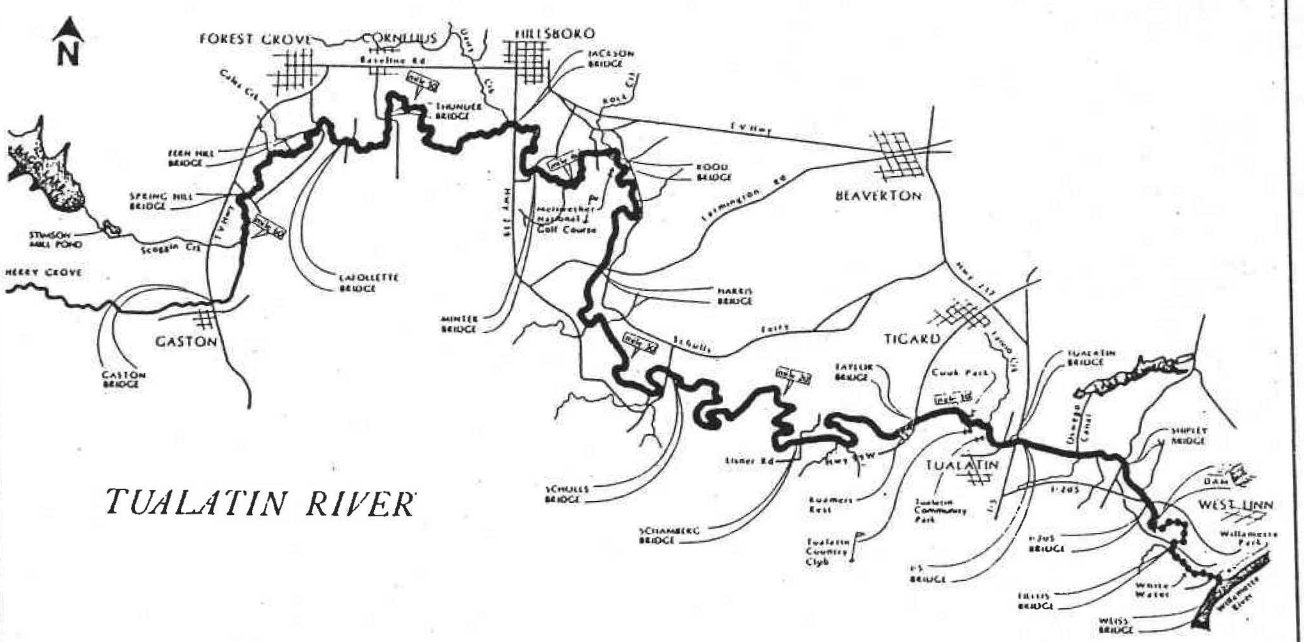
Landscape Change in the Tualatin Basin Following Euro-American Settlement



Oregon Water Resources Research Institute
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LANDSCAPE CHANGE IN THE TUALATIN BASIN FOLLOWING EURO-AMERICAN SETTLEMENT

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Tualatin River Basin Water Resources Management
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TUALATIN RIVER BASIN SPECIAL REPORTS

The Tualatin River Basin in Washington County, Oregon, is a complex area with highly developed agricultural, forestry, industrial, commercial, and residential activities. Population has grown in the past thirty years from fifty to over 270 thousand. Accompanying this population growth have been the associated increases in transportation, construction, and recreational activities. Major improvements have occurred in treatment of wastewater discharges from communities and industries in the area. A surface water runoff management plan is in operation. Agricultural and forestry operations have adopted practices designed to reduce water quality impacts. In spite of efforts to-date, the standards required to protect appropriate beneficial uses of water have not been met in the slow-moving river.

The Oregon Department of Environmental Quality awarded a grant in 1992 to the Oregon Water Resources Research Institute (OWRRI) at Oregon State University to review existing information on the Tualatin, organize that information so that it can be readily evaluated, develop a method to examine effectiveness, costs and benefits of alternative pollution abatement strategies, and allow for the evaluation of various scenarios proposed for water management in the Tualatin Basin. Faculty members from eight departments at Oregon State University and Portland State University are contributing to the project. Many local interest groups, industry, state and federal agencies are contributing to the understanding of water quality issues in the Basin. This OWRRI project is based on all these research, planning and management studies.

This publication is one in a series designed to make the results of this project available to interested persons and to promote useful discussions on issues and solutions. You are invited to share your insights and comments on these publications and on the process in which we are engaged. This will aid us in moving towards a better understanding of the complex relationships between people's needs, the natural environment in which they and their children will live, and the decisions that will be made on resource management.

"..a finer Stream than the Wallamitte I presume is not to be found in any part of the Indian Countries...no doubt ere many years a Colony will be formed on this Stream and I am of opinion it will with little care flourish and Settlers by having a sea port so near them with industry might add greatly to their Comforts also probably to their happiness..."

Peter Skene Ogden in his Snake Country Journals, July 17, 1826.

TABLE of CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The Tualatin Basin landscape has undergone extensive change since the initiation of Euro-American settlement, with important consequences for basin hydrology and water quality. Changes that include the isolation of the Tualatin River from its floodplain areas, losses of important wetlands and riparian areas, and urbanization associated with population growth in the Basin have produced a landscape that is functionally different from the pre-contact landscape. These changes, though they have occurred over a 130 year period, began to be important in the late 19th and early 20th centuries when timber production and agricultural activities began. Any effective watershed management plan developed for the Basin must address these landscape changes and the loss of important landscape features such as wetlands and riparian areas.

INTRODUCTION

The landscape of the Tualatin Basin in northwestern Oregon has undergone extensive change since the initiation of Euro-American settlement in the early nineteenth century. This has important consequences for the hydrology and water quality of the Tualatin River. Water quality has become a matter of great concern in the Basin. A statewide assessment of nonpoint source surface water pollution conducted by the Oregon Department of Environmental Quality in 1987 showed this to be a "water quality limited" basin. Point sources and nonpoint source surface water pollution in urban and rural areas all contribute. Especially important are elevated levels of phosphorus, which are considered to be key factors in excessive growth of algae.

The major types of landscape change that have occurred in the Basin include: 1) the isolation of the Tualatin River from its floodplains and associated losses of riparian areas and related wetlands, 2) the draining and conversion of wetlands to agricultural and other developed land uses, and 3) urbanization and the covering of important water retentive soils in the Basin with impervious surfaces. These changes have produced a landscape that is functionally different from the pre-contact landscape that greeted early explorers and settlers. The objective of this paper is to discuss landscape change and implications for the Tualatin Basin's hydrology and nutrient dynamics since the initiation of Euro-American settlement in this area.

HYDROLOGY and NUTRIENT DYNAMICS of LOWLAND RIVERS

The hydrologic character and nutrient dynamics of any stream or river are influenced by a number of biotic and abiotic factors that operate most directly in areas of interface between the aquatic system and terrestrial system: riparian areas and floodplain systems (Ward and Stanford, 1989). The controls on basin hydrology related to large-scale abiotic factors such as basin size, shape, elevation, slope, parent material, and soil structure are generally understood hydrologic principles and will not be reviewed here.

Abiotic Factors

Local or small-scale abiotic factors that have an influence on a stream's hydrologic character, nutrient dynamics, and water quality include: channel form, channel complexity, and interactions between the stream channel and its floodplain. Each of these factors, individually and in concert, can be seen as having an influence on the amount of contact that exists between surface waters and the landscape. It is also true that each of these factors is influenced in some way by biotic factors which include both plants and animals (Beschta and Platts, 1986; Naiman et al., 1986; Sedell and Froggatt, 1984; Sullivan et al., 1982).

Channel form and complexity can have an important influence on local hydrology. As channels widen or become more complex (split into multiple channels), the amount of stream bed and bank that is in contact with surface waters (wetted perimeter) increases, causing a consequent reduction in velocity and an increase in hydraulic residence time (the amount of time required for a given unit of water to move a particular distance) (Beschta and Platts, 1986; Mitsch and Gosselink, 1986; Morisawa, 1968). An increase in hydraulic residence serves to increase the potential for interactions between the water column and the stream bed and banks. This can have a direct influence on groundwater - surface water interactions, and on nutrient dynamics (Dahm et al., 1987; Wolf, 1992).

Biotic Factors

Increased channel complexity and a resultant loss in velocity can also result from the presence of live vegetation and woody debris within the wetted channel. This is an example of biotic control of hydraulic residence by biotic roughness elements (Mitsch and Gosselink, 1986). During high flow or flood events, these roughness elements serve to increase the interactions between streams and their floodplains by slowing the downstream migration of the flood crest, and by blocking existing channels through debris jamming resulting in the creation of new channels or reactivation of previously abandoned channels (Sedell and Froggatt, 1984; Sedell and Luchessa, 1982). These interactions are also important with respect to the creation and maintenance of wetland environments on the floodplain (Mitsch and Gosselink, 1986; Sedell and Froggatt, 1984; Sedell and Luchessa, 1982).

Animal activity represents another important biotic control on a stream's hydrologic character. Of particular importance for North American rivers and streams is the beaver (*Castor canadensis*) which alters local hydrology, channel geomorphology, and nutrient dynamics in the stream environment through its feeding and dam building activities (Mitsch and Gosselink, 1986; Naiman et al., 1986). Beaver dams increase hydraulic residence and flood extensive areas, capture and retain sediment, and facilitate nutrient processing and storage (Dahm et el., 1987; Naiman et al., 1986).

Human or anthropogenic impacts on hydrologic systems such as the Tualatin Basin are many and include disruption of the abiotic and biotic processes discussed above, as well as manipulation of seasonal flows through the construction of surface water storage facilities, withdrawal of surface waters for irrigation, and changing the amounts and timing of sediment and nutrient inputs into surface waters (Wolf, 1992).

Wetlands

Wetlands are recognized as being very important to the regulation of basin hydrology and nutrient dynamics through serving as sources and sinks of both water and nutrients (Mitsch and Gosselink, 1986). Utilizing the generic classification scheme presented by Mitsch and Gosselink (1986), three major types of wetlands may be identified within the Tualatin Basin. These include: 1) freshwater swamps, 2) freshwater marshes, and 3) riparian areas or wetlands. The distinctions among these different wetlands are not always clear, but in general the riparian wetland is characterized by its proximity to a surface water body and its exposure to episodes of flooding. Swamps are generally distinguished from marshes by the presence of woody vegetation (trees and shrubs).

The importance of wetland areas within the Tualatin Basin with regard to hydraulic retention and summer time base flow conditions in the river is described by Van Staveren et al. (1991) in their report on the Jackson Bottom Wetland area near Hillsboro. They estimated the travel time for groundwater across the Bottom's floodplain deposits as 120 feet per year which translates to a residence time of some 30 years for any given unit of water migrating through the 4,000 feet of wetland area.

The interactions between the various factors influencing the hydrology and nutrient dynamics of lowland rivers are complex and not easily summarized. Complicating this further is that the importance of each varies spatially and temporally. The reader is referred to the sources cited for discussion of these factors, their interactions, and their significance to the hydrology and nutrient dynamics in the Tualatin Basin. The discussion that follows is devoted to describing the landscape changes that have occurred in the Tualatin Basin since Euro-American settlement, and their significance with respect to these interactions.

LANDSCAPE CHANGE in the TUALATIN BASIN

Consulting the Historical Record

A number of investigators have utilized historical documents and records to gain insight into the character of what might be termed the pre-settlement landscape in western Oregon and Washington. Habeck (1961; 1962) utilized original land survey records from the 1850s to describe and document the pre-contact vegetation and forest succession in areas of the middle Willamette Valley, Oregon.

This same approach was utilized by Johannessen et al. (1971) in documenting vegetation changes in the upper Willamette Valley in the vicinity of Eugene, Oregon. Both of these investigations relied on the written accounts of early explorers, surveyors, settlers, and on the mapping of specific areas in order to compare the historical record to the current landscape.

Other investigations that have attempted to reconstruct the historical landscape from historical records and documents include Towle's (1974) examination of Willamette Valley woodlands, and Shively's (1989) study of slope geomorphology in the Oregon Coast Range near Corvallis, Oregon. Two studies that are of particular interest with respect to the Tualatin Basin were conducted by Sedell and Luchessa (1982), and Sedell and Froggatt (1984). These investigations were concerned with human activity as it affected the character of lowland rivers in the Pacific Northwest, and are examined in further detail in the text that follows.

A Chronology of Landscape Change in the Tualatin Basin

Because historical references to particular areas of the Tualatin Basin are limited, the following discussion is organized in the form of a chronology of descriptions and activities that are of significance to the Basin. The first descriptions of the Tualatin Basin landscape are credited to Hudson's Bay Company trappers who explored the Willamette Valley and Oregon Coast in search of beaver. A trapping party headed by Alexander R. McLeod traversed the area between Fort Vancouver and the headwaters of the North Fork of the Yamhill River on their way to the central coast region in the spring of 1826 (Dicken and Dicken, 1979: 55). Their route took them across a portion of the Basin and was described as following "the Borders of the Mountain" (Chehalem Mountain) because of wet conditions in the valley floors. Dicken and Dicken note that early roads were generally located along the valley sideslopes so as to avoid these wet areas.

The next foray into the Basin was made by Peter Skene Ogden, a Hudson's Bay Company trapper and explorer who transferred to Fort Vancouver in 1825 (Dicken and Dicken, 1979). He compiled a journal that described his travels through most of Oregon and portions of Northern California, and in this journal he described the Tualatin Valley as "mostly water connected by swamps" (Sedell and Luchessa, 1982: 211). Local flooding was attributed to the activity of beaver, and to "accumulated sediment, fallen trees, and living vegetation in the channels."

The next description of the Tualatin Basin landscape is found in the original land survey records compiled during the subdivision of the Willamette and tributary valleys in the early 1850's by employees of the Federal Land Survey Office. These descriptions are based upon the establishment of township boundaries, and upon the frequent "randoms" made by the surveyors in their travels to and from the work site. The "general description" of Township 1 South, Range 3 West, Willamette Meridian, which is situated southeast of Forest Grove and upstream of the Tualatin River-Dairy Creek confluence, reads as follows:

> On both sides of the Tualatin river are some bottom lands which are subject to innundation to the depth of 10 or 12 feet and have a sandy soil timbered with fir, ash, maple, vine maple...These bottoms have many swamps principaly [sic] caused by beaver dams on small streams. The timber in the swamps is principaly [sic] willow from 10-20 feet high and so thick that they are almost impenitrable [sic] (Surveyor General's Office, 1852).

A description of the east boundary of an adjacent township (Township 1 South, Range 2 West, Willamette Meridian) states that "[t]his boundary is level and gently rolling and has some wet and swampy places along the Tualatin River" (Surveyor General's Office, 1852).

Once surveys were completed for any given area, plat maps were drawn for each township from field notes. Because the maps of the Tualatin Basin townships were made in the Office of the Surveyor General located at Oregon City, it is likely that the cartographers had the benefit of consulting the surveyor(s) for more detailed impressions of the landscape. Inspection of these original Survey Plats show extensive areas bordering the Tualatin River and its tributaries which are labeled: alder bottoms, rich brushy bottoms, swamp, and miry swamp (see Figures 1 and 2).

Adjacent upland areas are described as being dominated by timber consisting of fir (Douglas Fir). Yellow Pine Cedar, Alder, and Maple. Significant portions of these upland areas, especially on the valley floor, had been burnt prior to the survey and contained large amounts of dead and fallen timber. Although this information is quite subjective and is not always planimetrically accurate, it does serve as the earliest cartographic description of the landscape in the early post-contact period.

Modification of the River

In discussing the importance of the pre-contact landscape to anadromous salmonids (Pacific salmon), Sedell and Luchessa (1982) utilized Reports of the Secretary of War (1875-1899) to compile a list of rivers in Oregon and Washington blocked by

Township No. 2 South, Range No. 1 West,
Willamette Meridian, Oregon.

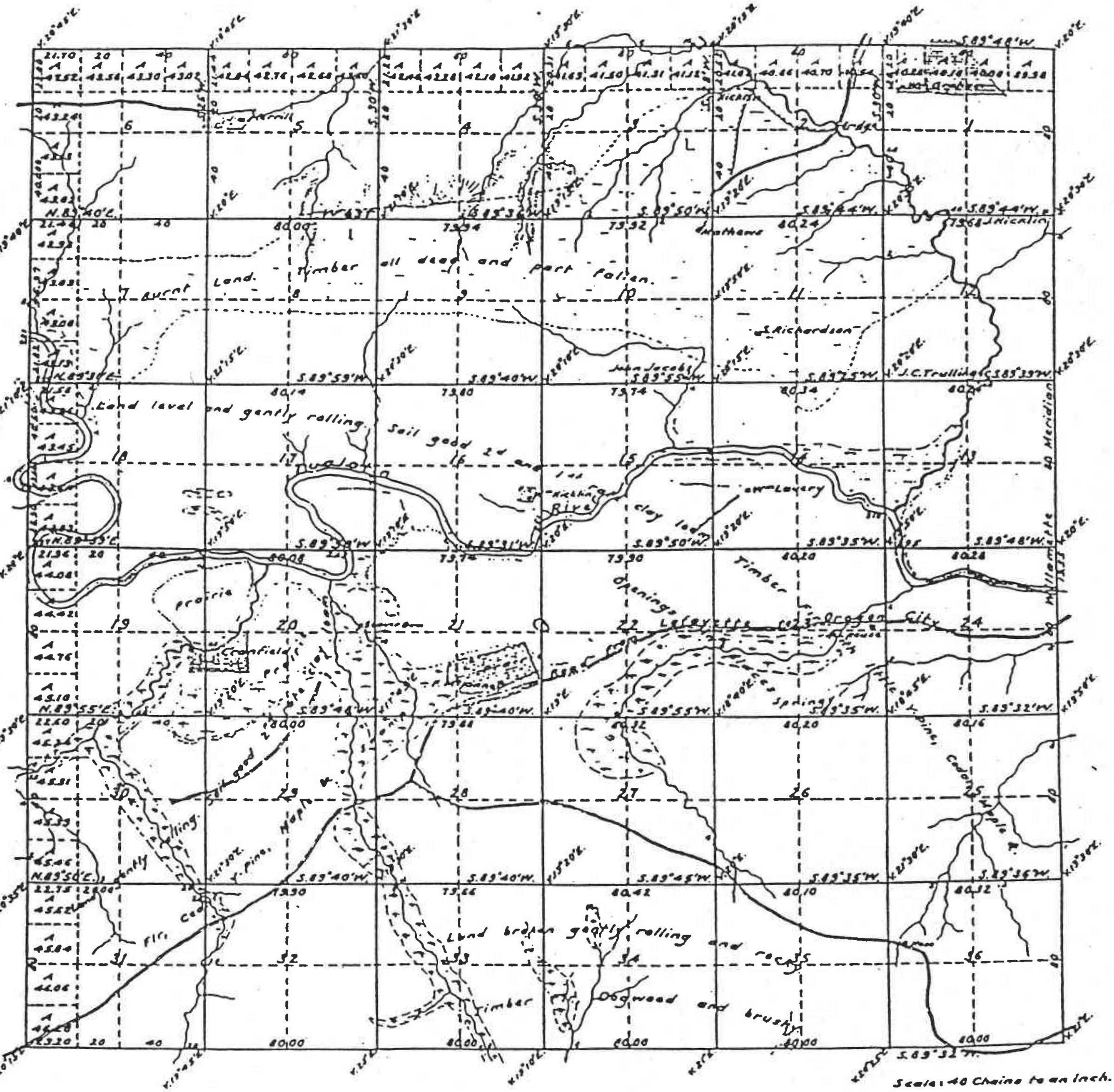

Figure 1. General Land Office survey plat of T2S, R1W, Willamette Meridian (Surveyor General's Office, 1852).

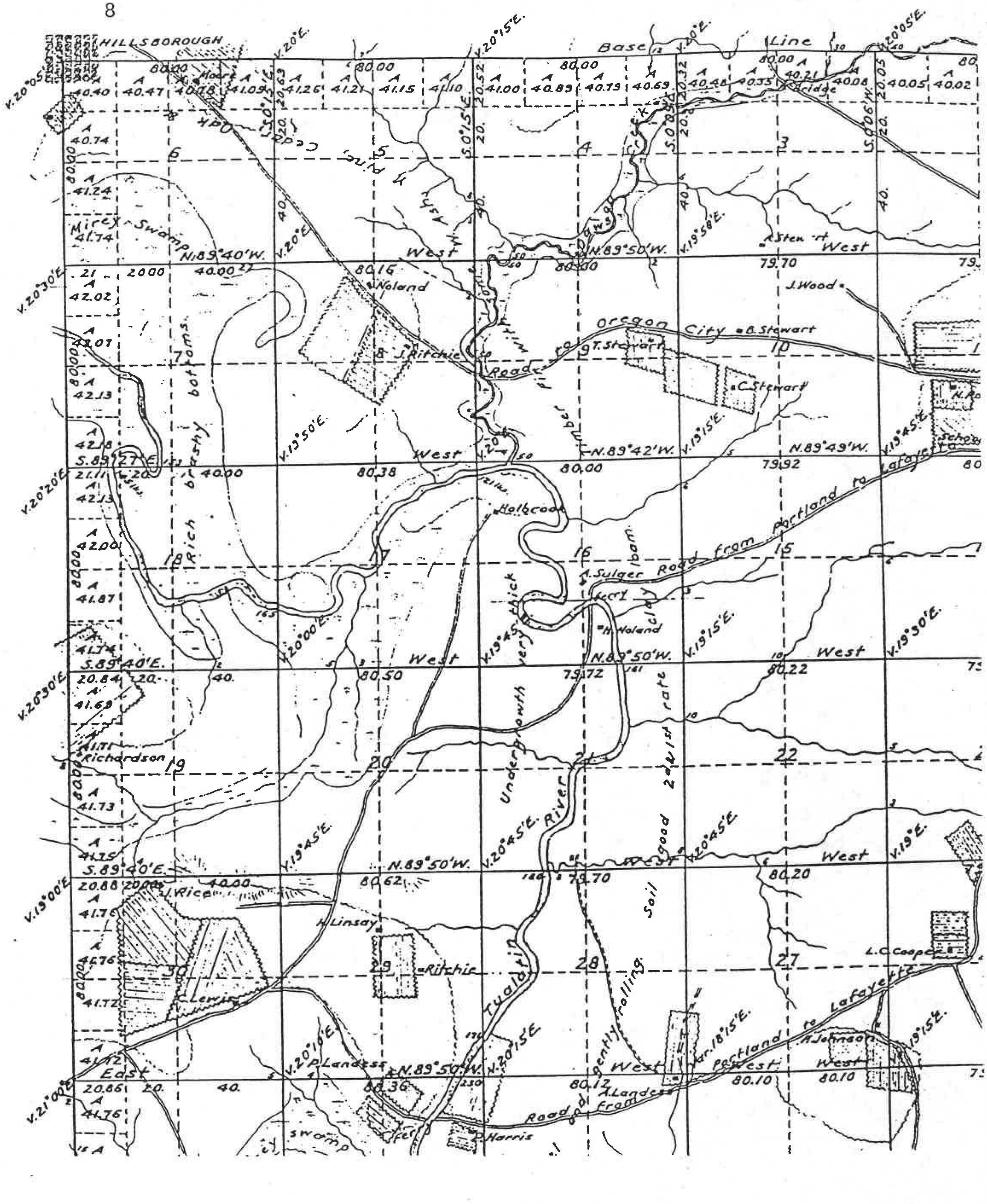

Figure 2. Portion of General Land Office survey plat of T1S, R2W, Willamette Meridian (Surveyor General's Office, 1852).

debris or drift jams. The Tualatin River, along with other streams draining the east slope of the Oregon Coast range (Yamhill, Luckiamute, Long Tom) contained concentrations of large woody debris in the form of drift jams that completely obstructed major channels for a distance of 100-1500 meters at some channel location during the mid 1800s. This was of primary importance with respect to the capture of sediments, ponding of water or hydraulic retention, and side channel and slough formation and maintenance.

Sedell and Luchessa (1982) attribute the early transformations of the pristine or pre-contact landscape of western Oregon and Washington to activities related to the timber industry, navigation improvements, and agricultural development. Log driving represented the earliest means of transporting timber to mills for processing and this required the blocking of sloughs, swamps, low meadows, and banks by log cribbing with the objective of keeping water in main channels. Obstructions including boulders, leaning trees, large woody debris and debris jams were removed from these channels as well.

Splash dams were often constructed in upstream locations in order to float logs on artificial freshets created by releasing large quantities of water from the impoundments created by the dam structures. It sometimes happened that these large releases were achieved by demolishing the dam structure itself. Nine different splash dam locations in the Tualatin Basin were mapped by Sedell and Luchessa (1982) based upon research conducted by Dr. James E. Farnell of the Oregon Division of State Lands. These are listed in Table 1. The authors note that these represent main dams that were in operation for more than one season, and that temporary dams were used on many smaller streams in their study area on a seasonal basis and were not documented in any records.

The bottom lands or valley floors in much of western Oregon and Washington, though they were notably wet, were highly regarded for agriculture (Sedell and Luchessa, 1982). Oregon State Agricultural College soil scientist I.A. Williams (1914: 114), in commenting on the condition of the Willamette Valley streams of 1910, observed that

Stream	No. Splash Dams
W. Fork Dairy Creek	1
Gales Creek	2
Scoggins Creek	4
Tualatin River above Roaring Creek	2

Table 1. Splash dams in the Tualatin Basin, 1880-1910 (from Sedell and Luchessa, 1982)

"[m]any of the smaller streams that have their course through these flat sections of the valley flow sluggishly and frequently overflow their banks during periods of heavy winter rainfall." He continued:

> The annual overflow is caused from the obstructing of the channel by the growth of trees and the extension of their roots, the dams thrown across the channels by beavers and the consequent accumulation of sediment and other debris, etc. The particular streams in which such a state of affairs has been brought to the writer's attention are the Little Muddy and Long Tom Rivers...the Little Pudding River...the Tualatin and its branches in Washington County. It is a common condition, however, and usually all that is necessary is a clearing out and opening up of the clogged channel of the stream to afford entire relief from overflow and the discouraging handicap which it is to the farmer in such a locality."

Land Use Changes

Sedell and Luchessa (1982:211) note that "because the bottom land had accumulated fine silts and organic material of alluvial origin, the land was fertile and the task of draining the land for farming began early in Oregon and Washington." The presence of several ditches dug along former water courses traversing the Jackson Bottom wetland area on the Tualatin River's north bank at Hillsboro serves as an example of early drainage projects in the Basin (Van Staveren et al., 1991).

Census of Agriculture data for the period 1900-1969 show that the land area in Washington County (whose boundaries virtually overlap those of the Tualatin Basin) devoted to agricultural land uses was at its greatest in 1900 and remained somewhat static with minor declines and fluctuations thereafter (Table 2). These figures are based on the extent of all land in farms including all cropland, woodlands, and other lands which can include wetland and riparian areas. The census data concerning the total amount of land in farms in 1974 and 1978 seemed inexplicably high and may include lands not considered in previous estimates. The amount of improved land in farms is more telling, however, and shows a steady increase during this period as woodland and other areas where improved for crop or pasture lands.

Date	Land in Farms (acres)	Improved Lands (acres)
1900	251,568	92,512
1910	240,328	107,919
1920	223,406	121,325
1930	234,798	130,092*
1940	244,957	139,908*
1950	251,253	201,154
1954	236,203	192,926
1969	172,055	
1974	458,240	117,682+
1978	458,240	121,082+

Table 2. Extent of land in farms and improved agricultural lands in Washington County, 1900-1969 (Census of Agriculture data, U.S. Bureau of the Census).
* These figures obtained the previous year.
\+ These figures include only cropland and pasture.

Land improvement for agricultural land uses is often accompanied by changes in soil nutrient loading, and in the quantity and quality of water stored in agricultural soils (Wolf, 1992). Also important is the increased susceptibility of agricultural soils to detachment and erosion. Wolf (1992:33) has noted that most of the particulate phosphorus that is lost from agricultural lands is transported as sediment in runoff associated with storm events.

Sedell and Luchessa also observed that the clearing of brush along many lowland streams occurred through Works Progress Administration (WPA) projects during the 1930s. Much of this activity was focused on agricultural areas, and was particularly important following passage of the Federal Flood Control Act on 1936.

Early maps of the Tualatin Basin help to demonstrate the impact of these drainage activities on the landscape. The first topographic map of the Forest Grove area (including portions of Gales and Dairy Creeks) was prepared in 1940 under the direction of the Chief of Engineers, U.S. Army, at a scale of 1:62,500 and shows the areal extent of Lousiqnont Swamp (see Figure 3). The Army Corps of Engineers were concerned with wetland features even at this time for a number of reasons, and took some care to document them in their mapping endeavors. That this feature is absent from a subsequent edition of this same map produced in 1943 indicates that it may have been drained in the interim period. Williams (1914: 10) notes, however, that a drainage district had been organized by 1914 to drain the waters of "Lake Lousignout" for agricultural uses.

Irrigation became important in the Tualatin Basin during the period 1919-1939 as shown in Table 3. This is due in part to the introduction of portable sprinkler irrigation in Oregon in 1932 (Collins, 1978). That early irrigation was successful in the Tualatin Basin is verified by the Willamette Valley Irrigation Tours sponsored by the Oregon Agricultural College Extension Service during this era, which made stops at two farms in the Gales Creek watershed in 1933 and 1936 (Collins, 1978).

Irrigation is important with respect to summer base flows because much of this acreage is irrigated with surface waters withdrawn directly from the Tualatin River and its tributaries. Much of this water is lost to the Basin through evapotranspiration, and that which remains is subject to changes in quality from agricultural activities.

Figure 3. Portion of Gales Creek (Forest Grove) 15 minute topographic quadrangle showing Lousiqnont Swamp in 1939 (Chief of Engineers U.S. Army, 1941).

Date	Irrigated Acres
1902	448*
1919	2,892*
1939	2,917
1949	6,857
1954	16,697
1969	13,936
1974	14,649
1978	17,454

Table 3. Irrigated lands in Washington County, Oregon (Census of Agriculture data, U.S. Bureau of the Census). * These figures represent irrigated lands within the greater Willamette Basin.

Conversion of Wetlands

Few attempts have been made to quantify wetland losses and conversion in Oregon. Gabriel's (1993) study represents the sole attempt which deals with the Tualatin Basin, and relied upon mapping techniques. The method employed estimates wetland losses in the greater Willamette Valley by comparing the area and extent of hydric soils, as indicated on 1:250,000 soil association maps prepared by the Soil Conservation Service, to information contained on National Wetland Inventory maps prepared by the Army Corps of Engineers. Utilizing this technique, he has found that wetland losses in the Tualatin Basin total 61 percent for areas below 200 meters (660 feet) in elevation. Whether this is a liberal or conservative estimate may be debated, but this statistic does indicate the degree to which the landscape in this area has been impacted in post-contact time.

The well-known Jackson Bottom Wetlands Preserve is a remnant of the extensive wetlands which once lined the banks of the Tualatin River in the vicinity of Hillsboro. This 434 acre preserve has been developed for public and wildlife use, and receives large amounts of secondary effluent from the Hillsboro West sewage treatment plant (Van Staveren et al., 1991). An assessment of wetland functions and values was performed by two consulting firms for the Unified Sewerage Agency of Hillsboro, Oregon, in 1990 utilizing the Wetland Evaluation Technique (WET) (Van Staveren et al., 1991). The bottom was rated "high" for the social significance attributed to sediment/toxicant retention and nutrient removal/transformation. It received "moderate" ratings, however, for the functions of groundwater recharge and discharge, flood flow alteration, and sediment stabilization due to the low social significance associated with these functions in the immediate area. Given the importance of groundwater dynamics to the base flow conditions of the adjacent Tualatin River, and the importance of sediment-nutrient dynamics to water quality in the Basin, the low social significance associated with these functions may be inappropriate when viewed at the Basin scale.

Settlement and urbanization have been particularly intense within the Tualatin Basin due to its proximity to Portland and the initial settlements of the Willamette Valley, and to its timber and agricultural resources. In reviewing mapped data from the 1850 census, Dicken and Dicken (1979: 81) noted that of the rural clusters of population in western Oregon in 1850, the "Tuality Valley" was one of the most populated. Since that time Washington County experienced rates of population change that lagged behind that of Oregon until 1920 when the decennial rate of population change exceeded that of the state (Table 4).

Date	Washington County Pop.	Decennial Rate of Change (%)	Oregon Pop.	Decennial Rate of Change (%)
1850	2,652		12,093	
1860	2,801	5.6	52,465	333.9
1870	4,261	52.1	90,923	73.3
1880	7,028	66.2	174,768	92.2
1890	11,972	69.0	317,704	81.8
1900	14,467	20.8	413,536	30.2
1910	21,522	48.8	672,765	62.7
1920	26,376	22.6	783,369	16.4
1930	30,275	14.8	953,786	21.8
1940	39,194	29.5	1,089,684	14.2
1950	61,269	56.3	1,521,341	39.6
1960	92,237	50.5	1,768,687	16.3
1970	157,920	71.2	2,091,385	18.2
1980	245,808	55.7	2,633,105	25.9
1990	311,554	26.7	2,842,321	7.9

Table 4. Population and population changes in Washington County, and Oregon, during 1850-190 (Census of Population data, U.S. Bureau of Census).

The great migration of the 1960s and 1970s that prompted Oregon's adoption of strict land use controls can be seen to have had an influence upon Washington County and the Tualatin Basin. A report by the Oregon Student Public Interest Research Group noted that 1,100 acres of Washington County cropland were converted to non-agricultural uses during the period 1960-1970 (Aamodt, 1973). Rural land conversion and the effects of urban development in the lower basin have almost certainly had a negative impact on the basin's remaining wetland, riparian, and even upland areas; a problem that is of increasing concern to land managers and scientists alike. Changes in basin hydrology occur with the increase in impervious surfaces associated with transportation features such as roads and highways, and the roofs of residential and commercial structures. This loss in permeability undoubtedly has a negative effect on local groundwater recharge and the important storage and discharge functions of the Basin's shallow aquifers and floodplain deposits.

SUMMARY and CONCLUSIONS

Certain characteristics of the landscape are of particular importance with respect to basin hydrology and nutrient dynamics in the hydrologic environment. These include: 1) the physical complexity of the stream channel and interactions with adjacent floodplains; 2) the presence and integrity of wetland environments which include riparian wetlands, freshwater marshes, and freshwater swamps; and 3) the amount of developed urban areas with their associated impervious surfaces.

A review of the historical record has shown that the pre-contact landscape of the Tualatin Basin has been significantly altered by human activities related to timber production, agricultural development, and urbanization, much of which has been focused on the Basin's lowland streams and wetlands. These alterations have worked to reduce hydraulic residence times at both the local and basin scale, to eliminate landscape features that were important sites for nutrient storage and processing, and to change the susceptibility of agricultural and other soils to water erosion. The net effect of these alterations has probably been to impair the nutrient processing and retention ability of the landscape, and may have altered the magnitude of base flows occurring in the Tualatin River.

Any watershed management plan developed for the Basin must consider the importance of the landscape features discussed. Stream habitat improvement and wetland mitigation activities would not only assist in restoring water quality in the Tualatin Basin to more acceptable levels, but would provide important habitats for fish and wildlife as well as enhancing a number of other important values associated with aquatic and wetland environments.

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