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Use of geomorphology in the classification of riparian plant associations in mountainous landscapes of central Oregon, U.S.A.

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ABSTRACT

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Resource managers are increasingly interested in the importance, unique values, classification, and management of riparian zones. Understanding the ecology of the riparian zone is complicated by extreme variation in geology, climate, terrain, hydrology, and disturbances by humans. As a result, it is often difficult to determine the vegetation potential of riparian sites and develop management options. A recent riparian classification in central Oregon uses geomorphology in addition to traditional floristic classification to help identify vegetation potential in the riparian zone. A four-level geomorphic/floristic classification is proposed. Geomorphology is especially useful on riparian sites where the natural vegetation composition, soils, and/or water regimes have been altered by past disturbance, either natural or human-induced.

INTRODUCTION

Riparian zones often form a narrow interface between aquatic and terrestrial ecosystems in mountainous regions of the Pacific Northwest (Youngblood et al., 1985b). The interface occurs on a wide variety of sites such as floodplains, bogs, marshes, lakeshores, and basins. This paper is limited to riverine zones, and the examples discussed later are primarily from the Ochoco National Forest. Riverine riparian zones are composed of two ecosystems (Fig. 1).

(1) The riparian ecosystem includes frequently flooded, moist to wet fluvial surfaces such as streambanks, active channel shelves, active floodplains, and overflow channels. Riparian ecosystems as termed here are equivalent to the mesoriparian of Johnson and Haight (1985).

(2) The transitional ecosystem lies between the riparian and upland ecosystems (Cross, 1985). These sites include drier fluvial surfaces such as in-

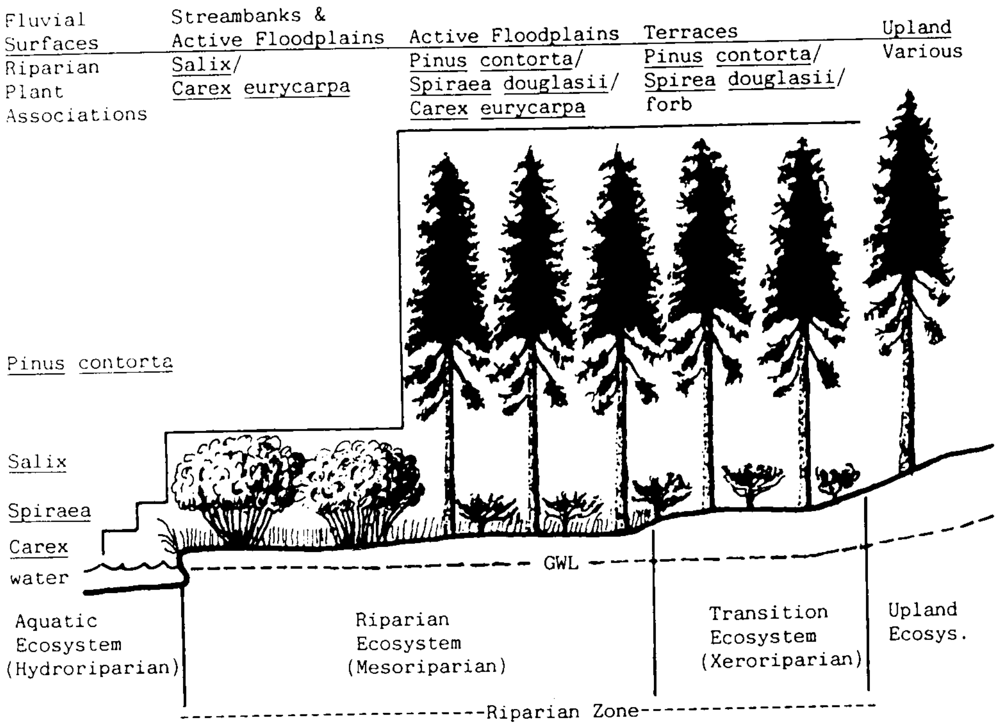

Fig. 1. Riparian zones often form a narrow interface between aquatic and terrestrial ecosystems in mountainous regions of the Pacific Northwest.

active floodplains and terraces. Transitional ecosystems correspond to the xeroriparian of Johnson and Haight (1985).

Because of their unique position at the interface of the aquatic and terrestrial ecosystems, riparian zones have great potential for multi-resource use (Hansen et al., 1987). Yet, until the last ten years, the structural, compositional, and fuctional components of riparian zones received little consideration in ecosystem research, management, and planning (Youngblood et al., 1985b). Present USDA Forest Service policy consists of riparian-resource management that concentrates on the importance and unique values of the system, as well as the classification, inventory, and delineation of riparian ecosystems for land-management planning (McGuire, 1977).

Many synecologists are developing vegetation-based site classifications for uplands in the western United States. The majority of these classifications either do not include the riparian zone or treat it broadly. With increased interest in riparian management, several comprehensive riparian classifications have also been been developed for portions of the National Forest System (Cowardin et al., 1979; Ratliff, 1982; Youngblood et al., 1985a,b; Pierce and Johnson, 1986; Hansen et al., 1987; Kovalchik, 1987; Padgett et al., 1990). We will use the riparian classification for central Oregon (Kovalchik, 1987) as an example in the rest of the paper.

GENERAL PHYSIOGRAPHY OF CENTRAL OREGON

The central-Oregon study area extends along the crest of the Cascade Mountains from Mount Jefferson in the north to the California border in the south, and eastward through the Deschutes, Winema, Ochoco, and Fremont National Forests (Fig. 2). This area includes some 19 000 km^2 in the National Forest System, only a small portion of which is in riparian zones (much less than 5% of the total area).

Precipitation is substantially less than areas west of the Cascades due to the orographic effect of cool, marine air from the Pacific Ocean flowing over the

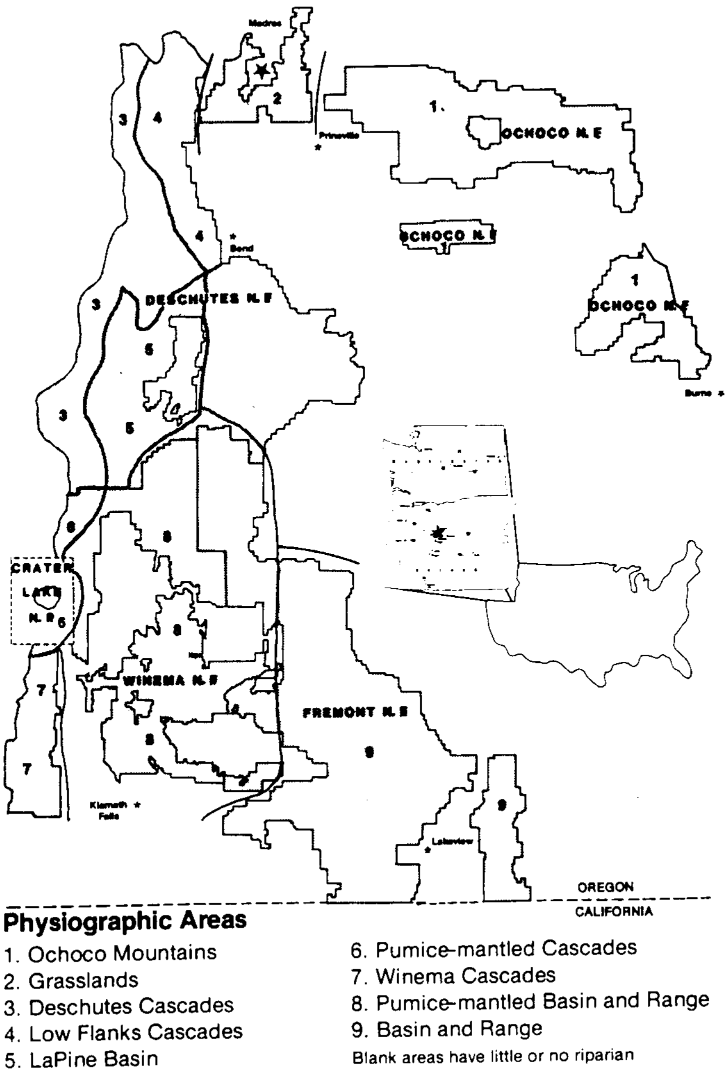

Fig. 2. Area covered by the classification of riparian plant associations in central Oregon showing boundaries of National Forests, nine physiographic areas, and major towns.

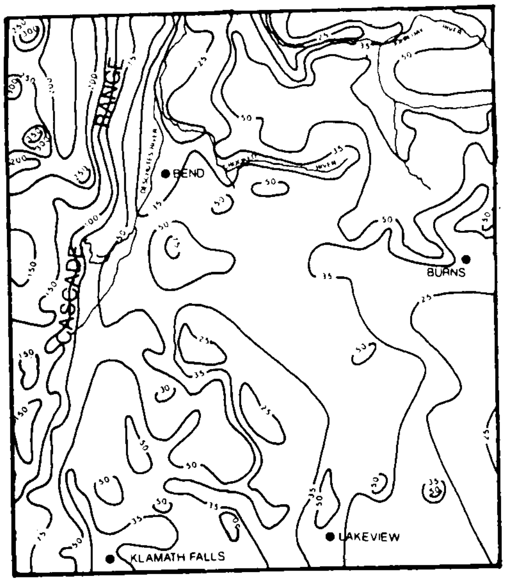

Fig. 3. Mean annual precipitation in central Oregon (Climatological Handbook, Columbia Basin States: Meteorology Committee, Pacific Northwest River Basins Commision, 1968–1969).

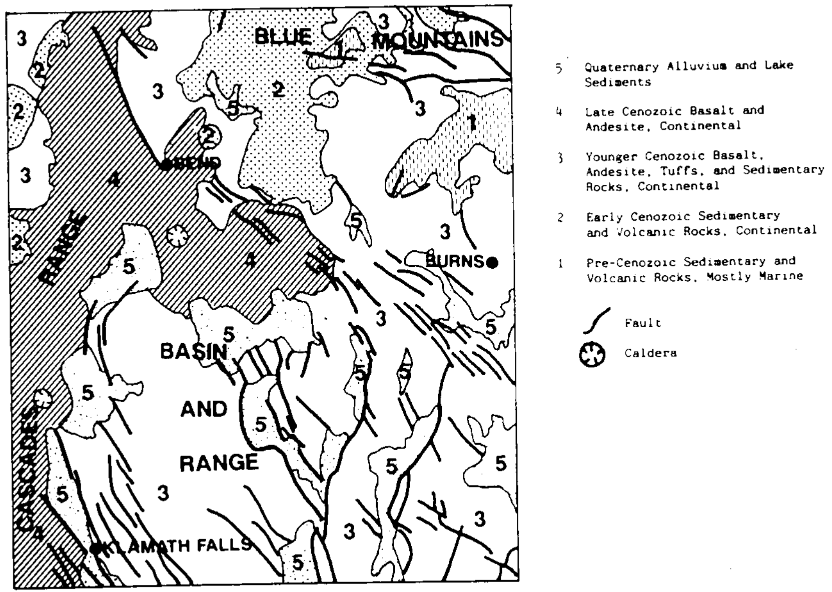

Fig. 4. Generalized geology map for central Oregon (modified from Walker and King, 1969).

Cascades. Annual precipitation ranges from about 35 to 75 cm, except in the Cascades where it rises to about 200 cm along the crest (Fig. 3). Most precipitation falls as winter snow. Summers are droughty. Elevation ranges from approximately 600 to 3500 m in an area with a remarkable diversity of geology and landforms (Fig. 4) such as volcanic peaks, fault-block mountains, pluvial lake basins, flat-lying and tilted plateaus, outwash plains, and deeply dissected volcanic uplands (Baldwin, 1981). Volcanism has dominated the geologic history of the area for the past 40 million years (m.y.), and continues today in the Cascade Range, as evidenced by the 1980 eruption of Mount St. Helens. For millions of years lava flows, mudflows, pyroclastic flows and surges, and air-fall ash, pumice, and cinders have created complex mosaics of volcanic deposits and landforms.

Episodes of fault-block uplift and tilting of these volcanic landscapes or damming of drainages by volcanic flows have created additional basins that have been subsequently filled by erosional sediments. Climatic changes and glaciation during the past million years have profoundly altered all landscapes.

FLORISTIC CLASSIFICATION

The riparian classification for central Oregon (Kovalchik, 1987) concentrated on sampling sites relatively undisturbed by human activities such as timber harvest and livestock grazing. The objective was to develop a site classification which would allow land managers to predict vegetation potential in riparian zones, even on highly degraded sites.

Fifty-four common and 24 incidental riparian plant associations were described; these include 27 forest and 51 nonforest associations. A riparian plant association is an assemblage of native vegetation in equilibrium with the en-

Fig. 5. Silver Creek showing streambanks anchored by the *Salix/Carex lanuginosa* association. Several species of *Salix* dominate the tall-shrub layer while *Carex lanuginosa* dominates the herbaceous layer. The association continues across a wide active floodplain.

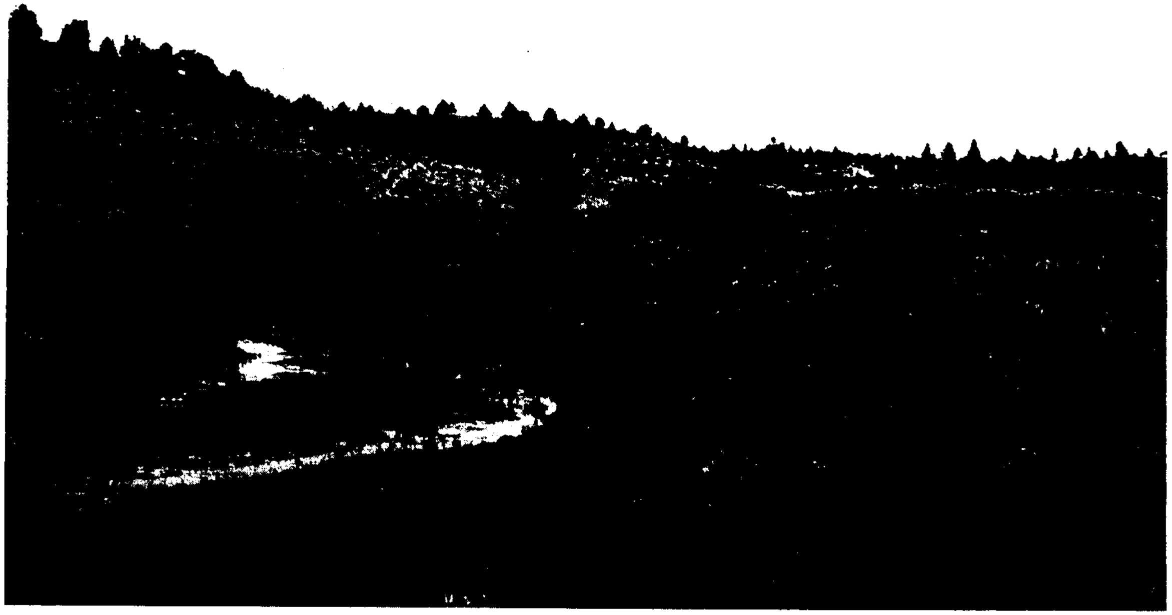

Fig. 6. Egypt Creek (a tributary of Silver Creek) showing severe change in vegetation composition due to streambank erosion, streambed downcutting, and lowered water-tables as a result of livestock grazing. The *Artemisia tridentata/A. cana/Poa cusickii* association has expanded into the now xeric floodplain. The potential with restored watertables is *Salix/Carex lanuginosa*, as along Silver Creek (Fig. 5).

vironment on a fluvial surface (Kovalchik, 1987). This equilibrium assemblage is the vegetation potential of the fluvial surface. The potential may change in time with changes in the soil and water characteristics of fluvial surfaces in response to erosion and deposition effects of stream meandering. Riparian plant associations are named on the basis of characteristic or dominant plant species in the various equilibrium plant layers (Fig. 5).

As the study progressed, it become apparent that traditional floristic classification theories developed for the upland were difficult to apply in the riparian zone (Kauffman, 1988). This is because processes and patterns of succession, stability, and site potential are different in riparian zones (Hansen et al., 1987). Complex mosaics of riparian associations develop in riparian zones in response to these processes. The size and shape of each riparian association is largely determined by watertables and soil structure, and may change in response to fluvial processes of the stream. Additionally, many riparian zones have had vegetation composition and/or site potential altered by effects such as timber harvesting and livestock grazing (Kovalchik, 1987) (Fig. 6). An alternative to a strictly floristic classification was needed to determine site potential on disturbed sites and to describe riparian dynamics on sites in all conditions. The alternative used was geomorphology in combination with floristic classification.

GEOMORPHIC/FLORISTIC CLASSIFICATION

Geomorphology is the study of landforms and the processes that create them (Thornbury, 1969; Ritter, 1978). Geology, climate, and time are the controlling factors in the evolution of landforms. Climatic forces carve landforms on materials supplied by geologic structure. Climate affects the many chemical and physical ways by which the earth's surface undergoes change, and provides energy and water to shape and drive watershed ecosystems. Geology and climate are the most constant factors influencing the formation of watersheds and both upland and riparian landforms. Time is how long these processes have been modifying a geological structure. Together, geology, climate, and time provide the landscape with its distinctive appearance and drainage pattern. These factors are neither static nor uniformly directional. In central Oregon, the wearing processes of all forms of erosion have been episodically interrupted by the building of new structures such as volcanoes and upthrust fault-blocks.

Concepts for developing the geomorphic classification centered on the classic text by Thornbury (1969) that allows the user to understand the basic processes of geomorphology. Formation of watersheds and both upland and riparian landforms is mostly determined by five interdependent factors (Thornbury, 1969; Lotspeich, 1980): geology, climate, valley gradient, soils, and vegetation. Using these factors, riparian classifications can be physically organized into four hierarchical levels:

Physiographic areas. Nine physiographic areas (Fig. 2) were recognized based on relative uniformity in geology, climate, and stage of modification in the evolution of landforms (Thornbury, 1969). The divisions were modified from those outlined by Franklin and Dyrness (1973) and Chitwood (1976).

Watersheds. Watersheds were not included in the riparian classification (Kovalchik, 1987) but are proposed for future work. Lotspeich (1980) proposed watersheds as the conceptual framework for a natural classification system. The erosional effects of climate on geology in watersheds ultimately determines the structure and function of the riparian zone. Watersheds allow a shift in focus, from the riparian zone only, to its relationship to the watershed. Because of their connectivity, management activities in uplands may change potentials in the riparian zone. Although watersheds are relatively uniform within a physiographic area, differences exist due to watershed order, aspect, elevation, local geology, soils, sediment transport, water regimes, timing and frequency of floods, and vegetation. These factors are critical for land-management planning in the riparian zone.

Riparian landforms. These are segments of riparian zones characterized by distinctive surface expression, internal structure, and vegetation (Fig. 7). Valley-floor gradient and width, elevation, fluvial processes, and soil parent material are important physical factors characterizing riparian landforms. Streams may occur in the headwaters of narrow, V-shaped valleys, in flat, wide depositional floodplains at lower elevations or behind debris jams or local masses of hard rock in otherwise steep terrain. A key helps to identify major riparian landforms, fluvial surfaces, and riparian plant associations in physiographic areas with degraded riparian zones (Table 1).

Fluvial surfaces/riparian plant association. Fluvial surfaces are the various land surfaces in riparian landforms such as active floodplains, terraces, channel shelves, streambanks, and overflow channels. Fluvial surfaces are response units to the interaction of stream erosion, deposition, and vegetation; they represent narrow portions of the environmental variation in a riparian landform and reflect a specific potential for vegetation development. Riparian associations respond to differences in soil structure, soil texture, and watertables in fluvial surfaces. Together, fluvial surfaces and riparian plant associations provide a meaningful way of integrating various environmental factors such as water regime and soils that affect vegetation potentials in riparian landforms.

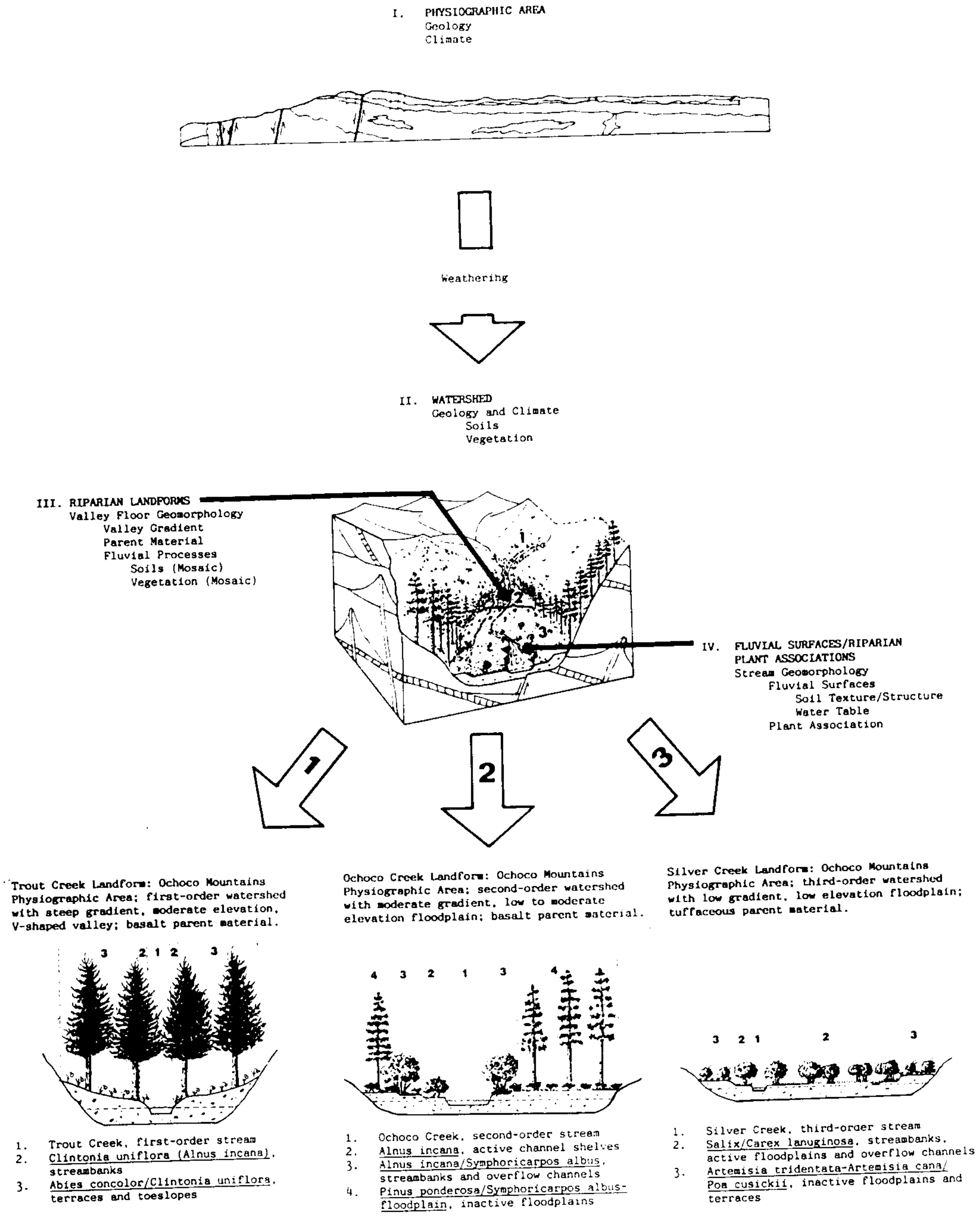

Fig. 7. This figure illustrates major geomorphology of the Ochoco Mountains Physiographic Area through a characterized watershed to riparian landforms and fluvial-surfaces/riparian-plant associations.

Relating riparian plant associations to physiographic areas, riparian landforms, and fluvial surfaces enables the prediction of potential on degraded sites. Cross-sectional sketches of major riparian landforms and included flu-

TABLE 1

First page to the key to riparian-zone plant associations on the Ochoco and Fremont National Forests, using physiographic areas, riparian land forms and fluvial surfaces (Kovalchik, 1987)

Ochoco National Forest	1
1a. Ochoco Mountains Physiographic Area	2
1b. Grasslands Physiographic Area	8
2a. Low gradient (less than 1% valley gradient) floodplains at elevations below 1600 m along streams such as Silver, Nicholl, Sawmill, and Gray Creeks. *Artemisia tridentata* or *A. cana* occur on inactive floodplains. Soil parent material primarily tuff:	
a1. Active floodplains	*Carex lanuginosa* *Salix/Carex lanuginosa* *(Salix/Poa pratensis)* *(Poa pratensis)* *(Artemisia tridentata-Artemisia cana/Poa cusickii)*
a2. Inactive floodplains and terraces	*Artemisia tridentata-Artemisia cana/Poa cusickii*
2b. Sites different	3
3a. Moderate gradient (2–4%) floodplains at elevations below 1700 m along streams such as Emigrant, Mill, McKay, Trout, and Black Canyon Creeks and N. Fk. Crooked River. *Pinus ponderosa* occurs on the inactive floodplain. Soil parent material primarily basalt:	
a1. Active channel shelves	*Scirpus microcarpus (Carex amplifolia)* *Alnus incana*
a2. Well developed active fluvial surfaces	*Alnus incana/Symphoricarpos albus*
a3. Inactive floodplains	*Pinus ponderosa/Symphoricarpos albus*-floodplain (Poa pratensis)
3b. Sites otherwise	4
4a. V-shaped valleys with steep valley gradients (greater than 4%) in first- order streams such as Bear, Bug, Owl, and Trout Creeks. Usually in cold air drainages on north to east exposures except for Howard Creek, which faces southeast:	
a1. Streambanks	*Clintonia uniflora (Alnus incana)* *Alnus incana*
a2. Narrow floodplains and toe slopes	*Picea engelmanni/Clintonia uniflora* *Abies concolor/Clintonia uniflora*
4b. Sites different	5

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[1] This key is provided for major riparian landforms. Parentheses around riparian-association names indicate altered sites where the natural association has been replaced by drier associations because of overgrazing or lowered watertables in order of increasing level of disturbance.

vial surfaces and riparian plant associations were developed for each physiographic area (see example cross-sections in Fig. 7).

AN EXAMPLE OF GEOMORPHIC/FLORISTIC CLASSIFICATION

The following example from the Ochoco Mountains Physiographic Area illustrates the use of the four-level geomorphic/floristic classification for central Oregon (Kovalchik, 1987) (Fig. 7).

The Ochoco Mountains are a broad, uplifted, volcanic region with considerable faulting, folding, and tilting (Swanson, 1969; Walker, 1977; Baldwin, 1981). The surface is completely erosional except for alluvial deposits on low gradient valley floors. No original or primary volcanic or sedimentary landforms remain. Elevations range from 1000 m at the forest perimeter to 2100 m at Round and Lookout Mountains.

Several important geologic formations are recognized. The oldest rocks (90–370 m.y.) are predominately marine deposits of mudstone, sandstone, argillite, limestone, and chert. The principal geologic units are the Clarno Formation (36–41 m.y.), John Day Formation (20–36 m.y.), Columbia River Basalt Group (15–17 m.y.), and Rattlesnake Formation (6 m.y.).

The Clarno Formation is a great pile of volcanic rocks several thousand m thick. It consists mainly of andesitic lava flows, breccias, mudflows, tuffs, and sedimentary rock. The John Day Formation is composed of volcanic ash and welded tuff up to 1000 m thick. The ash and tuffs originated in the Cascade Range and are the products of major, explosive volcanism. Fifteen million years ago, the Cascade Range was not high enough to block marine air from the ocean. Rocks of the Clarno and John Day Formations were exposed to substantial weathering and were partially altered to clays and other secondary minerals. The Columbia River Basalt Group consists almost entirely of extensive layers of basalt up to 300 m thick. They resulted from high-volume eruptions that flooded large areas and buried much of the existing landscape. The Rattlesnake Formation is a vast sheet of eroded rhyolitic tuff up to 60 m thick that resulted from a violent eruption from a caldera near Burns, Oregon. Much of the rimrock in the eastern Ochoco Mountains and areas near Burns consist of Rattlesnake tuff.

Climatic conditions interact with patterns of complex volcanic stratigraphy and the effects of faulting and folding. The resulting landforms are each unique but form distinctive patterns. For example, in the Clarno Formation, streams have cut narrow, steep-walled canyons in the resistant rock. Broad valleys, in a wide range of scales, have formed in the less-resistant rock of the John Day Formation.

Approximately 7000 years ago the area was blanketed with 20–40 cm of volcanic ash from the violent eruption of Mt. Mazama (Crater Lake). Subsequent erosion has largely removed this ash from south-facing slopes, where soils are generally shallow residuals (less than 1 m thick) developed on bedrock. Here, open forests of *Pinus ponderosa* and scattered ground vegetation allow direct impact of raindrops, frequent frost-heaving, surface erosion, and droughtyness on the soil surface. As a result, stream sediment loads can be high. Northerly slopes are less weathered and eroded because of dense ground vegetation and forests of *Abies grandis, Pseudotsuga menziessii*, and *Larix occidentalis*. Sediment loads here are usually low.

Figure 7 shows three watersheds of increasing order that are merged into a generalized drainage for the Ochoco Mountains Physiographic Area. Riparian landforms characteristic of each of these watersheds are described below:

The Trout Creek Landform is a narrow, well-incised, steep-gradient, first-order watershed. Valley deepening is a major geomorphic process. The small stream can carry a considerable sediment load during spring runoff or summer storms.The otherwise steep stream gradient is highly modified by large organic debris, rubble, and/or bedrock. Streambanks are composed of well-aerated cobbles, gravel, and sand derived from basalt alluvium and colluvium and support the *Clintonia uniflora (Alnus incana)* association. Brief floodplains and subirrigated toeslopes, when present, support the *Abies concolor/ Clintonia uniflora* association.

Trout Creek merges into larger-order watersheds represented by the Ochoco Creek Landform. Floodplains are moderately wide and stream gradients moderate. Stream energy decreases on entering this landform so that deposition and floodplain development can occur. Streams are slightly meandering. Surface soils are well-aerated, gravelly sands and sandy loams derived from basalt alluvium. Active channel shelves and streambanks support the *Alnus incana* and *A.- incana/Symphoricarpos- albus* associations. Inactive floodplains and terraces support the *Pinus- ponderosa/Symphoricarpos- albus* floodplain association.

At lower elevations, these streams merge into third- and larger-order watersheds represented by the Silver Creek Landform. This landform often intersects the John Day and Clarno Formations, forming wide, low-gradient floodplains. Soils are deep, erosive, fine sandy loams derived from tuffaceous alluvium. Streams are highly meandering and have numerous overflow channels. The *Salix/Carex- lanuginosa* association predominates on streambanks, overflow channels, and active floodplains. *Artemisia tridentata/A. cana/Poa cusickii*, when present, occurs on inactive floodplains and terraces.

CONCLUSIONS

A geomorphology-based classification for riparian zones is proposed that supplements traditional vegetation-based classification. It has four levels: physiographic area; watershed; riparian landform; and fluvial-surface/riparian-plant association.

Suggested needs for future use and refinement of a geomorphic/ floristic riparian classification include the following:

(1) Validate the four-level riparian classification for central Oregon using an interdisciplinary team of geologists, hydrologists, soil scientists, and ecologists.

(a) Describe and map appropriate physiographic areas, watersheds and riparian landforms on the Geographic Information System using soil resource inventories, geology maps, and other resource information; validate the mapping units in the field.

(b) Use the sample plot data from the riparian classification (Kovalchik, 1987) to verify the hypothesis.

(2) Riparian classifications are being developed for other areas in the dry mountainous areas of the western United States; these and future classifications might include the following two stages:

(a) Describe and map appropriate physiographic areas, watersheds, and riparian landforms as described above; validate the mapping units in the field.

(b) Intensively sample fluvial surfaces and riparian plant association using this map as the stratification; the data collected is used to develop the final riparian classification.

(3) The four-level classification is not limited to developing riparian classifications. For instance, the third and fourth levels might be used for collecting and organizing data for stream classification, classification of landforms and plant associations in upland ecosystems, or for developing models for water/sediment regimes or airsheds.

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