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**CHAPTER 5: History and Effects of Human Interventions in the Tillamook Basin**



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# 5. History and Effects of Human Interventions in the Tillamook Basin

Streams, rivers, and estuarine areas within the Tillamook Bay basin historically provided diverse habitats for a variety of aquatic, semi-aquatic, and terrestrial species of plants and animals. Aquatic systems within the Tillamook Bay basin were historically some of the most biologically productive on the Oregon Coast, and remain so for some species of fish and shellfish. The basin is characterized by streams and rivers that flow from steep and erosion-prone uplands, through extensive lowlands surrounding much of Tillamook Bay, and into a drowned-river estuary (the bay itself) that is one of the largest in Oregon (Bottom *et al.*, 1979). Environmental conditions within the basin, and patterns of change in these conditions over time, have been described in detail by Coulton *et al.* (1996a ) and TBNEP (1998a). Overall, the basin is typical of many in the Pacific Northwest in that important natural features, including streams, rivers, riparian areas, and the estuary, are exhibiting multiple problems attributed to land use practices (TBNEP, 1998a). Of particular concern to the basin's residents are the sedimentation of lowland rivers, reduced water quality, declining populations of multiple salmon species, and increasing flood damages to both public and private property within floodplain areas.

# 5.1 Historic Landscape Conditions

The present landscape conditions and the influences of human actions in the Tillamook Bay Basin, can be placed in a better context by reflecting on the history and evolution of the forests and floodplains of the region, the role of natural disturbances in them, and how their interactions support salmon.

### 5.1.1 Landscape Habitats

- ***Upland Forests***

Waring and Franklin (1979) described the historical and climatological origins of Pacific Northwest coniferous forests. According to these authors, these forests were unmatched in terms of the size and longevity of individual trees and accumulation of biomass. Conifers account for a thousand times more biomass than hardwoods in the Pacific Northwest, an enormous divergence from the hardwood or mixed forests typical of the northern temperate zone.

Conifer dominance in the Pacific Northwest dates back 12 to 18 million years to the late Miocene (Waring and Franklin, 1979). During this period, there was a high rate of hardwood extinction in the Pacific Northwest and unbroken conifer forests spread from Oregon to Alaska. By the early Pleistocene (1.5 million years ago) the native flora of the Pacific Northwest was essentially the same as today (Waring and Franklin,1979).

At the end of the last glacial period, Sitka spruce (*Picea sitkensis*) and lodgepole pine (*Pinus contorta*) dominated the forests west of the Cascade Mountains. These forests persisted roughly from 15,000 to 12,000 years before present. Toward the end of that period, western hemlock (*Tsuga heterophylla*) and Douglas fir (*Pseudotsuga menziesii*) became more prominent in the region. By 10,000 years ago the dominant species of this region were western hemlock and Douglas fir, with red alder (*Alnus rubra*) common in riparian zones. The period from 10,000 to 7,000 years ago was warmer and drier than today. Fires were more frequent and forests were predominantly Douglas fir. Over the past 7,000 years fires have been less frequent, allowing for an increase in the abundance of western hemlock and western red cedar (*Thuja plicata*) and leading to a decrease in Douglas fir which is less-shade tolerant.

The climate of the western Pacific Northwest is characterized by wet, mild winters and warm, dry summers and is a principal factor favoring conifers. Generally less than 10-percent of the annual precipitation falls during the summer months. In the dormant season precipitation is heavy, with daytime temperatures usually above or near freezing. This is strikingly different from most other temperate forests where precipitation is distributed much more evenly through the year.

- ***Lowland Forests and Wetlands***

The lowland areas of the coast were characterized by wetlands, wet and dry prairie, and riparian forest crossed by the main channels and side channels of rivers. The native plant communities found in these areas evolved within a cycle of annual high water and periodic flooding. Flood tolerant species are very resilient and respond well to disturbance. For this reason, riparian areas are one of the most highly productive ecosystems.

- ***Estuaries***

The Tillamook Bay estuary is a relatively shallow, depositional environment whose bathymetry reflects the interaction of underlying geologic features, sedimentation, subsidence processes, and tidal action. The earliest bathymetric survey of the bay, in 1867, showed it to have complex features, numerous wide channels, and deep scour holes. Original maps and field notes from early land surveys of lowlands adjacent to the bay clearly indicate the presence of abundant and often sinuous tidal sloughs surrounded by varied marshes (Coulton *et al.*, 1996a). These sloughs, and particularly shallower portions of the bay near the mouths of the larger rivers, were areas where substantial quantities of large wood tended to accumulate (Maser and Sedell, 1994).

### 5.1.2 Landscape Processes

#### ■ *Wildfires and Landslides*

Within the forested upland areas, high-quality habitats in streams and rivers were created and maintained through cycles of natural disturbance and recovery. Recent research suggests that along the northern Oregon Coast, these cycles were generally driven by large, catastrophic wildfires with a mean return interval exceeding several hundred years (Benda, 1994) followed by long periods of natural recovery punctuated by flood events. The fires probably covered areas of entire forested watersheds, causing over 70 percent mortality and leaving up to 30 percent of the area as unburned islands (Ward, 1977). Resultant landslides introduced substantial volumes of sediment and large woody material to stream channels, legacy effects that reset the affected areas for another cycle of recovery (Reeves *et al.*, 1995). Over time these materials were transported downstream via the river system enriching the lowland ecosystem.

#### ■ *Floods and Fluvial Processes*

Under natural conditions lowland streams were relatively sinuous, complex (i.e., with diverse hydraulic conditions and variable numbers of active channels), and characterized by abundant amounts of large wood. This large wood, interacting with periodic flood flows, played an integral role in creating and maintaining channel complexity. The large wood frequently formed massive drift jams in the lower reaches of the larger rivers. Riparian areas and floodplains in the lower reaches were frequently inundated by floods generated by intense Pacific storms. The jams caused localized flooding facilitating the spread of floodwaters over the floodplain and the deposition of fine sediments. The distribution of flood water across the floodplain helped to limit the magnitude of scouring forces acting upon stream channel beds and banks.

A vivid image of the complexity and dynamics of natural flood events is presented in an historic account of flooding and flood response in Tillamook County at the time of settlement in the 1850s (Collins, 1933):

*Freshets of innumerable spring seasons had shoved and tumbled the fallen trunks [in the Wilson River valley]. Swirling red flood water had shouted and tugged at them and flung them into every elbow of the river channel; had piled new trunks upon them with each succeeding year and had plastered the whole conglomeration with red clay and dark loam torn from the higher levels of the hills.*

*Finally—and long before the first white settlers came—Nature had completed a series of formidable dams all along the stream. Under and around these obstacles the Wilson River found its way in the slack months of summer. Against them it raged and bunted in the high tide of winter. When the melting snows of the Coast Range poured down into the already swollen stream, the waters backed up into flood lakes that went eddying and swirling farther and farther across the level floor of the valley until they lapped the lower edges of the hills.*

*And each of these flood lakes, as they drained away, when the freshets ceased and the Wilson River returned to its channel, left toll of black loam upon the valley floor, deeper and richer each year until one can hardly compute their depth and the richness of the black fertility that had been storing up for ages before the settlers came.*

This account provides a compelling view of the role flooding played in the evolution of the fertile floodplains in the Tillamook Bay area.

#### ■ *Tides*

Tidal action is responsible for the development of the sloughs and marshes that make up the estuary. Marsh environments are commonly described as either high or low marsh. The elevation difference between these two is very subtle, about 8 inches, but can have a substantial effect on the frequency of inundation, and salinity of tidal marshes. As a result, plant communities in high and low marshes vary considerably having evolved to withstand a variety of combinations of inundation and salinity. The highest elevation areas within the tidal zone of the Pacific Northwest coast support a unique tidal spruce forest community.

## 5.2 Human Alterations to the Landscape

Extensive conifer forests, occasional wildfires, floods, landslides, and the tides all contributed to the productivity of the vast Tillamook Bay estuary by contributing large wood and nutrients to the system and creating complex channel and slough forms. Flooding, fire, landslides, and sedimentation are all natural processes that occur in the Tillamook Bay Basin. However, these processes dramatically increased since settlement in the late 1800s, with effects to the ecological, social, and economic vitality of the region.

### 5.2.1 Changes in Upland Forests

Timber harvesting has been the primary human land use in the uplands. Logging activity historically increased fire frequency which, in turn, accelerated salvage logging with impacts to both aquatic habitat and down stream flood risk.

#### ▪ *Increased Fire Frequency*

Historically, the evergreen coniferous forests of the Pacific Northwest have a low-frequency high-intensity fire regime. In western Oregon the estimated fire interval for cedar, spruce, and hemlock forest was estimated to be 400 years.

After settlement in the mid 1800s, the frequency of fire ignition increased dramatically in the Pacific Northwest and enormous acreages were burned in the late 19th and early 20th centuries. In the Oregon Coast Range, very large areas of the Nestuca, Alsea, Smith, Nehalem, Tillamook and other rivers were consumed by human-caused fires between the mid 1800s and the early 1900s. In the large Coast Range fires of the 1800s, riparian forests were often left unburned and afforded an important source of seed for regeneration.

In 1902, the Tillamook watershed was described by a newspaper reporter as a continuous, unbroken old-growth conifer forest. In 1918 a runaway slash fire burned more than 100,000 acres in the Tillamook Basin. The great Tillamook fire of 1933 was one of the last of a series of catastrophic fires in the Coast Range.

A prolonged drought descended on the Oregon Coast Range in July and August of 1933. On August 14, 1933 logging operations ignited a small fire. The fire spread steadily in the tinder dry forest until August 24th, when a combination of extremely low relative humidity and strong winds caused the fire to erupt. It consumed 220,000 acres in 20 hours, exposing this massive area to severe winter storms. Two other fires were started in the Tillamook Basin in 1933, one by an arsonist. The fires burned along a 100-mile front for another two weeks until the first September rains came.

The major watersheds to the north and south of the Tillamook had been heavily burned in the six decades prior to the 1993 Tillamook fire. There were reburns of the Tillamook Basin during the summers of 1939, 1945, and 1951. The total acreage burned through 1951 was 360,882 acres, and much of this had been burned two or even three times, severely damaging the soil and inhibiting natural forest regeneration.

#### ▪ *Salvage Logging*

After the fires an enormous salvage logging and fire control effort began. A public/private conglomerate, called the Consolidated Timber Company, was created to conduct the salvage operations. The Rogers plan was adopted to guide the salvage and restoration effort which called for fire control, intensive salvage logging, the felling of millions of snags, the construction of a vast network of fire roads and the planting of extensive acreages of even-aged monocultures.

Although initiated with the best intentions, the Rogers plan lead to very serious environmental impacts and degradation. The felling of snags and salvage of burned wood lead to a regenerating forest that was lacking in large snags and large downed wood, which are among the most critical habitat components in Pacific Northwest forests. The honeycomb of logging roads severely fragmented the landscape and greatly increased surface erosion and mass wasting. The legacy of these impacts still affects habitat in the Tillamook Basin.

- ***Timber Harvesting***

Non-salvage timber extraction also has a profound effect on aquatic ecosystems. Logging and road construction near streams leads to increases in sediment load and water temperatures, and generally a decrease in fish production and/or diversity. The Coast Range is dominated by sedimentary and igneous rocks. Sedimentary rocks are more vulnerable to erosion. Both surface and mass erosion occurs on steep slopes, mostly after road construction and logging disturbance. Drainage systems and salmon habitats have developed in close association with oldgrowth conifer forest.

Logging of the valleys of the Tillamook Bay Basin began in the 19th century with ox teams and horses. With the advent of steam trains and donkey engines, logging expanded into the upland areas. In latter part of the 19th century, settlers moved into the woods from the estuary. There were more than 50 families settled on homesteads along the Wilson River. During WWI, spruce forests along the Oregon Coast were heavily logged to supply light and resilient wood for fighter planes. Commercial logging of the burn areas began again in 1983.

Past timber management practices have caused increases in sediment and temperature, decreases in available volumes and distribution of large wood, changes in water chemistry, increases in biological oxygen demand, and changes in hydrology. Activities of greatest impact have been logging in riparian zones and yarding activities in stream channels.

Poorly-managed logging in riparian areas leads to a disruption of the relationship between aquatic and terrestrial systems (Malanson 1993). Clearcutting and road building have been shown to be a significant cause of habitat fragmentation (Tinker *et al.*, 1998). Poorly managed logging has been shown to cause a reduction in juvenile anadromous salmonid diversity and abundance in several basins on the Oregon coast (Reeves *et al.*, 1993).

Cumulative effects of land cover changes are a significant source of ecological degradation in the Tillamook Basin. Much of the present day logging in the basin is done on steep slopes where cumulative effects are severe and frequent. Cumulative effects result from the collective impacts of one or more management activities and can exhibit threshold behavior, in which the impacts of management reach a critical point at which they cause major disturbances (Franklin, 1992). Cumulative impacts are likely to be a major cause of landslides, flooding damage, and salmonid population declines (Franklin, 1992).

A significant amount of the sedimentation that is affecting salmon spawning grounds in the Basin can be attributed to steep slope timber harvest which has been shown to cause dramatic increases in sedimentation infiltrating stream beds (Davies and Nelson, 1993). The sedimentation caused by logging has also been shown to have significant negative affects on stream amphibians (Corn and Bury, 1989).

- ***Landslides***

In the Coast Range, most landslides in recent years have occurred on managed lands between 1,000 and 2,000 feet in elevation, where slopes are steepest and precipitation heaviest. In the transient snow zone, landslides occur frequently as a result of rain-on-snow events in which large amounts of water infiltrate the soil on steep slopes (Berris and Harr, 1987). According to Pierson (1977), landslides with a mean volume of $270m^3$, occur at a frequency of about one slide per $km^2$ every 17 years. This makes up approximately one quarter of the sediment that flows into streams from slopes in the Coast Range each year (Pierson, 1977).

Most debris torrents originate on steep slopes within headwater swales and on adjacent steeply-sloped and incised tributary stream channels. Many road fill failures result in large slides. Once these landslides enter steep stream channels they generate large-scale debris torrents. Approximately 65-percent of observed landslides end up as debris torrents, some of which can travel over two miles (Pierson, 1977).

The frequency of landsliding and debris torrent events is much higher in areas that have been recently clearcut and/or roaded. Land management actions play a clear role in the impacts of storms. Clear associations have been documented between roads and landsliding and recent clear-cutting and landsliding (Pierson, 1977).

#### ■ *Summary of Upland Changes*

***Causes***

- Construction of logging roads.
- Removal of live and downed trees from hill slopes, riparian areas, and channels.

***Primary Effects***

- increased water delivery to stream and transportation downstream
- increased sediment delivery to streams and transportation downstream to lowlands
- decreased nutrient input to streams
- decreased pool numbers
- decreased quality of spawning habitat
- decreased vegetative cover

***Secondary Effects***

- increased flood risk downstream
- decreased food, cover, and spawning habitat for salmon

### 5.2.2 Changes in Lowlands and Estuaries

Beginning in the late 1800s, the lowland rivers, floodplains, and estuary of the Tillamook Bay Basin were altered to ensure safe navigation of ships and to support the increasing use of the land for settlement and farming. These alterations frequently incorporated flood control measures. Similar strategies were employed to reduce flood risk and increase productivity in both the lowland and estuary environments so it is appropriate to discuss alterations to these areas together. Alterations can be grouped into three general categories: channelization, levee construction and floodplain dewatering.

#### ■ *River Channelization & Simplification*

Channelization simplifies the form of a channel. Channelization strategies include **dredging** and **large wood removal**, and the construction of **cut-off dams**. Dredging increased channel depth and flow capacity while wood removal improved navigation access to upstream areas and increased river flow capacity. Cut-off dams were constructed to block the mouths of secondary channels or to shorten the course of the river by eliminating bends (Figure 5-1). When a bend is eliminated the river drops the same elevation in a shorter distance. The result of this is fewer channels carrying the same amount of water in steeper, larger channels. The simplification of what was once a complex system of side channels reduced the amount of channel area that the river had access to at high flows and eliminated off-channel areas that sheltered salmon during those same high flow events. This simplification also increased flow velocities and the erosive forces acting on the banks of the main channels.

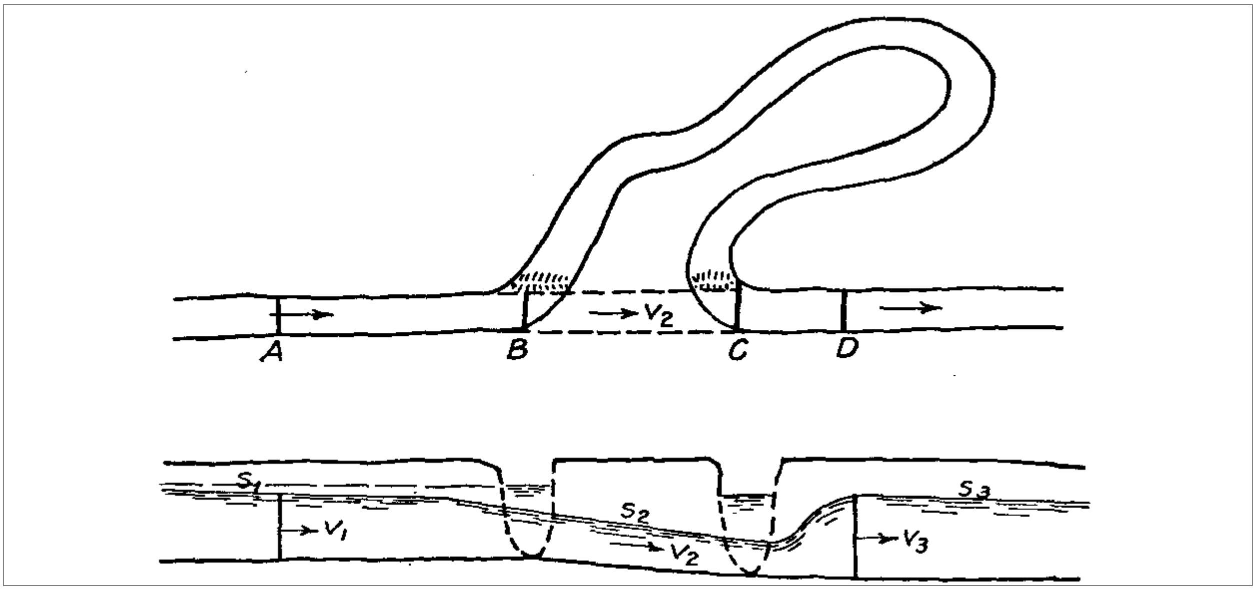

**Figure 5-1. Effect of a River Channel Cut-off on River Flow** Source: Etcheverry, 1931

## ■ *Levee and Dike Construction*

In a natural river system, as floodwaters overflow the river banks, coarser sediments are initially deposited along the banks often forming natural levees several feet higher than the surrounding floodplain. The elevated river banks naturally divided the lowland valley into overflow basins bounded by the valley hillslopes (Etcheverry, 1931). Finer sediments are typically carried further onto the floodplain where they are deposited in areas of slack water during floods.

In the early 1900s, the traditional practice for reclaiming floodplain lands for agricultural purposes was to place a levee, or dike, along or near the riverbank to take advantage of the higher ground provided by the natural ridge of high ground formed from sediment deposits from past overbank flooding (Figure 5-2). Besides protecting the greatest amount of floodplain land from flood overflows, this practice resulted in the construction of levees requiring less height and less cost than would otherwise be necessary if they were constructed at lower ground elevations farther from the river.

The design of a levee and its foundation was dependent on the anticipated duration and height of floodwaters against the levee (Etcheverry, 1931) (Figure 5-3). Levees bordering bays and not exposed to wave action were recommended to be built to an elevation 3 to 5 feet above the highest tide (Etcheverry, 1931). The use of willows as protection for levees was recognized in a 1931 engineering textbook. It was recommended to plant rows of willows in front of levees because they "grow rapidly and their branches break up the waves and decrease the currents [against levees] (Etcheverry, 1931). It is interesting that these same techniques are now being advocated for salmon habitat restoration.

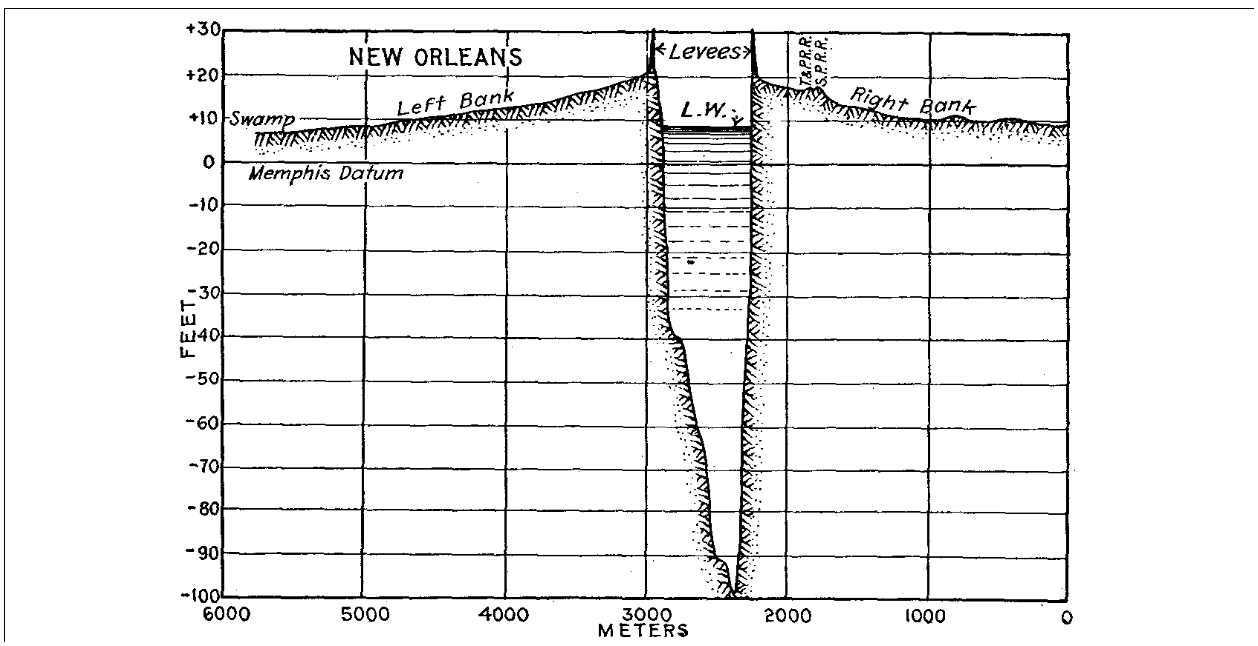


**Figure 5-2. One example of Levee Construction on top of the Natural Levees of a River**
Source: Van Ornum, 1914

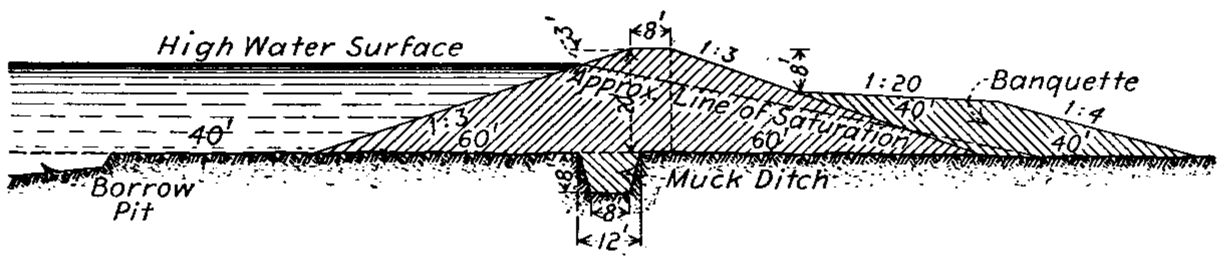


**Figure 5-3. A Typical Levee Section** Source: Van Ornum, 1914

The protection of lands in lowland valley floodplains typically occurred gradually over time, as various landowners or drainage districts would isolate their particular areas without regard for the future conditions caused by these cumulative impacts in the floodplain. Levees alongside one side of a river were constructed to heights to contain the highest floodwater experienced, but as subsequent drainge projects occurred in upstream areas and on opposite banks of a river flood waters would increase and lead to competition of levee heights (Etcheverry, 1931).

Although the concept of cumulative effects was probably not considered as levees and dikes were being constructed in the early part of this century, it is interesting to note that the engineering textbooks published at this time for guidance in land drainage and flood protection addressed these effects. Etcheverry (1931) did caution against constricting both sides of a river with levees because the loss of natural overflow areas would increase flood levels against the levees. He also acknowledged the removal of natural floodplain overflow areas by levees would increase the "intensity of flood discharge." The practice of levee construction was generally promoted in the early textbooks as an effective method to protect lands from flooding, if only one side of a river was to be leveed (Etcheverry, 1931). With both sides leveed, it was recognized that the loss of the floodplain overflow areas would eliminate the floodplain's absorbing effect on the flood peak and result in higher water levels against the levees. Setting both levees back from the riverbank was proposed as an economical solution to this problem (Etcheverry, 1931).

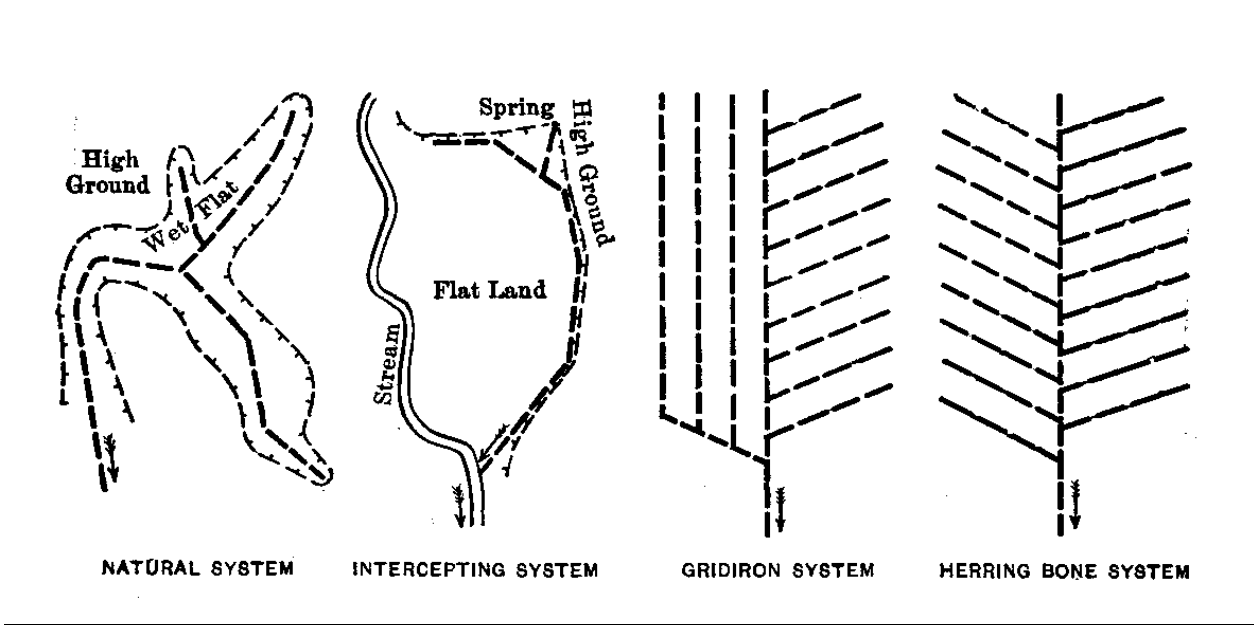


**Figure 5-4. Types of Tile Drainage Systems** Source: Powers and Teeter, 1932

### ■ *Floodplain Drainage*

Complete reclamation of diked and leveed floodplain lands often required the additional use of surface and subsurface drainage facilities to remove excess water from direct precipitation, high seasonal groundwater levels, or flood overtopping of dikes and levees. Land drainage was achieved through the use of ditches, tidegates and buried drain tile.

Drainage techniques were employed to increase the productivity of land in agricultural use. Drainage tiles, placed below the surface of agricultural land removed excess water and increased the length of the growing or grazing season. It is understood that drain tiles were installed across much of the Tillamook Bay lowland valley floodplains to provide seasonal subsurface drainage of lands protected by dikes and levees (Figure 5-4). However, information on the exact location and extent of these drainage features is not readily available.

The dewatering of floodplain soils for agriculture has proved effective for converting these natural lands over to productive lands for grazing and field crops. However, the long term effects of these activities typically results in significant physical changes to the land. The predominant change is land subsidence, or a lowering of the land surface. Land subsidence within drained floopdlains can be caused by oxidation of the soil, when naturally moist soils are drained and exposed to the air, resulting in changes in soil chemistry and a compaction of the soil structure. Subsidence can also occur from the direct compaction of soil due to the weight of grazing animals and vehicles.

Floodplain drainage efforts typically interrupt the supply of sediments and inorganic materials from the rivers and the bay to floodplain lands. This reduces the ability of tidal marsh lands to receive natural sedimentation and increase in elevation to keep pace with a rising sea level.

These physical changes to the elevation of the land surface can lead to dramatic changes in the movement of water on the land. Lower land areas, if restored to river flow and tidal action, may experience more frequent inundation and changes in fresh and salt water flow and mixing. Hydrologic changes can, in turn, lead to changed vegetatio patterns and aquatic habitats.

## ■ *Summary*

The history of river channelization and levee and dike construction in the Tillamook Bay lowlands was typical of this era of land reclamation and drainage, in that it proceeded in a manner that solved immediate drainage problems for individual landowners without consideration for the cumulative and longterm effects of the flood protection structures. In order to maximize the amount of land to be protected from flooding and minimize the costs of levee and dike construction, these flood control features were often built immediately alongside of rivers to take advantage of the higher ground where natural levees had formed. The cumulative effects of these drainage alterations were not considered as their use spread across the lowland valleys.

Interestingly, many of the actions considered today to improve the integrity and effectiveness of these types of flood control structures, while improving the environmental conditions of floodplains and riparian areas for fish and wildlife habitats, were promoted at the beginning of this century. The same engineering textbooks that provided guidance for the construction of levees and dikes advocated setting back levees from rivers to reduce the potential for erosion and overtopping of the structures. The use of natural vegetation, such as willows, in front of dikes and levees was also recommended to absorb the energy of waves and river currents and reduce the chances of erosion and minimize maintenance needs.

## ■ Summary of Lowland Changes

Lowland changes and their causes, and primary and secondary effects, are summarized below.

***Causes***

- Construction of roads
- Removal of live and downed trees from riparian areas, and channels
- Removal of wetland vegetation
- Cutting-off side channels from main channels
- Reinforcement of channel banks
- Construction of dikes and levees
- Construction of drainage projects
- Grazing in riparian area
- Gravel mining

***Primary Effects***

- increased volume and velocity of water in main channels
- decreased water quality
- decreased flooding and sediment deposition on the floodplain
- increase in the amount of sediment passed downstream to estuary
- decreased nutrient filtering in wetlands
- decreased pool number and frequency
- decreased spawning gravel
- decreased vegetative cover
- decreased refugia
- 

***Secondary Effects***

- increased flood risk downstream
- increased bank erosion
- decreased food, cover, rearing, and spawning habitat for salmon

■ **Summary of Estuary Changes**

***Causes***

- Removal of live and downed trees from riparian areas, and channels
- Removal of marsh vegetation
- Cutting-off sloughs from main channels
- Reenforcement of channel banks
- Construction of dikes and levees
- Construction of drainage projects
- Dredging
- Grazing

***Primary Effects***

- increased volume and velocity of water in main channels
- increase in the amount of sediment passed downstream into the bay
- decreased water quality
- decreased tidal action in marshes
- decreased nutrient filtering in marshes
- decreased scour hole numbers
- decreased quality of spawning habitat
- decreased vegetative cover
- decreased refugia
- oxidation and compaction of soil
- soil surface subsidence
- increased duration of surface inundation by freshwater in highly subsided diked marshes

***Secondary Effects***

- increased flood risk downstream
- increased bank erosion
- decreased food, cover, and rearing habitat for salmon
- shellfish closures
- decreased palatability of vegetation where subsidence leads to development of freshwater wetlands

## 5.3 Historic Salmon Abundance

The historic salmon productivity of the Tillamook Basin is directly related to the historic landscape conditions and alterations to these conditions just described. Understanding the connection between historic salmon populations and these changing landscape conditions allows us to determine how human alterations to the landscape may have detrimentally affected salmon productivity.

### 5.3.1 Estuary Size

Although small when compared to estuaries globally, Tillamook Bay is a significant size and large in proportion to its drainage basin when compared to other estuaries along the Oregon Coast (Figure 5-5). This is of significance because estuaries and tidal wetlands are the most productive natural systems. Tiner (1984) has demonstrated that saltmarshes are the most productive ecosystem in terms of biomass generated per unit area, greater than even tropical rainforests.

However, it is not just biological productivity that is impacted by the loss of wetland acreages but also biological diversity. A general 'rule-of-thumb' for ecosystems is that 80% loss of habitat will result in a 50% reduction in the number of species. Since many of the coastal regions of the U.S. have already exceeded this critical number, the need to preserve or enhance remaining wetlands is of paramount importance. Further, the type of sub-habitat is important to many species which use wetlands and it is important to maintain the diversity of open water, mud-flats, channels, pannes and eco-tones. The timing and volume of freshwater inflows affect patterns of mixing within estuaries, and because of linkages between salmon production in freshwater and estuarine habitats these are critical habitats for protection and restoration.

Drainage basins with proportionally larger estuaries may be inherently more productive for salmon than basins with smaller estuaries, at least for those species with extended periods of estuarine residency. One of the reasons for this is that large estuaries may be less prone to perturbations in water quality or anthropogenic influences, and able to recover faster. For example, a wildfire in a small system may influence the entire system, resulting in overload of fine sediments, loss of streamside vegetation, altered geomorphic characteristics that makes the entire system untenable for certain species - pushing the species to extinction. A larger system is less likely to be 100% impacted, allowing isolated pockets of habitat and fish to survive, allowing the population to build out again as the physical system recovers.

### 5.3.2 Historic Abundance

Salmon evolved with the patterns of disturbance and recovery described above and use the upland, lowland, and estuary environments at different stages of their life cycles. Information on turn of the century abundance of salmon in the Tillamook Bay basin and other coastal Oregon drainages is imperfect but important in helping to gain insights on the inherent productivity of their aquatic systems. This information, usually in the form of cannery records and old fishery statistics, can often be used to establish reasonable (although by no means precise) estimates of the sizes of historic salmon runs and thus to establish points of reference that may provide useful guidance to restoration planners.

Lichatowich and Nicholas (1991) and Huntington and Frissell (1997) have developed these types of estimates for many of Oregon's coastal river basins. For most basins, these estimates reflect salmon abundance after Euro-Americans had caused a considerable amount of environmental change in lowland areas and estuaries.

The Tilamook Bay basin’s historic capacity to produce immense numbers of salmon reflect the areas diverse environment. The significant historic abundance of chum salmon in Tillamook Bay, documented in cannery records, is evidence that much of the river system's historic productivity was linked to the presence of high-quality habitat in the extensive lowlands surrounding Tillamook Bay and the bay itself because chum salmon spawn in low-gradient streams and spend up to a month as juveniles rearing in estuaries.

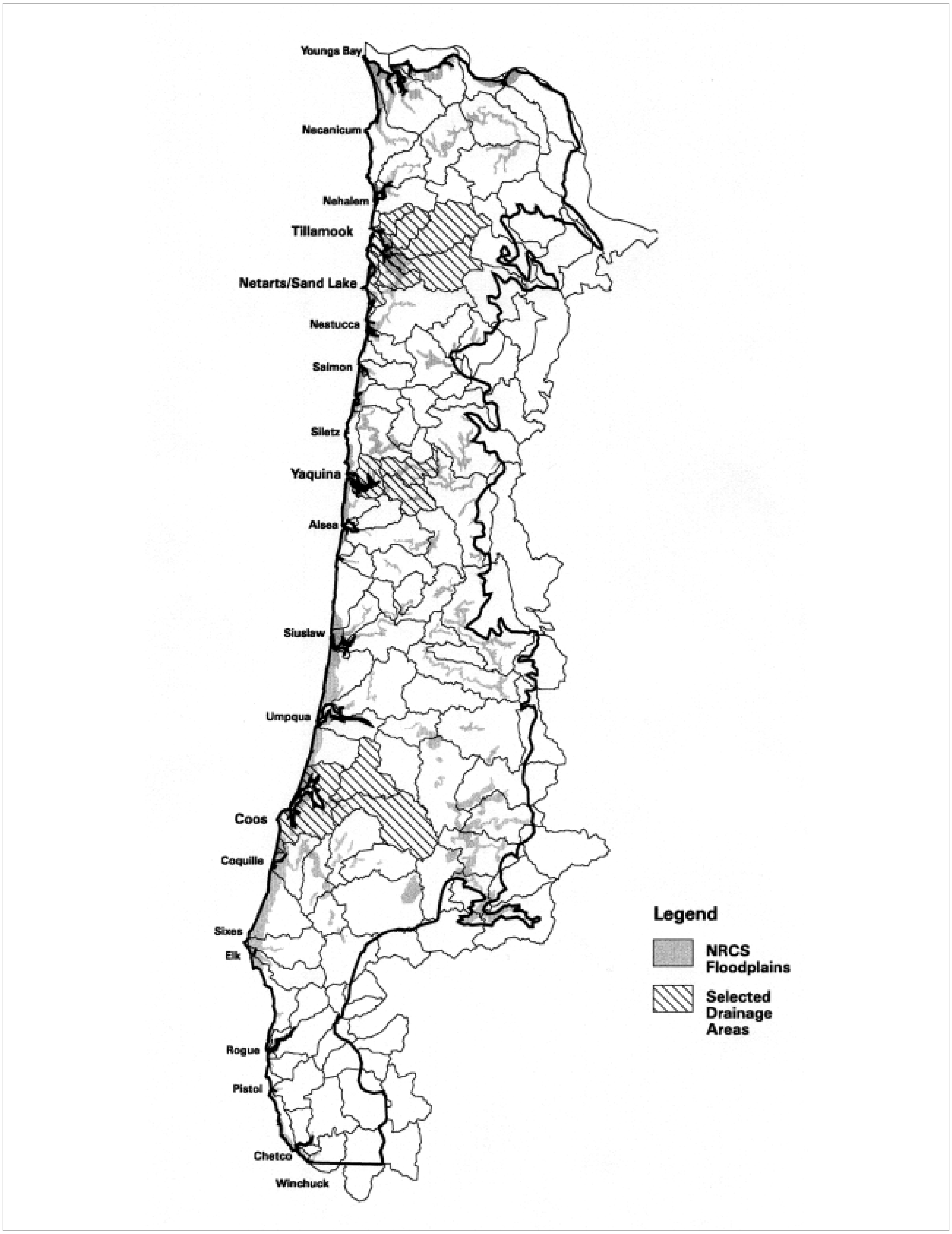


**Figure 5-5. Oregon Coast Ecoregion with River Basins**