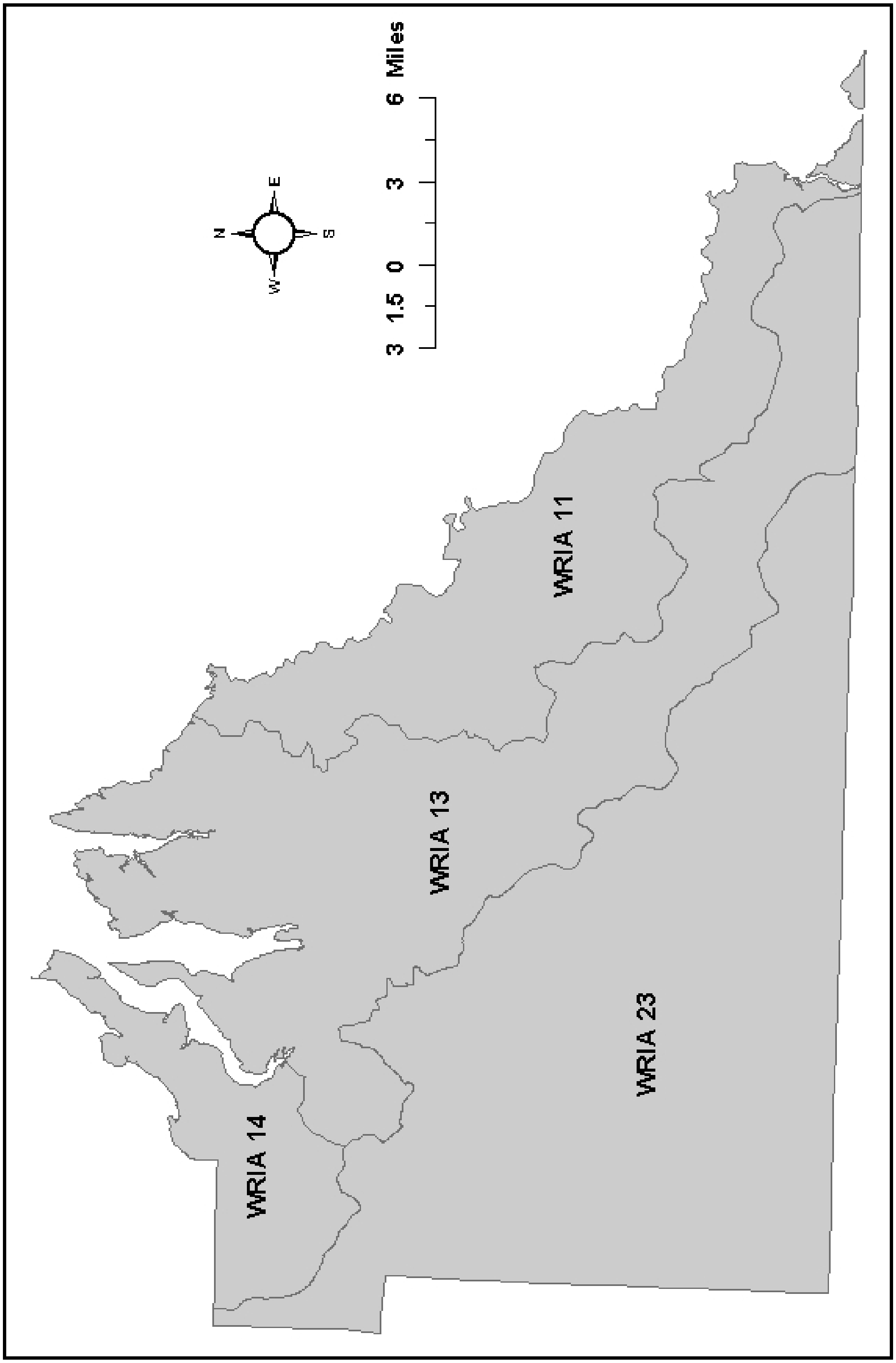

FIGURE 4: THURSTON COUNTY WRIAS.

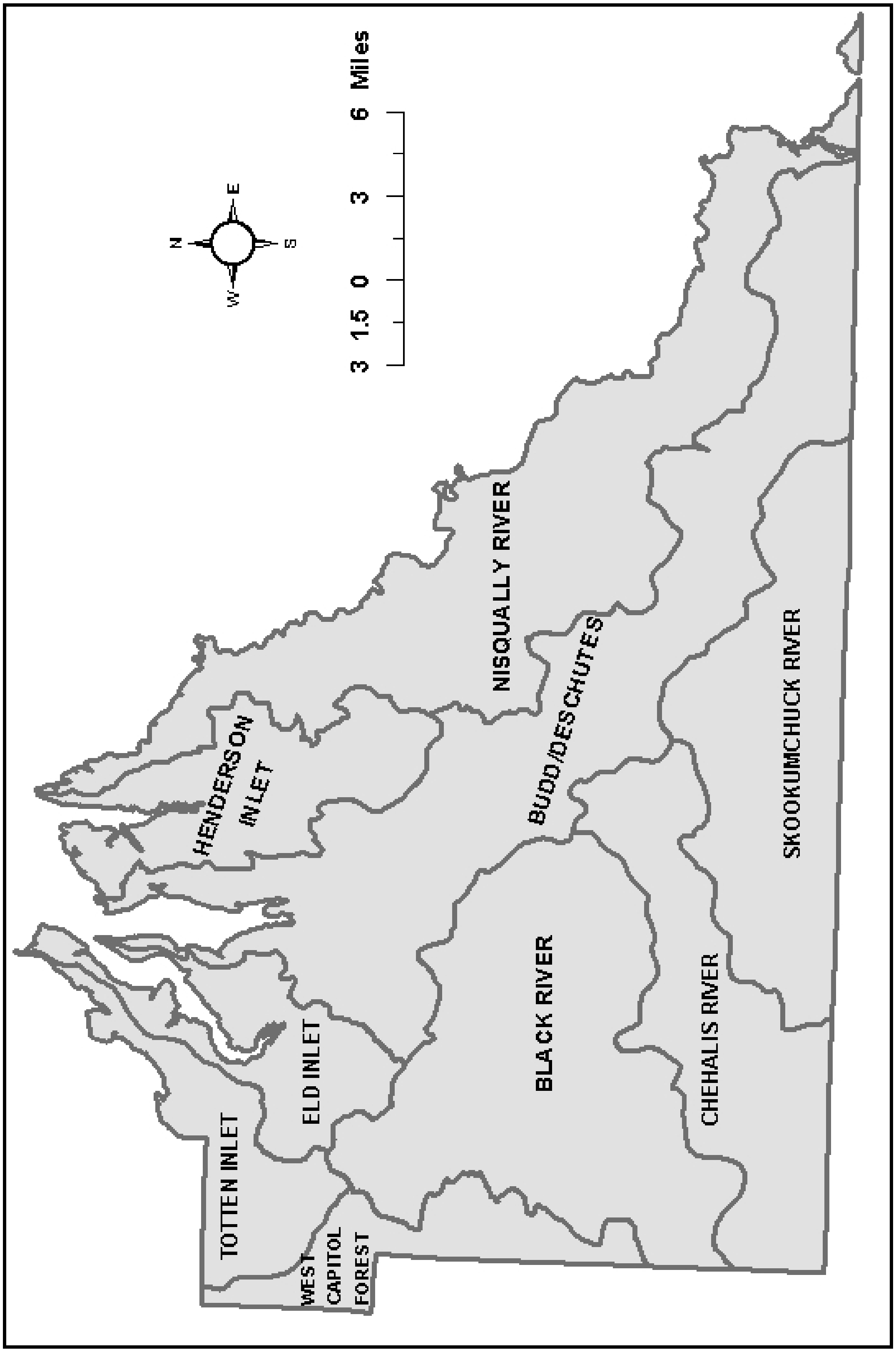

FIGURE 5: THURSTON COUNTY WATERSHEDS.

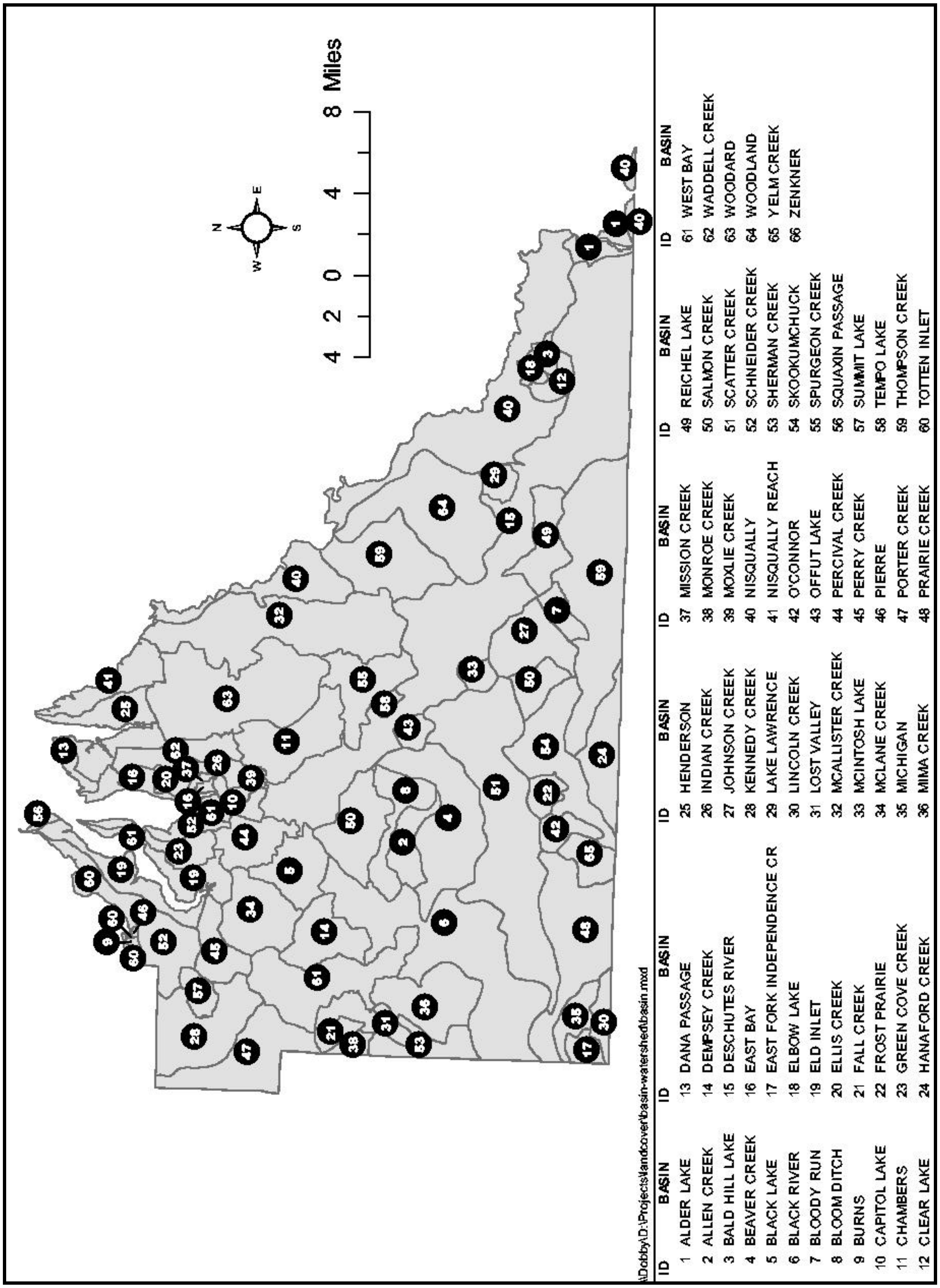

FIGURE 6: THURSTON COUNTY BASINS.

D. Effects of Urbanization

The water quality in many of the watersheds in the U.S. has been degraded due to the effects of urbanization. Urbanization leads to changes in the hydrological cycle, such as increased urban runoff, mainly as a result of increases of impervious surfaces (roads, rooftops, driveways) and associated loss of vegetation (Booth, 1991; *Urbanization and Streams: Studies of Hydrologic Impacts*, 1997). Nationwide, the EPA reports that urban runoff has resulted in, or contributed to, the impairment of: 17 percent of total assessed estuary miles; 4 percent of total assessed river miles; 8 percent of total assessed lake acres; and 7 percent of total assessed ocean shorelines (*National Water Quality Inventory: 1996 Report to Congress*, 1998).

Urban runoff resulting from increased impervious surfaces affects both the quality and quantity of water entering natural water bodies in many ways, and can lead to severe environmental impacts such as flooding, habitat loss, erosion, channel widening, and streambed alteration (Table 9) (Booth, 1991; Grant, 2000; *Urbanization and Streams: Studies of Hydrologic Impacts*, 1997).

Impervious surfaces, by definition, are materials that prevent the infiltration of water into the soil. The most common impervious surfaces in the built environment are roads and rooftops, and features such as sidewalks and patios. While these structures are almost 100 percent impervious, other features such as gravel roads, compacted soils and even lawns are impervious to varying degrees, as they allow for less infiltration than natural ground cover such as forests (Arnold, 1996; May, 1997). As urbanization increases, so does the amount of impervious surface, which leads to changes in the way water is transported, or the hydrology of a drainage basin (Figure 7).

One of the most notable changes is the increase in runoff or surface water flow, and associated decrease in infiltration. Decreased infiltration reduces groundwater supplies, which may lead to a lowering of the water table. Groundwater provides a consistent water supply to streams, wetlands, and lakes, and decreases in groundwater supply may cause a stream or wetland to dry out during months when precipitation is low (Arnold, 1996).

Increases in impervious surfaces lead to increases in volume, rate (peak discharges) and duration of surface runoff (Figure 8). Efforts at mitigating stormwater runoff, such as building detention basins, serve to lessen peak flows, but do not lower the total volume of runoff (Harbor, 1994). The increased volume of both water and sediment load, and the increased energy associated with peak flows, tend to make natural drainage channels straighter and wider (Arnold, 1996; *Urbanization and Streams: Studies of Hydrologic Impacts*, 1997).

TABLE 9: IMPACTS FROM INCREASES IN IMPERVIOUS SURFACES.

Increased Imperviousness leads to:	Resulting Impacts				
	Flooding	Habitat Loss	Erosion	Channel widening	Streambed alteration
Increased volume	X	X	X	X	X
Increased peak flow	X	X	X	X	X
Increased peak flow duration	X	X	X	X	X
Changes in sediment loading	X	X	X	X	X
Decreased base flow		X			
Increased stream temperature		X			
Increased stream acidity		X			
Increased water pollution		X			

SOURCES: (GRANT, 2000; URBANIZATION AND STREAMS: STUDIES OF HYDROLOGIC IMPACTS, 1997).

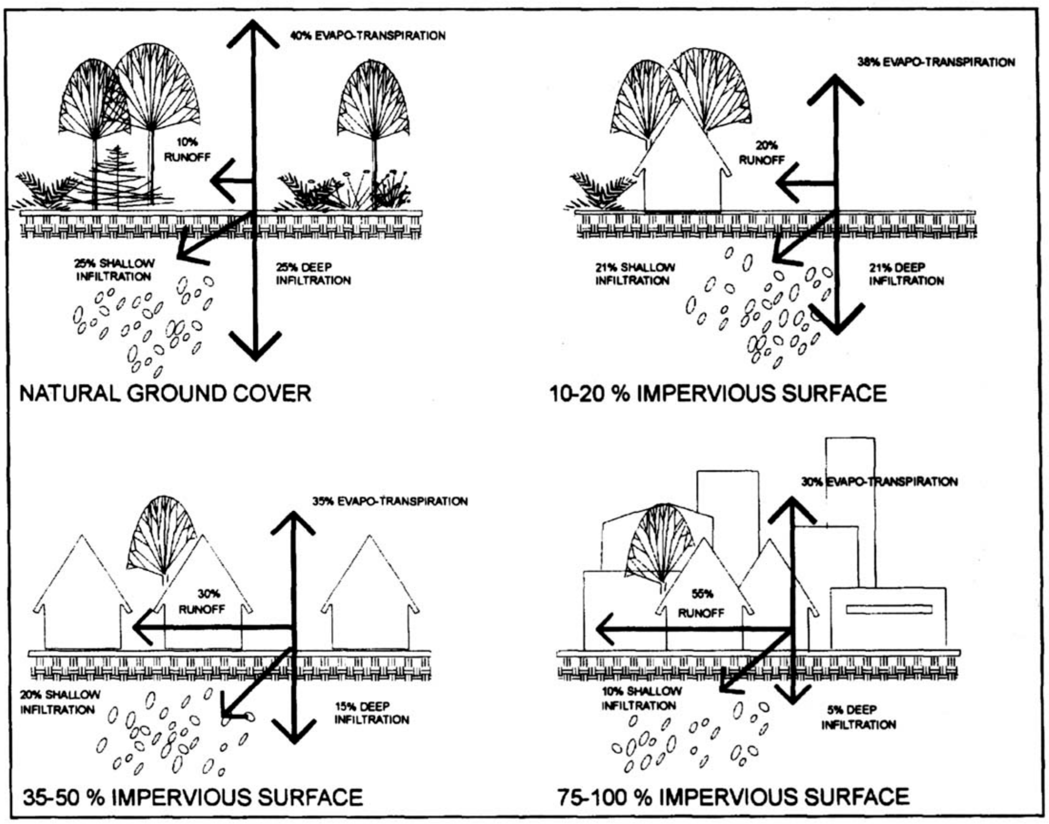

FIGURE 7: WATER CYCLE CHANGES ASSOCIATED WITH URBANIZATION.
SOURCE: (GUIDANCE SPECIFYING MANAGEMENT MEASURES FOR SOURCES OF NONPOINT SOURCE POLLUTION IN COASTAL WATERS, 1993) AS SHOWN IN (ARNOLD, 1996).

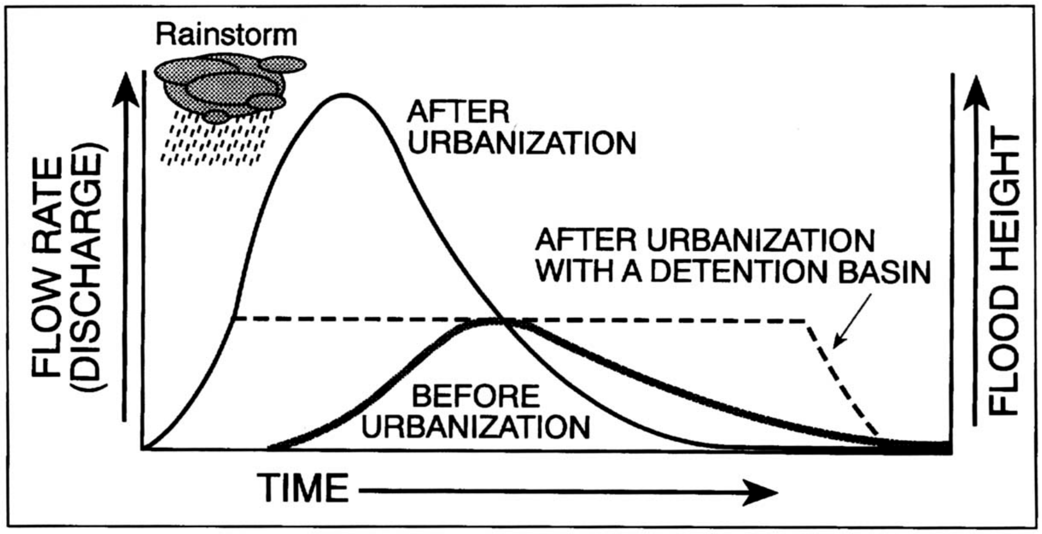

FIGURE 8: THE IMPACT OF URBANIZATION ON STORMWATER RUNOFF.
SOURCE: (HARBOR, 1994).

Erosion of the stream bank during peak flows removes vegetation that provides stability and natural cover for wildlife and aquatic species (Booth, 2000). Increased sediment load and scour during peak events alter the morphology of stream beds, altering spawning habitat for salmon (*Onchorynchus sp.*). All of the above-mentioned changes combine to make the risks of downstream flooding increase (*Urbanization and Streams: Studies of Hydrologic Impacts*, 1997).

Figure 9 shows the stylized relationship between impervious surface and stream health. As impervious surface reaches 10 percent of the area in a basin, stream health begins to be impacted. At 30 percent, stream health is degraded (Arnold, 1996). In another attempt to conceptualize this relationship, Figure 10 shows how the percent of riparian forest and land use combine to be indicators of biotic integrity of a stream (Booth, 2000). Only with an intact riparian forest, and urban land use under 10 percent, is biotic integrity considered excellent.

In addition to causing a disruption in flows, impervious surfaces can also affect water temperature. Water heated on hot pavements and rooftops contributes to stormwater runoff, and may cause an elevation in water temperature in streams, lakes, and wetlands (Grant, 2000). In addition, lack of forest cover in riparian areas, caused by either stream bank instability or infringement of the urban environment to the stream edge, can cause losses in shade and subsequent rises in water temperature (Arnold, 1996).

Increased water temperatures can cause favorable environments for algae blooms, changing the nutrient load in a stream or lake. In addition, increases in temperature cause a decrease in dissolved oxygen in water. Many cold water fish and insects are extremely temperature sensitive in their reproduction and health (Grant, 2000).

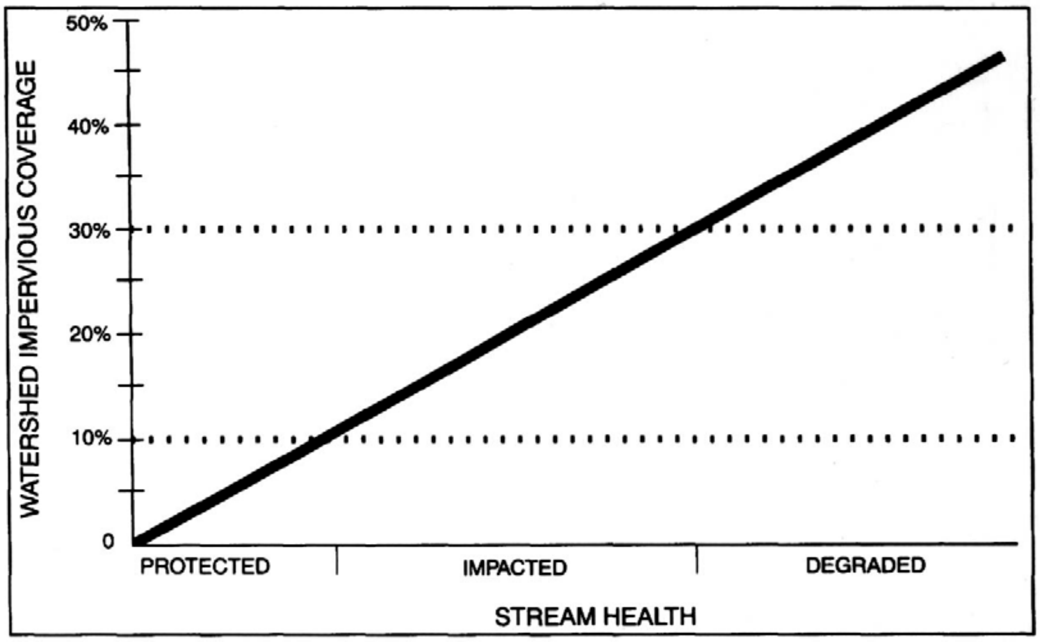

FIGURE 9: STYLIZED RELATIONSHIP OF IMPERVIOUSNESS TO STREAM HEALTH.
SOURCE: (ARNOLD, 1996).

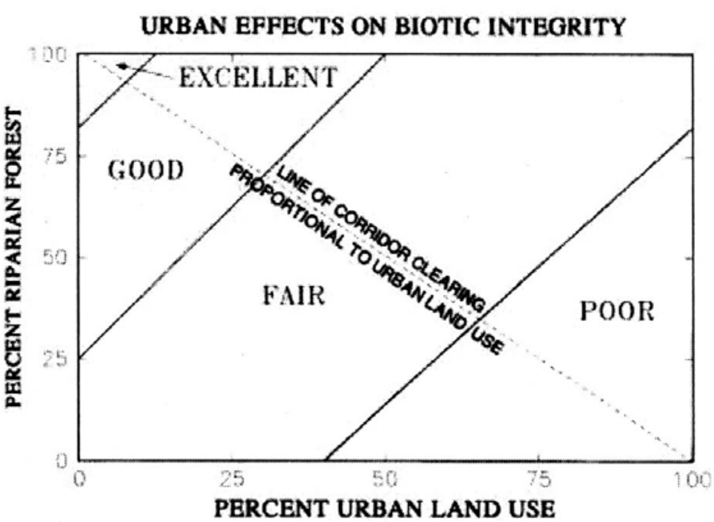

FIGURE 10: CONCEPTUAL RELATIONSHIP BETWEEN URBAN LAND USE (IMPERVIOUS SURFACES), FOREST COVER AND BIOLOGICAL CONDITIONS.
SOURCE: (BOOTH, 2000).

E. Increase in Urban (Built) Land Cover

Trends in urbanization over time provide insight into changes in the physical environment of Thurston County. As mentioned previously, the urban landscape is composed of a variety of physical features, including distinctly urban features such as roads and buildings, as well as trees, lawns, and other non-urban land cover. Measuring the change in land cover of built or urban features over the last 15 years in Thurston County can provide insight into conditions in the future.

Total land area covered by built or urban features has increased by 1 percent in Thurston County as a whole over the last 15 years. In the cities and towns, built features covered 23 percent of the total land area in 1985, or 7,700 acres. By 2000, this had increased to 29 percent (9,700 acres), for an increase of over 20 percent. Built features include roads, houses, other buildings, and parking lots. In the urban growth areas, urban land cover increased from 12 percent (3,300) of the total land area to 16 percent (9,600). This was an increase of 28 percent. In the rural county an additional 2,300 acres of land area were covered by impervious surfaces. This translates to an increase of almost 22 percent over the 7,900 acres in 1985.

Urban land cover has increased by over 1,700 acres in the Budd/Deschutes Watershed in the last 15 years, an increase of over 19 percent. Other watersheds that have experienced rapid changes in urban land cover are Henderson Inlet (1,300 acres; 25 percent), and the Nisqually River Watershed (1,100 acres; 27 percent).

In general, watersheds or basins that have an urban or built land cover of less than 10 percent are generally considered protected in terms of water quality. Most of the rural basins in Thurston County fall into this category. Many of the basins on the urban fringe: Black Lake, Green Cove Creek, McAllister Creek, Salmon Creek, and East Bay are approaching the 10 percent threshold to degraded stream health, and will surpass it by 2015 if urbanization continues at the same rate as it has in the last 15 years. Other basins are approaching the threshold between potential impacted and degraded stream health. Basins of concern are Mission Creek, Indian Creek and Percival Creek (Figure 11).

While urban or built land cover data represent only one factor that influences stream health, it can be used as a prioritizing tool in developing basin plans.

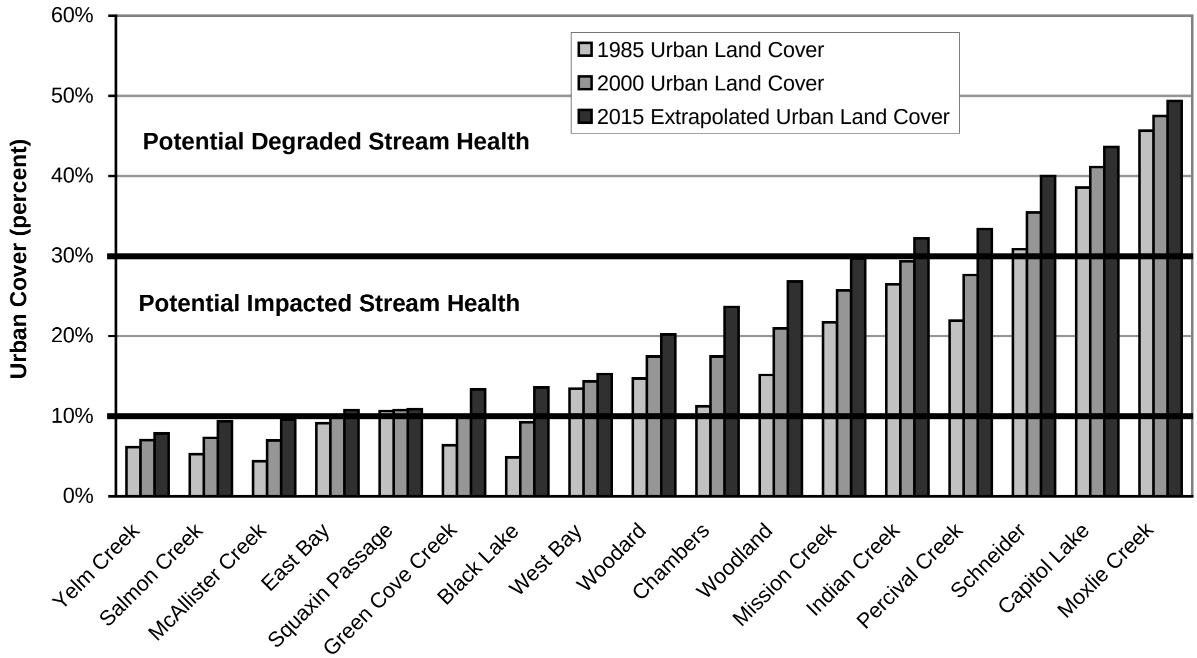

FIGURE 11: CHANGE IN URBAN (BUILT) COVER OF THURSTON COUNTY BASINS AND RELATIONSHIP TO CONCEPTUAL THRESHOLDS OF IMPACTED AND DEGRADED STREAM HEALTH.
NOTE: 2015 DATA EXTRAPOLATED BASED ON 1985-2000 TRENDS. ONLY THOSE BASINS WITH GREATER THAN 7 PERCENT URBAN COVER IN 2000 ARE SHOWN.

TABLE 10: CHANGE IN URBAN (BUILT) LAND COVER BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Urban Cover		1985 Urban Cover		1985-2000 Increase in Urban Cover		
Jurisdiction	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
Cities	33,296	9,701	29%	7,725	23%	1,975	6%	20%
Urban Growth Areas	29,015	4,638	16%	3,338	12%	1,299	4%	28%
Rural County	407,562	10,202	3%	7,935	2%	2,266	1%	22%
Total	**469,873**	**24,540**	**5%**	**18,999**	**4%**	**5,541**	**1%**	**23%**

	Total	2000 Urban Cover		1985 Urban Cover		1985-2000 Increase in Urban Cover		
WRIA	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
WRIA 11	83,978	3,732	4%	2,784	3%	948	1%	25%
WRIA 13	149,136	14,182	10%	11,180	7%	3,003	2%	21%
WRIA 14	30,781	722	2%	661	2%	60	0%	8%
WRIA 23	205,978	5,884	3%	4,354	2%	1,530	1%	26%
TOTAL	**469,873**	**24,520**	**5%**	**18,979**	**4%**	**5,541**	**1%**	**23%**

TABLE 10 (CONTINUED): CHANGE IN URBAN (BUILT) LAND COVER BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Urban Cover		1985 Urban Cover		1985-2000 Increase in Urban Cover		
WATERSHED	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
BLACK RIVER	78,971	2,507	3%	1,795	2%	712	1%	28%
BUDD/DESCHUTES	104,019	8,864	9%	7,154	7%	1,710	2%	19%
CHEHALIS RIVER	47,034	2,040	4%	1,517	3%	524	1%	26%
ELD INLET	23,534	932	4%	765	3%	166	1%	18%
HENDERSON INLET	31,832	4,989	16%	3,730	12%	1,260	4%	25%
NISQUALLY RIVER	88,640	3,964	4%	2,891	3%	1,073	1%	27%
SKOOKUMCHUCK RIVER	55,163	693	1%	641	1%	52	0%	7%
TOTTEN INLET	21,401	400	2%	354	2%	45	0%	11%
WEST CAPITOL FOREST	19,272	131	1%	131	1%	0	0%	0%
TOTAL	**469,867**	**24,520**	**5%**	**18,979**	**4%**	**5,541**	**1%**	**23%**

	Total	2000 Urban Cover		1985 Urban Cover		1985-2000 Increase in Urban Cover		
BASIN	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
ALDER LAKE	2,656	1	0%	1	0%	0	0%	0%
ALLEN CREEK	3,418	162	5%	98	3%	64	2%	40%
BALD HILL LAKE	794	1	0%	1	0%	0	0%	0%
BEAVER CREEK	13,166	397	3%	306	2%	92	1%	23%
BLACK LAKE	5,526	510	9%	269	5%	241	4%	47%
BLACK RIVER	25,092	958	4%	649	3%	309	1%	32%
BLOODY RUN	2,062	9	0%	9	0%	0	0%	0%
BLOOM DITCH	5,010	127	3%	93	2%	35	1%	27%
BURNS	166	6	3%	0	0%	5	3%	96%
CAPITOL LAKE	1,663	683	41%	641	39%	42	3%	6%
CHAMBERS	8,416	1,468	17%	945	11%	523	6%	36%
CLEAR LAKE	1,850	8	0%	3	0%	5	0%	62%
DANA PASSAGE	1,146	35	3%	34	3%	1	0%	2%
DEMPSEY CREEK	5,844	116	2%	91	2%	25	0%	21%
DESCHUTES RIVER	56,284	2,368	4%	2,014	4%	353	1%	15%
EAST BAY	2,761	275	10%	252	9%	23	1%	8%
EAST FORK INDEPENDENCE CR	1,551	14	1%	13	1%	1	0%	8%
ELBOW LAKE	1,163	7	1%	7	1%	0	0%	0%
ELD INLET	9,061	441	5%	409	5%	32	0%	7%
ELLIS CREEK	1,472	79	5%	72	5%	7	0%	9%
FALL CREEK	1,443	11	1%	11	1%	0	0%	0%
FROST PRAIRIE	1,844	6	0%	5	0%	1	0%	16%
GREEN COVE CREEK	2,636	260	10%	168	6%	92	3%	35%
HANAFORD CREEK	6,095	38	1%	38	1%	0	0%	0%
HENDERSON	7,335	213	3%	180	2%	33	0%	15%

TABLE 10 (CONTINUED): CHANGE IN URBAN (BUILT) LAND COVER BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Urban Cover		1985 Urban Cover		1985-2000 Increase in Urban Cover		
BASIN (CONTINUED)	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
INDIAN CREEK	1,500	440	29%	397	26%	43	3%	10%
JOHNSON CREEK	6,495	37	1%	36	1%	1	0%	2%
KENNEDY CREEK	9,876	101	1%	101	1%	0	0%	0%
LAKE LAWRENCE	1,687	88	5%	59	4%	28	2%	32%
LINCOLN CREEK	1,879	14	1%	14	1%	0	0%	0%
LOST VALLEY	1,143	8	1%	8	1%	0	0%	0%
MCALLISTER CREEK	19,818	1,383	7%	870	4%	513	3%	37%
MCINTOSH LAKE	1,486	32	2%	25	2%	7	0%	23%
MCLANE CREEK	7,305	97	1%	57	1%	40	1%	41%
MICHIGAN	2,630	31	1%	31	1%	0	0%	0%
MIMA CREEK	7,941	57	1%	57	1%	1	0%	1%
MISSION CREEK	359	92	26%	78	22%	14	4%	16%
MONROE CREEK	1,072	10	1%	10	1%	0	0%	0%
MOXLIE CREEK	1,463	695	47%	668	46%	27	2%	4%
NISQUALLY	31,736	745	2%	514	2%	232	1%	31%
NISQUALLY REACH	4,662	232	5%	107	2%	125	3%	54%
O'CONNOR	2,189	12	1%	12	1%	0	0%	0%
OFFUT LAKE	1,532	63	4%	33	2%	30	2%	47%
PERCIVAL CREEK	4,712	1,302	28%	1,033	22%	270	6%	21%
PERRY CREEK	4,047	81	2%	79	2%	2	0%	2%
PIERRE	103	2	2%	1	1%	0	0%	10%
PORTER CREEK	9,427	63	1%	63	1%	0	0%	0%
PRAIRIE CREEK	13,551	737	5%	596	4%	141	1%	19%
REICHEL LAKE	5,147	91	2%	91	2%	0	0%	0%
SALMON CREEK	7,318	535	7%	384	5%	151	2%	28%
SALMON CREEK (SK)	2,831	11	0%	11	0%	0	0%	0%
SCATTER CREEK	27,423	1,245	5%	863	3%	382	1%	31%
SCHNEIDER	680	241	35%	210	31%	31	5%	13%
SCHNEIDER CREEK	5,243	123	2%	108	2%	15	0%	12%
SHERMAN CREEK	6,187	39	1%	39	1%	0	0%	0%
SKOOKUMCHUCK	9,472	275	3%	227	2%	48	1%	18%
SPURGEON CREEK	6,662	151	2%	102	2%	49	1%	32%
SQUAXIN PASSAGE	485	52	11%	52	11%	1	0%	1%
SUMMIT LAKE	1,900	55	3%	50	3%	5	0%	9%
TEMPO LAKE	749	9	1%	5	1%	3	0%	38%
THOMPSON CREEK	10,295	489	5%	425	4%	64	1%	13%
THOMPSON CREEK (SK)	21,174	290	1%	288	1%	2	0%	1%
TOTTEN INLET	4,113	113	3%	94	2%	20	0%	17%
WADDELL CREEK	11,182	154	1%	119	1%	36	0%	23%
WEST BAY	1,918	275	14%	258	13%	18	1%	6%
WOODARD	4,479	782	17%	659	15%	123	3%	16%
WOODLAND	18,873	3,960	21%	2,856	15%	1,103	6%	28%
YELM CREEK	15,667	1,098	7%	964	6%	134	1%	12%
ZENKNER	3,002	15	1%	15	1%	0	0%	0%
TOTAL	**469,867**	**24,520**	**5%**	**18,979**	**4%**	**5,541**	**1%**	**23%**

F. *Decrease in Forest Cover*

Total forest cover was reduced by almost 13,000 acres (3 percent of total land area) between 1985 and 2000 due to urbanization. Much of that decrease, almost 5,000 acres, occurred in the cities and urban growth areas, reducing the forest cover in these areas from 33 percent to 25 percent. In the rural county, forest cover was reduced from 60 percent to 58 percent in the same interval of time, a loss of 8,000 acres of forest cover.

Forest cover refers to that portion of the land that is covered at any given time with trees, and includes young trees planted after harvest activity. Thurston County's forest lands are in a continuous state of flux as a result of active harvest activity on commercial forest lands. For the purposes of this analysis, a constant rate of forest harvest was assumed to estimate 1985 forest cover. Therefore, the only decrease in forest cover shown in the following tables was due to urbanization of forest lands. Only that component of the total harvest area where forest cover was removed and replaced by shrubs, lawns, building, roads, parking lots, and other non-forest features was considered a loss in forest cover. Many urban developments retain a portion of urban land as forest cover in individual back yards or in areas of open space.

At the watershed level, the greatest percent of reduction in forest cover due to urbanization occurred in the Henderson Inlet watershed, with a loss of 6 percent of the total land area, or almost 2,000 acres (Table 11).

TABLE 11: CHANGE IN FOREST COVER DUE TO URBANIZATION BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Forest Cover		1985 Forest Cover		1985-2000 Decrease in Forest Cover		
Jurisdiction	**(acres)**	**(acres)**	**(%)**	**(acres)**	**(%)**	**(acres)**	**(% of Total)**	**(% of 1985)**
Cities	33,296	8,331	25%	10,952	33%	2,621	8%	24%
Urban Growth Areas	29,015	7,301	25%	9,544	33%	2,243	8%	24%
Rural County	407,562	237,831	58%	245,866	60%	8,035	2%	3%
Total	**469,873**	**253,463**	**54%**	**266,362**	**57%**	**12,898**	**3%**	**5%**

	Total	2000 Forest Cover		1985 Forest Cover		1985-2000 Decrease in Forest Cover		
WRIA	**(acres)**	**(acres)**	**(%)**	**(acres)**	**(%)**	**(acres)**	**(% of Total)**	**(% of 1985)**
WRIA 11	83,978	45,095	54%	47,739	57%	2,644	3%	6%
WRIA 13	149,136	75,015	50%	81,046	54%	6,031	4%	7%
WRIA 14	30,781	21,182	69%	21,628	70%	446	1%	2%
WRIA 23	205,978	112,171	54%	115,942	56%	3,770	2%	3%
TOTAL	**469,873**	**253,463**	**54%**	**266,355**	**57%**	**12,891**	**3%**	**5%**

TABLE 11 (CONTINUED): CHANGE IN FOREST COVER DUE TO URBANIZATION BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Forest Cover		1985 Forest Cover		1985-2000 Decrease in Forest Cover		
WATERSHED	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
BLACK RIVER	78,971	40,018	51%	42,642	54%	2,624	3%	6%
BUDD/DESCHUTES	104,019	53,313	51%	56,680	54%	3,367	3%	6%
CHEHALIS RIVER	47,034	19,524	42%	19,950	42%	427	1%	2%
ELD INLET	23,534	14,721	63%	15,441	66%	720	3%	5%
HENDERSON INLET	31,832	11,766	37%	13,740	43%	1,974	6%	14%
NISQUALLY RIVER	88,640	47,911	54%	51,399	58%	3,487	4%	7%
SKOOKUMCHUCK RIVER	55,163	35,578	64%	35,596	65%	18	0%	0%
TOTTEN INLET	21,401	15,026	70%	15,299	71%	273	1%	2%
WEST CAPITOL FOREST	19,272	15,604	81%	15,604	81%	0	0%	0%
TOTAL	**469,867**	**253,459**	**54%**	**266,350**	**57%**	**12,891**	**3%**	**5%**

	Total	2000 Forest Cover		1985 Forest Cover		1985-2000 Decrease in Forest Cover		
BASIN	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
ALDER LAKE	2,656	2,503	94%	2,503	94%	0	0%	0%
ALLEN CREEK	3,418	1,197	35%	1,197	35%	0	0%	0%
BALD HILL LAKE	794	598	75%	598	75%	0	0%	0%
BEAVER CREEK	13,166	6,706	51%	7,119	54%	413	3%	6%
BLACK LAKE	5,526	1,443	26%	2,145	39%	701	13%	33%
BLACK RIVER	25,092	8,714	35%	9,737	39%	1,023	4%	11%
BLOODY RUN	2,062	1,836	89%	1,836	89%	0	0%	0%
BLOOM DITCH	5,010	2,357	47%	2,672	53%	316	6%	12%
BURNS	166	96	58%	150	91%	55	33%	36%
CAPITOL LAKE	1,663	191	11%	250	15%	60	4%	24%
CHAMBERS	8,416	2,420	29%	3,142	37%	722	9%	23%
CLEAR LAKE	1,850	1,409	76%	1,500	81%	90	5%	6%
DANA PASSAGE	1,146	693	60%	701	61%	9	1%	1%
DEMPSEY CREEK	5,844	3,726	64%	3,881	66%	155	3%	4%
DESCHUTES RIVER	56,284	33,229	59%	34,093	61%	864	2%	3%
EAST BAY	2,761	1,197	43%	1,296	47%	99	4%	8%
EAST FORK INDEPENDENCE CR	1,551	989	64%	1,004	65%	15	1%	1%
ELBOW LAKE	1,163	847	73%	851	73%	4	0%	0%
ELD INLET	9,061	5,281	58%	5,492	61%	211	2%	4%
ELLIS CREEK	1,472	673	46%	676	46%	4	0%	1%
FALL CREEK	1,443	1,174	81%	1,174	81%	0	0%	0%
FROST PRAIRIE	1,844	1,528	83%	1,533	83%	4	0%	0%
GREEN COVE CREEK	2,636	1,284	49%	1,490	57%	206	8%	14%
HANAFORD CREEK	6,095	2,739	45%	2,739	45%	0	0%	0%
HENDERSON	7,335	3,842	52%	4,086	56%	245	3%	6%

TABLE 11 (CONTINUED): CHANGE IN FOREST COVER DUE TO URBANIZATION BETWEEN 1985 AND 2000, BY VARIOUS GEOGRAPHIES.

	Total	2000 Forest Cover		1985 Forest Cover		1985-2000 Decrease in Forest Cover		
BASIN (CONTINUED)	(acres)	(acres)	(%)	(acres)	(%)	(acres)	(% of Total)	(% of 1985)
INDIAN CREEK	1,500	306	20%	329	22%	24	2%	7%
JOHNSON CREEK	6,495	5,216	80%	5,216	80%	0	0%	0%
KENNEDY CREEK	9,876	7,857	80%	7,857	80%	0	0%	0%
LAKE LAWRENCE	1,687	771	46%	867	51%	96	6%	11%
LINCOLN CREEK	1,879	1,196	64%	1,196	64%	0	0%	0%
LOST VALLEY	1,143	914	80%	914	80%	0	0%	0%
MCALLISTER CREEK	19,818	10,020	51%	11,190	56%	1,171	6%	10%
MCINTOSH LAKE	1,486	1,125	76%	1,176	79%	51	3%	4%
MCLANE CREEK	7,305	5,022	69%	5,282	72%	260	4%	5%
MICHIGAN	2,630	1,571	60%	1,571	60%	0	0%	0%
MIMA CREEK	7,941	6,158	78%	6,158	78%	0	0%	0%
MISSION CREEK	359	107	30%	118	33%	11	3%	9%
MONROE CREEK	1,072	782	73%	782	73%	0	0%	0%
MOXLIE CREEK	1,463	244	17%	287	20%	43	3%	15%
NISQUALLY	31,736	19,305	61%	20,091	63%	786	2%	4%
NISQUALLY REACH	4,662	2,816	60%	3,660	78%	844	18%	23%
O'CONNOR	2,189	1,624	74%	1,624	74%	0	0%	0%
OFFUT LAKE	1,532	883	58%	991	65%	107	7%	11%
PERCIVAL CREEK	4,712	1,330	28%	1,714	36%	383	8%	22%
PERRY CREEK	4,047	2,947	73%	2,982	74%	35	1%	1%
PIERRE	103	52	51%	52	51%	0	0%	0%
PORTER CREEK	9,427	7,888	84%	7,888	84%	0	0%	0%
PRAIRIE CREEK	13,551	5,093	38%	5,131	38%	38	0%	1%
REICHEL LAKE	5,147	3,540	69%	3,540	69%	0	0%	0%
SALMON CREEK	7,318	2,445	33%	2,959	40%	514	7%	17%
SALMON CREEK (SK)	2,831	2,492	88%	2,492	88%	0	0%	0%
SCATTER CREEK	27,423	10,675	39%	11,049	40%	373	1%	3%
SCHNEIDER	680	128	19%	137	20%	9	1%	7%
SCHNEIDER CREEK	5,243	3,471	66%	3,499	67%	28	1%	1%
SHERMAN CREEK	6,187	4,845	78%	4,845	78%	0	0%	0%
SKOOKUMCHUCK	9,472	4,553	48%	4,567	48%	14	0%	0%
SPURGEON CREEK	6,662	4,408	66%	4,573	69%	166	2%	4%
SQUAXIN PASSAGE	485	187	39%	195	40%	8	2%	4%
SUMMIT LAKE	1,900	984	52%	1,009	53%	25	1%	2%
TEMPO LAKE	749	583	78%	594	79%	11	2%	2%
THOMPSON CREEK	10,295	5,227	51%	5,587	54%	360	3%	6%
THOMPSON CREEK (SK)	21,174	13,566	64%	13,566	64%	0	0%	0%
TOTTEN INLET	4,113	2,567	62%	2,732	66%	165	4%	6%
WADDELL CREEK	11,182	8,716	78%	8,920	80%	205	2%	2%
WEST BAY	1,918	735	38%	751	39%	17	1%	2%
WOODARD	4,479	1,630	36%	1,779	40%	148	3%	8%
WOODLAND	18,873	5,601	30%	7,173	38%	1,572	8%	22%
YELM CREEK	15,667	5,185	33%	5,419	35%	233	1%	4%
ZENKNER	3,002	2,022	67%	2,022	67%	0	0%	0%
TOTAL	**469,867**	**253,459**	**54%**	**266,350**	**57%**	**12,891**	**3%**	**5%**

VI. APPLICATIONS TO SALMON HABITAT PROTECTION

One of the primary challenges facing local governments in the Pacific Northwest is to provide a balance between economic growth, which includes both residential and commercial development, and habitat protection. This challenge was intensified in June 2000, when the National Marine Fisheries Service (NMFS) adopted a rule prohibiting "take" of Puget Sound chinook and Hood Canal chum salmon, which are both listed as *threatened* under the Endangered Species Act. Under section 4(d) of the Endangered Species Act, NMFS has the authority to approve local plans that meet conservation standards set out in the rule.

In the draft of the Kitsap Salmon Habitat Protection Plan (Kitsap County, 2001), for example, proposed habitat preservation and restoration activities include placing watersheds in a tiered system based on existing watershed conditions and regional significance to salmonid populations. Priority will be given to actions that have the greatest benefit for imperiled salmon stocks, while maintaining healthy stocks. Existing watershed conditions were estimated through a land cover analysis of the Kitsap County, and are shown schematically in Figure 12.

The basis for this generalization is the empirical data showing a direct correlation between forest cover, impervious area, and stream conditions (Booth, 2000). In addition, modeling efforts have explored the hydrologic flow response of basins based on differing levels of forest cover and impervious surfaces, and it is becoming apparent that land cover is a predictor of stream stability. Data should be used with caution as hydrologic flow responses are also dependent on other factors such as soil type and slope parameters.

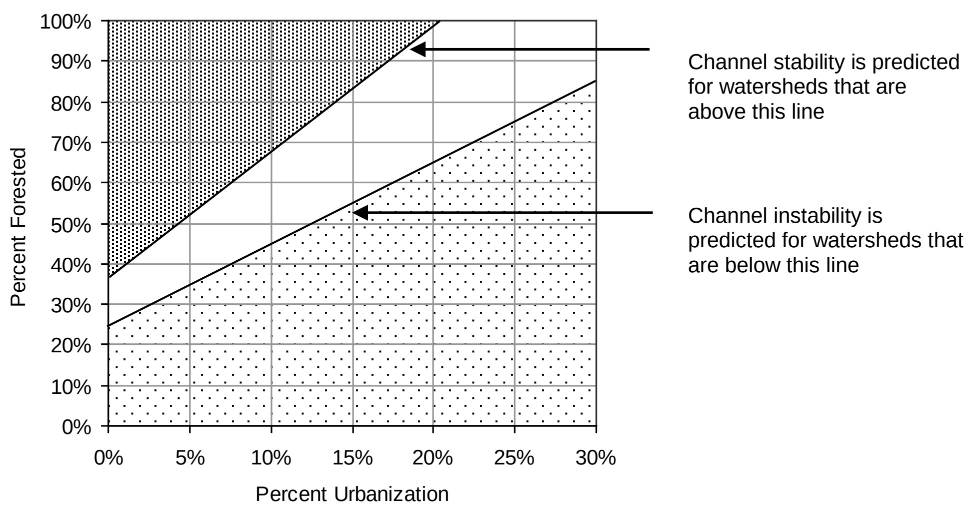

FIGURE 12: KITSAP COUNTY APPROACH TO TIERED WATERSHED RECOVERY EFFORTS.
SOURCE: BASED ON CHART ADAPTED FROM BOOTH, 2000. (KITSAP COUNTY, 2001).
NOTE: THE KITSAP COUNTY PLAN RECOMMENDS A THREE TIERED APPROACH TO HABITAT RESTORATION AND RECOVERY, BASED ON THE THRESHOLDS SHOWN IN THIS DIAGRAM.

Water quality data are available for select basins within Thurston County (Thurston County, 1997-1999). A comparison of water quality conditions with land cover trends from 1985 to 2000 show that in general land cover characteristics can be used as an indication of water quality. Those basins identified as having poor, or poor to fair water quality include Moxlie Creek, Indian Creek, and Mission Creek. All reflect a relatively high component of urban land cover and lower component of forested land cover relative to other basins. Schneider Creek, which has been characterized as having land cover characteristics similar to Moxlie Creek, Indian Creek, and Mission Creek basins has a riparian buffer (150 feet from stream center) that contains 76 percent forest cover, which may account for its fair to good water quality. Other basins with fair or fair to good water quality include Woodard, Woodland, East Bay, Ellis Creek, and Green Cove Creek. Spurgeon Creek, Chambers, and Percival Creek are all characterized by good water quality (Figure 13).

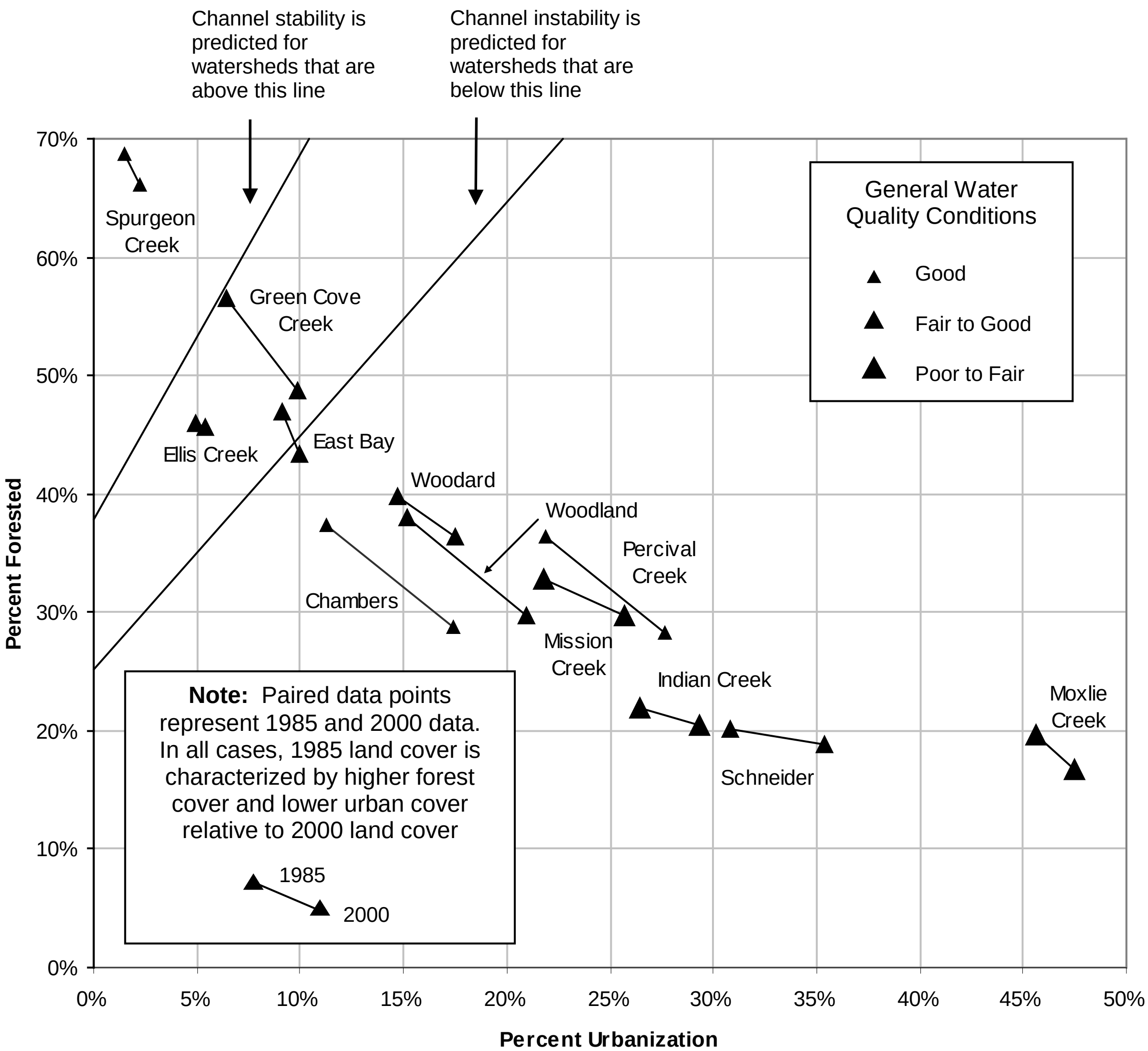

FIGURE 13: CHANGE IN FOREST COVER AND URBANIZATION BETWEEN 1985 AND 2000 FOR SELECT BASINS IN THURSTON COUNTY AND ITS RELATIONSHIP TO CHANNEL STABILITY PREDICTORS AND GENERAL WATER QUALITY CONDITIONS.
NOTE: BASINS SELECTED BASED ON WATER QUALITY DATA AVAILABILITY. DATA ARE GENERALIZED FROM STREAMFLOW AND WATER QUALITY REPORTS, THURSTON COUNTY, 1997-1999.

VII. CONCLUSIONS

In the last 30 years the population of Thurston County has more than doubled. Trying to balance rapid growth while protecting the environmental quality of streams, wetlands, and marine shorelines, and at the same time recognizing the region's strong economic base of commercial forest lands and a thriving agricultural industry, presents a challenge.

Of primary concern is the rapid urbanization of Thurston County's land base. In the last 15 years, 32,000 acres of new urban lands were converted from forest lands, agricultural lands, and shrub lands. This urbanization resulted in an increase in urban land cover or built features of over 1 percent across the county as a whole, and an increase of 6 percent within city and town boundaries, and 4 percent in the urban growth areas, or those areas adjacent to cities and towns that have been identified as likely to be incorporated within the next 20 years.

Much of the increase in urban land cover has come with a decrease in forest cover; some 13,000 acres of forest cover has been permanently removed from Thurston County lands within the last 15 years.

These changes have had serious impacts on the water quality of many of the county's streams, wetlands, and marine shorelines. Recent downgrading of shellfish beaches in the Nisqually Reach and Eld Inlet are one example of measurable changes in water quality that have occurred over the last 15 years. While the health of Thurston County's rural streams remains intact, those streams crossing through urban environments have been impaired.

Land cover is one indicator of stream health and water quality, but there are also many other factors, including the riparian corridor, soil conditions, and topography.

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