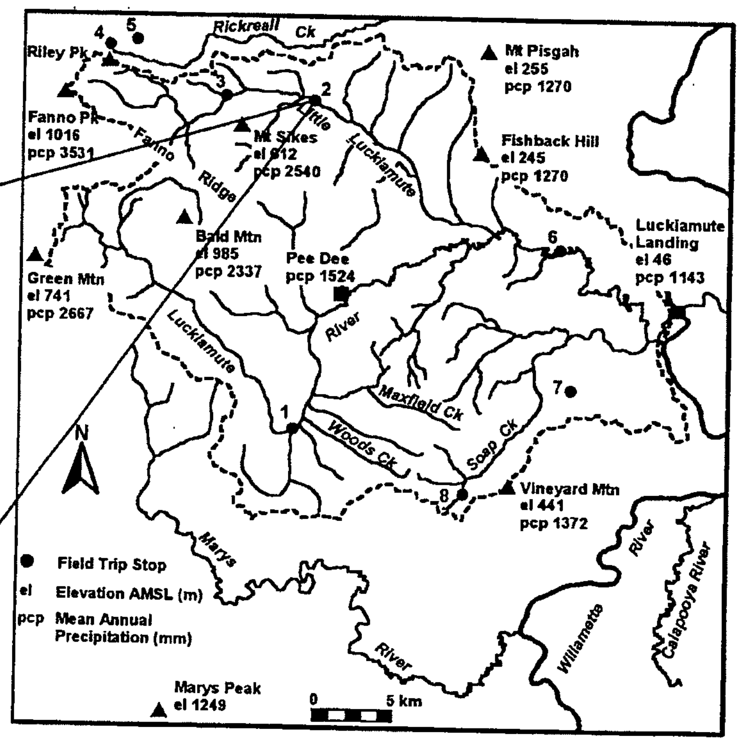
Field Guide to the Luckiamute River Watershed, Upper Willamette Basin



Trip Leaders:

Steve Taylor, Ph.D., Earth and Physical Science Dept., Western Oregon University

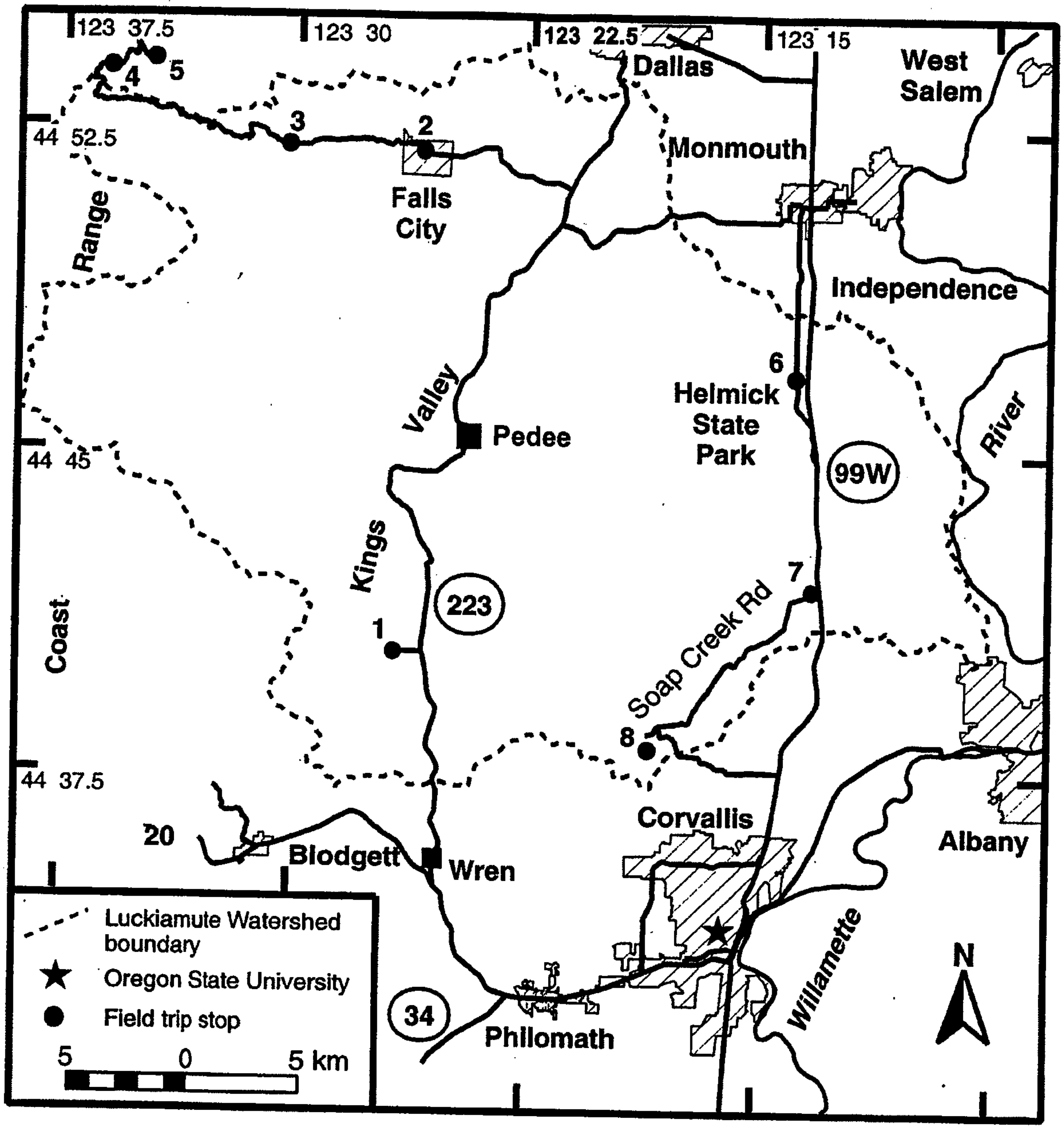


Figure 1. Location map and field trip route for the Luckiamute Watershed.

River to 1016 m (3333 ft) at Fanno Peak. The Luckiamute has an average gradient of 3 m/km, a total stream length of 90.7 km, and an average basin elevation of 277 m (910 ft) (Rhea, 1993; Slack and others, 1993). Fanno Ridge separates the watershed into two tributary subbasins, with the Little Luckiamute to the north and the main stem of the Luckiamute to the south (Kings Valley) (Fig. 2). Lower-order tributaries include Boughey Creek, Waymire Creek, Vincent Creek, Plunkett Creek, Woods Creek, Maxfield Creek, and Soap Creek.

The greater Willamette Valley extends northward 190 km from Eugene to Portland, Oregon. This lowland is up to 60 km wide, separating the Coast Range to the west from the Cascade Range to the east. Valley floor elevations range from 150 m (500 ft) to 3 m (10 ft), with an average gradient of 2 m/km (Slack and others, 1993).

Physiographic Setting of the Luckiamute Watershed

- Boundaries
  - Crest of Coast Range to West (headlands)
  - Willamette River to East

- Drainage Area = 815 km^2

  - Largest Fifth-Field Watershed in central and northern Coast Range

  - Primary Tributaries
    - Little Luckiamute – northern watershed
    - Luckiamute – southern watershed

  - Secondary Tributaries
    - Soap Creek, Maxfield Creek, Woods Creek, Teal Ck

- Elevation Range:
  - Min: 46 m (150 ft) at Willamette
  - Max: 1016 m (3333 ft) at Fanno Peak
  - Avg. Basin Elevation: 277 m (910 ft)

- Basin Morphometry
  - Average Stream Gradient: 3 m /km
  - Total Stream Length: 90.7 km

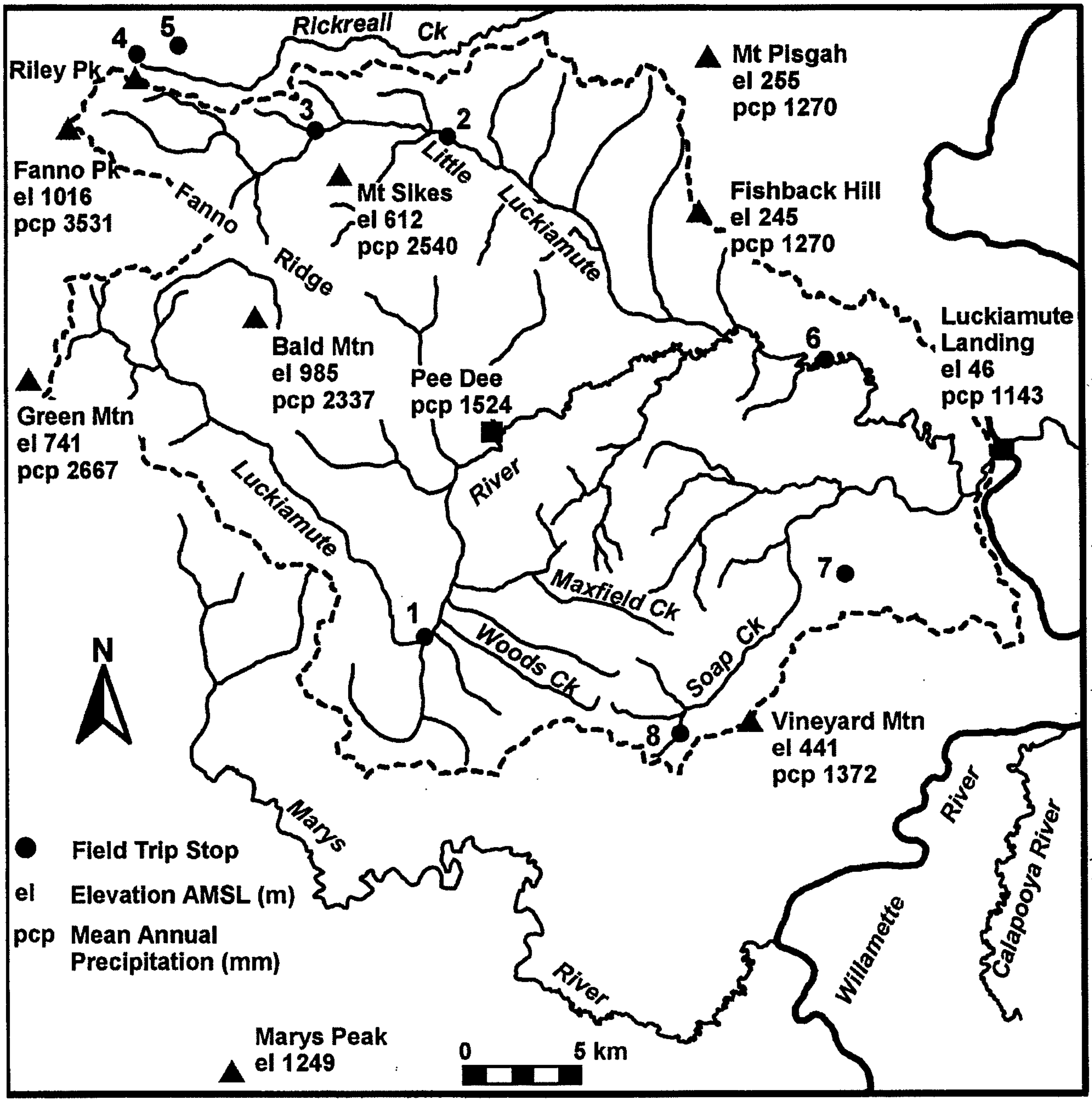


Figure 2. Physiographic map and spot annual precipitation for the Luckiamute Watershed.

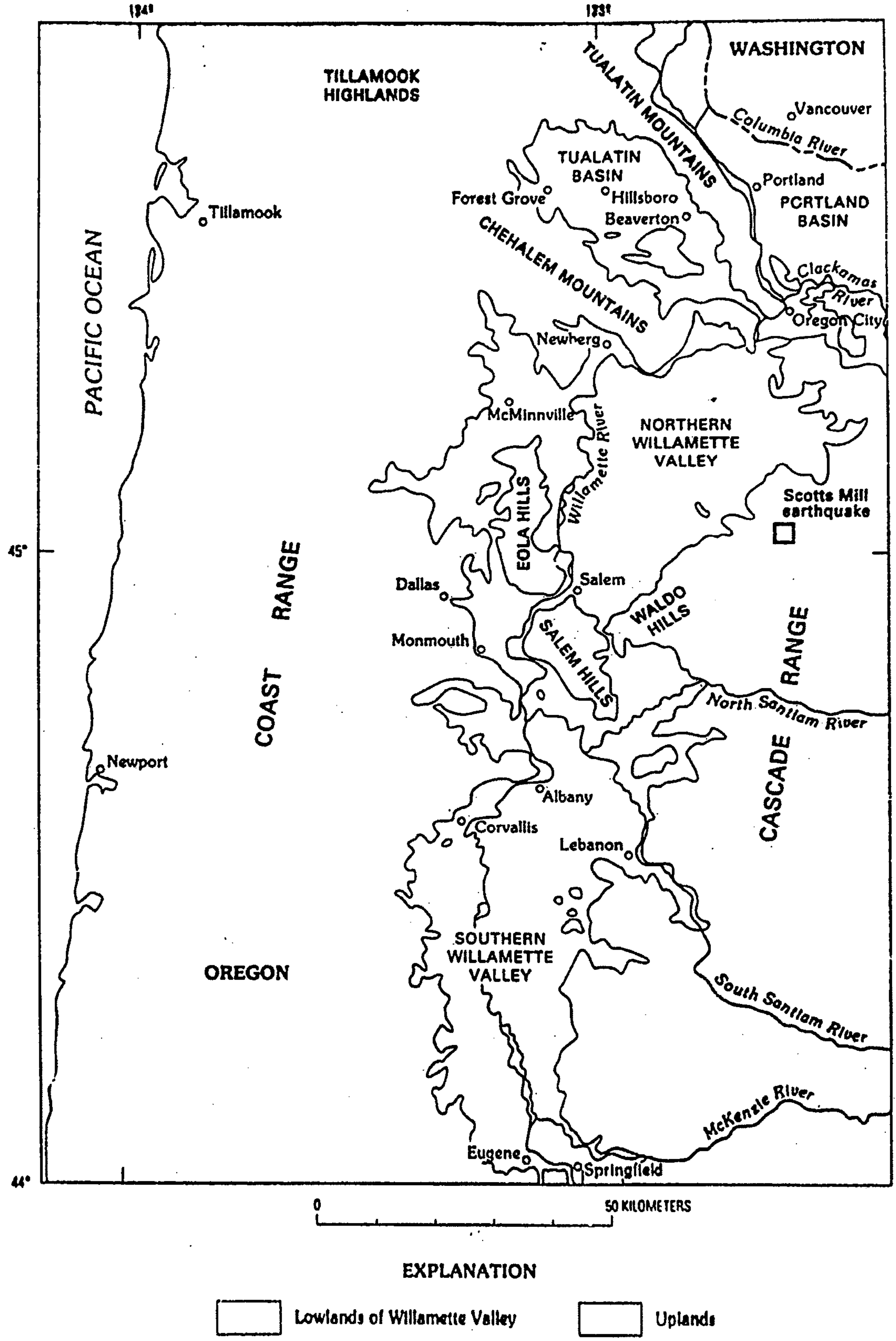


Figure 77. Geographic and physiographic features of the Willamette Valley and Portland and Tualatin basins, northwestern Oregon. The square indicates the epicenter of the March 25, 1993, Scotts Mills earthquake.

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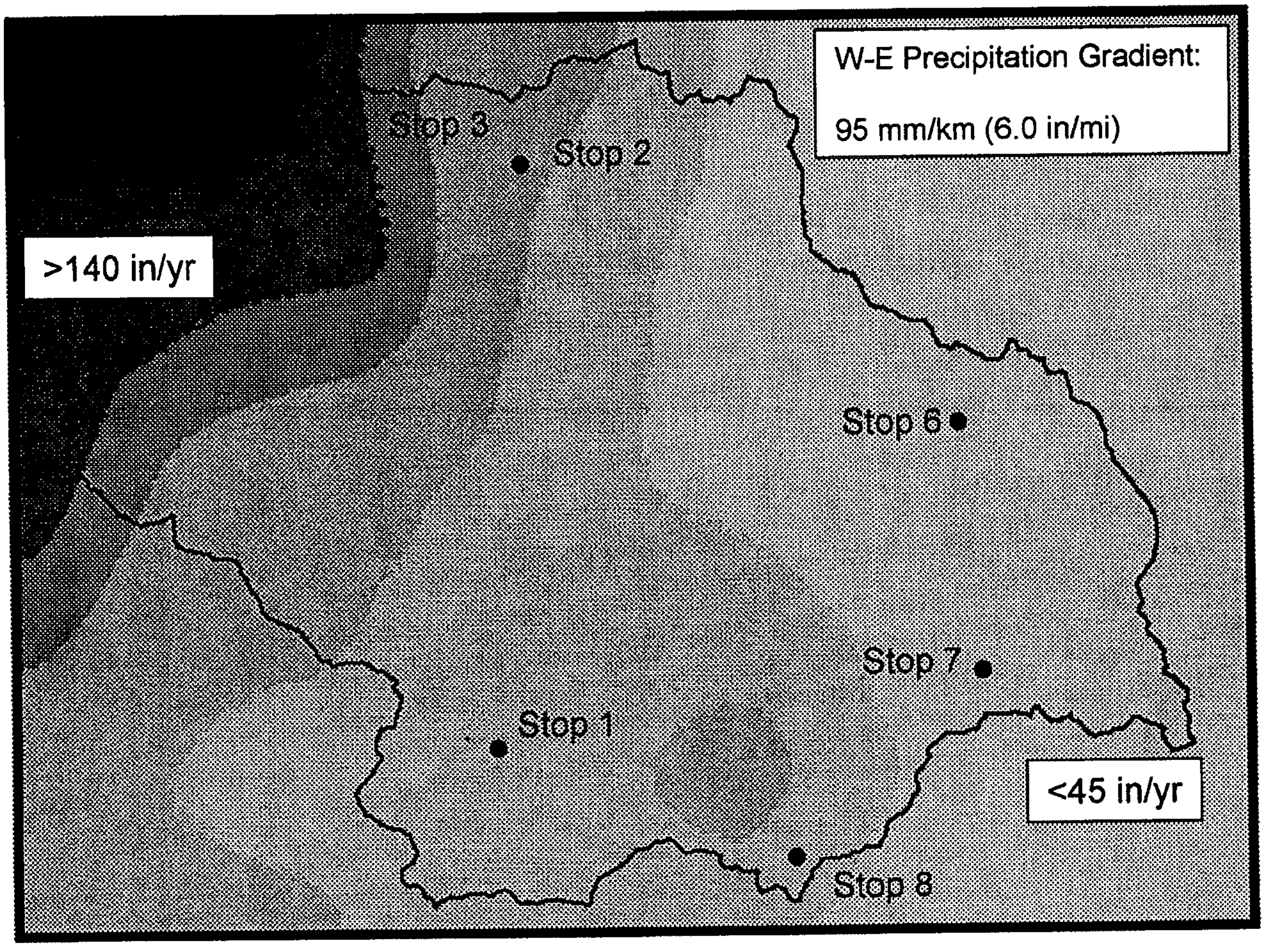
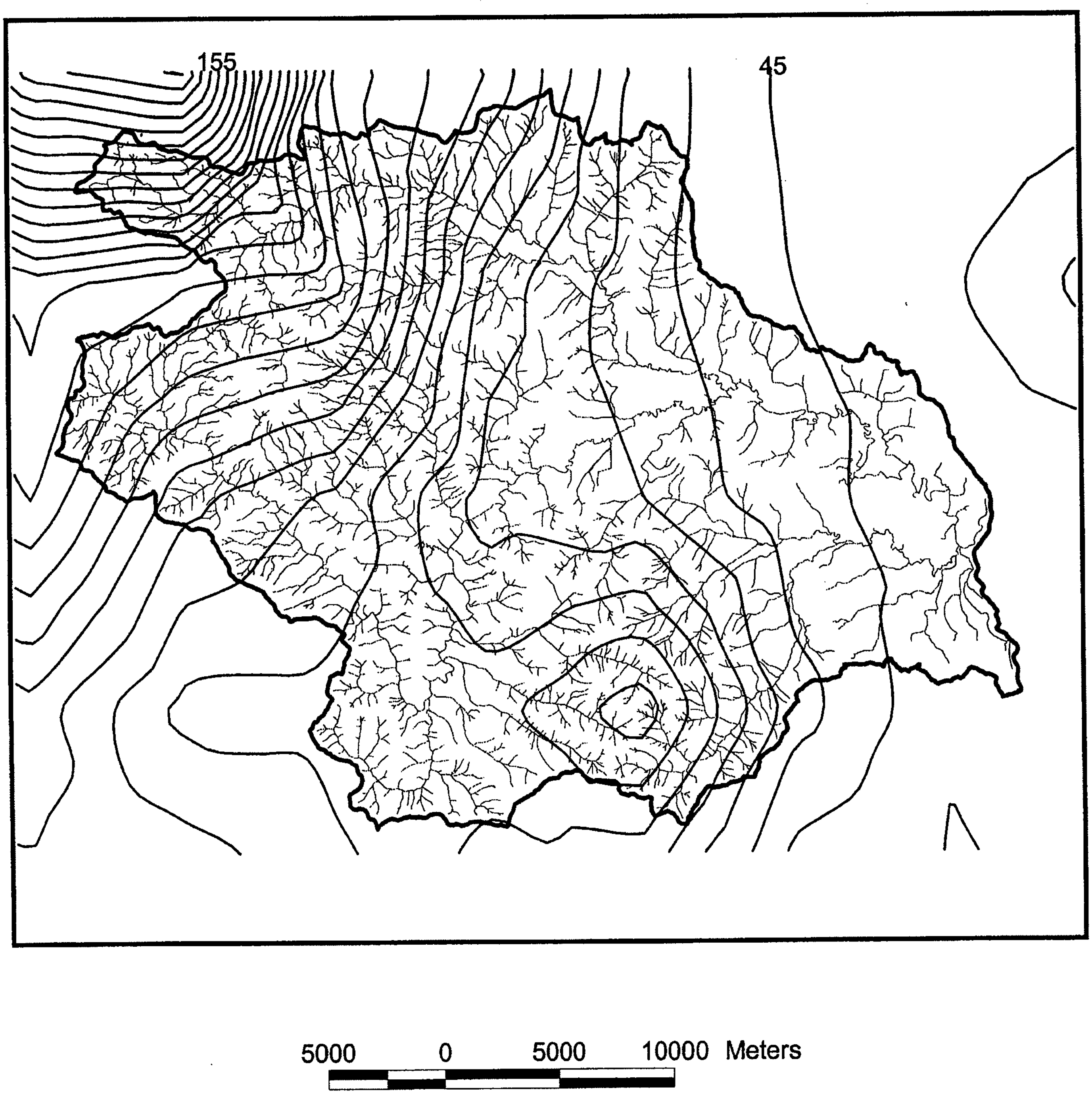


1990 Average Annual Precipitation for the Luckiamute Watershed (inches) (from the Oregon Climate Service)

Annual Precipitation
- Basin Maximum: 3600 mm (>140 in) – Divide
- Basin Minimum: 1140 mm (~45 in) – Willamette Valley
- Basin-wide Precipitation Average = 1894 mm (~75 in)
- Seasonal Precipitation Cycle (October – March)

Luckiamute Basin Avg. Annual Rainfall (CI = 5 inches /yr)



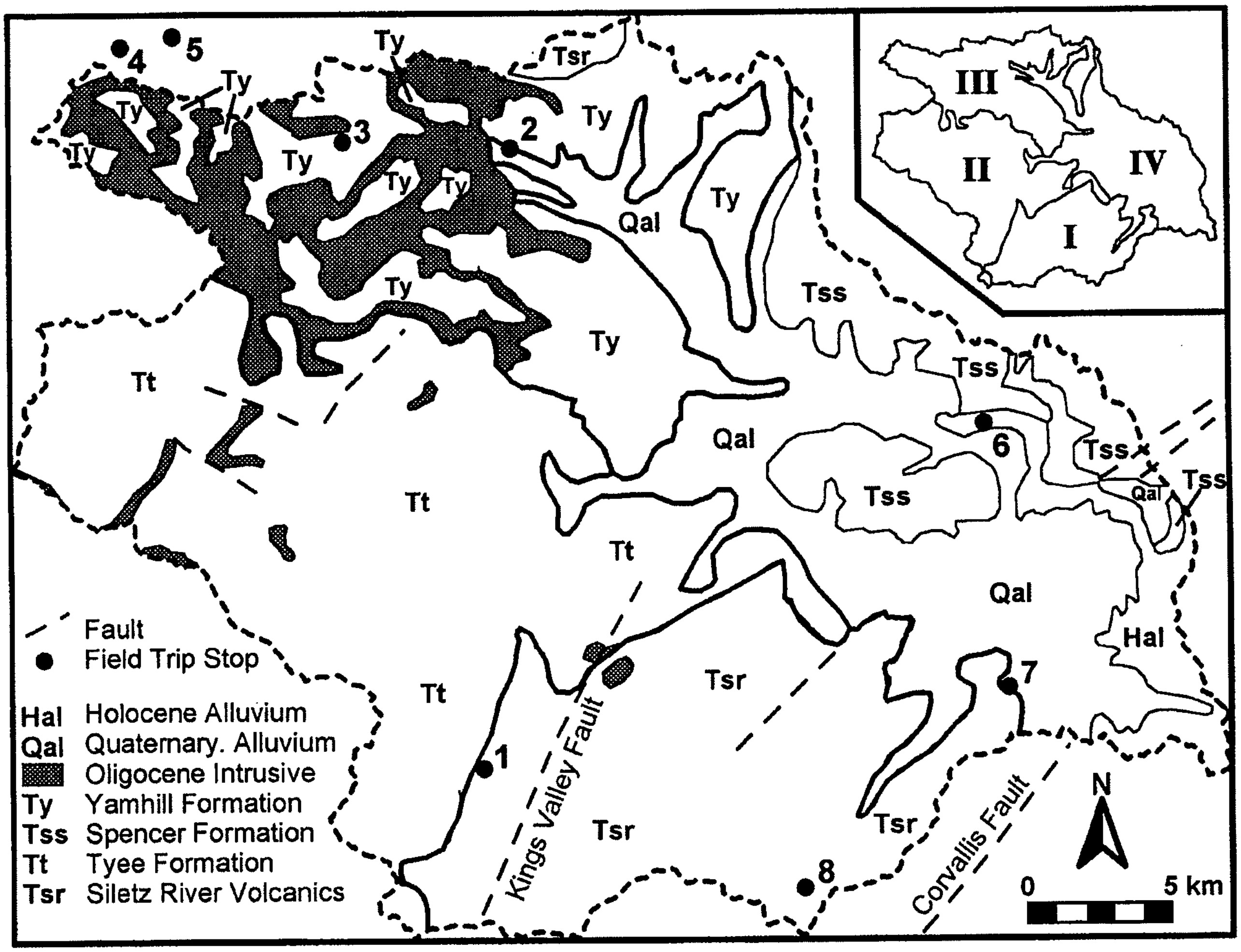


Figure 3. Bedrock geology of the Luckiamute Watershed (after Walker and MacLeod, 1991). Inset map shows grouping of recognized lithospatial domains: I = Siletz River Domain, II = Tyee Domain, III = Yamihill-Ti (Tertiary Intrusive) Domain, IV = Spencer-Valley Fill Domain.

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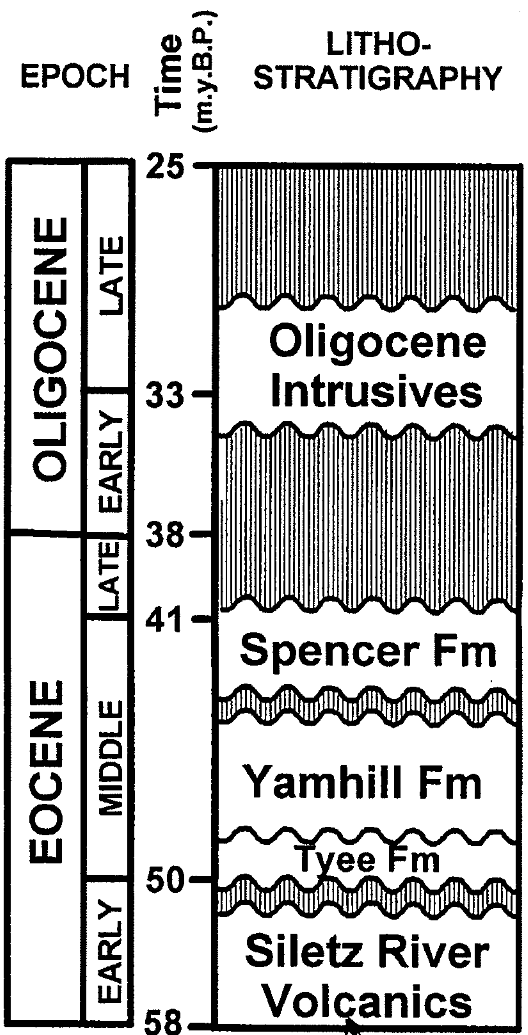
Bedrock Geology of the Luckiamute Watershed



Qal – Quaternary Alluvium

Ti – Oligocene Mafic Intrusives: Sheets, sills, and dikes of massive gabbro.

Tss – Spencer Formation: Thick- to thin-bedded marine tuffaceous sandstone, siltstone, and mudstone.

Ty – Yamhill Formation: Massive to thinly bedded marine silstone and sandtone interbeds. Locally includes interlayered basalt lava flows.

Tt – Tyee Formation: Rhythmically bedded, medium-grained feldspathic sandstone and carbonaceous siltstone. Interpreted as deposits of submarine turbidity currents and fans.

Tsr – Siletz River Volcanics: Aphanitic to porphyritic, vesicular pillow flows, tuff breccia, and lava flows. Local interbeds of basaltic siltstone and sandstone. Prevasively zeolitized and veined with calcite. Marine origin interpreted as accreted oceanic crust and seamounts.

Spencer rolling hills

Steep hills [illegible]

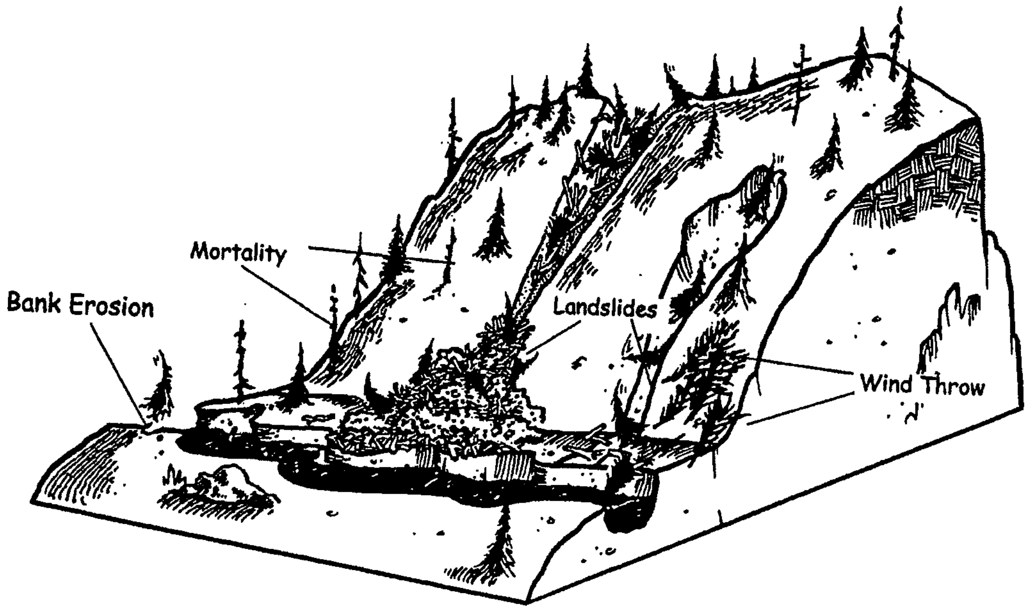
w/ both @ same elevation
- means [illegible]
uplift [illegible]

Flat floor [illegible] - Maulla[illegible] - [illegible]
Mayola [illegible]

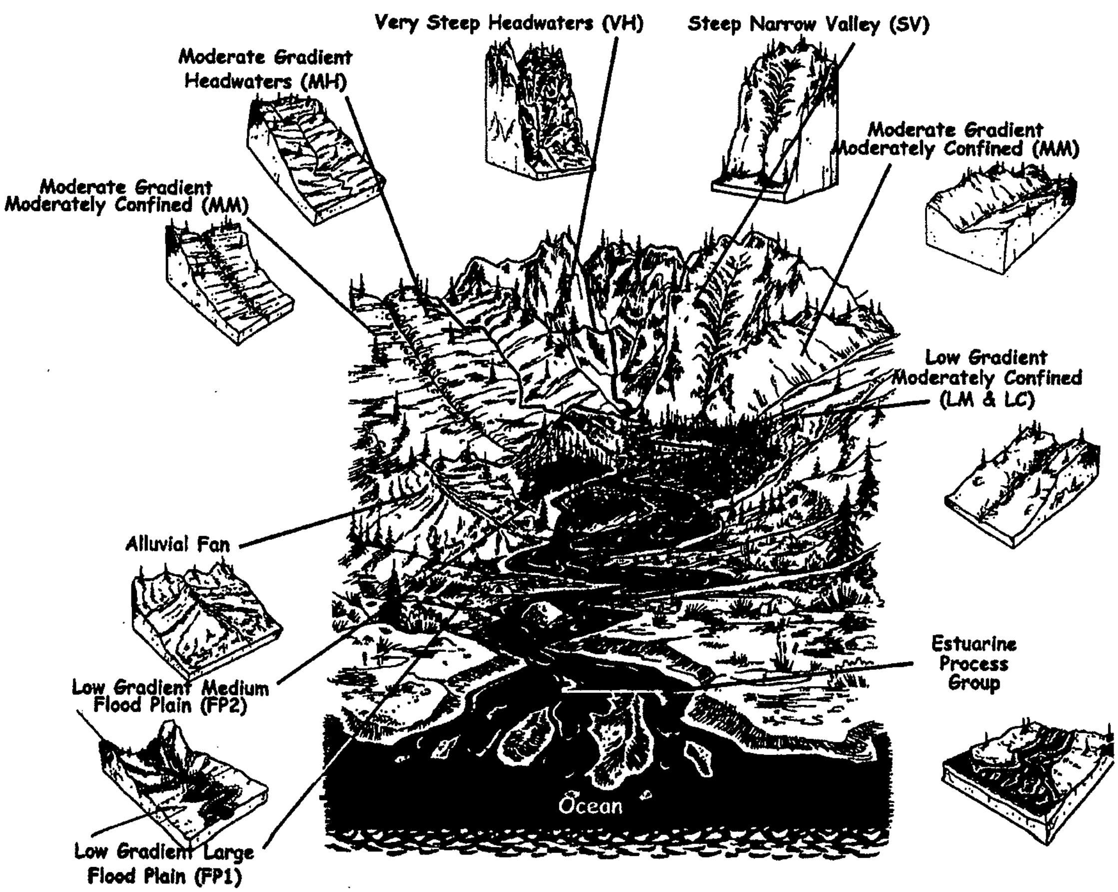
Geomorphology of the Luckiamute Watershed

Valley Floor-Fluvial Regime
- Landforms
  - Channel
  - Floodplain
  - Terrace
  - Small-scale Fans
  - Strath-pediment surfaces
  - Low-relief colluvial hillslopes (Spencer Fm)
- Deposits
  - Alluvial Fill (sorted sand and gravel)
  - Debris Flow Deposits (diamicton)
  - Slackwater Silts and Clay
- Processes
  - Channel Transport
  - Overbank Sedimentation

- Hillslope-Colluvial Regime
  - Landforms
    - Ridge tops
    - Hillslopes-Sideslopes
    - Hollows
    - Pediment Surfaces
  - Deposits
    - Colluvium (gravel diamicton)
    - Residuum (gravel diamicton)
  - Processes
    - Collvial Creep
    - Debris Slide / Flow
    - Tree-throw / Bioturbation



Geomorphic configuration of mountainous watersheds in the Coast Range.



Typical distribution of CHTs in a mountainous watershed.

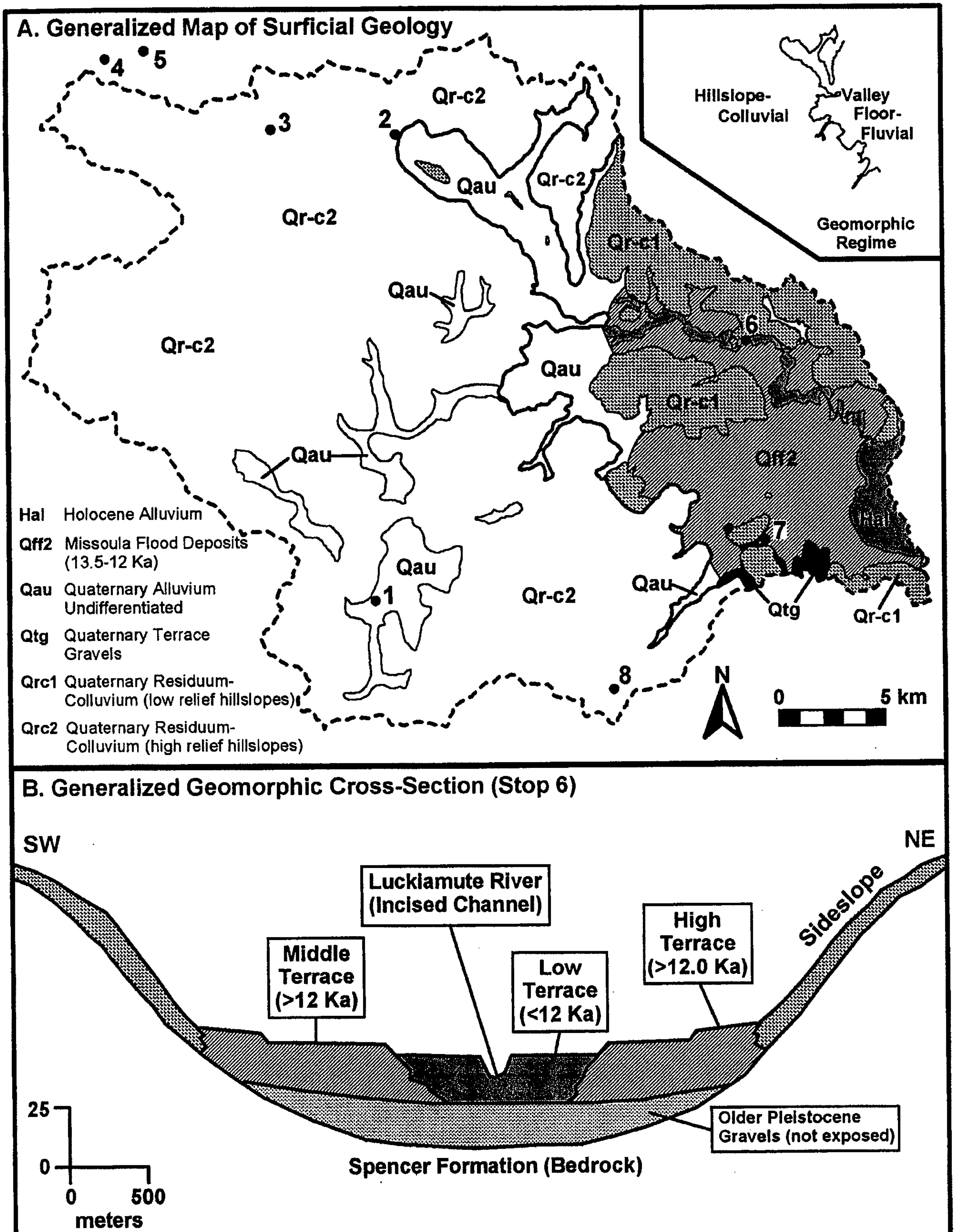
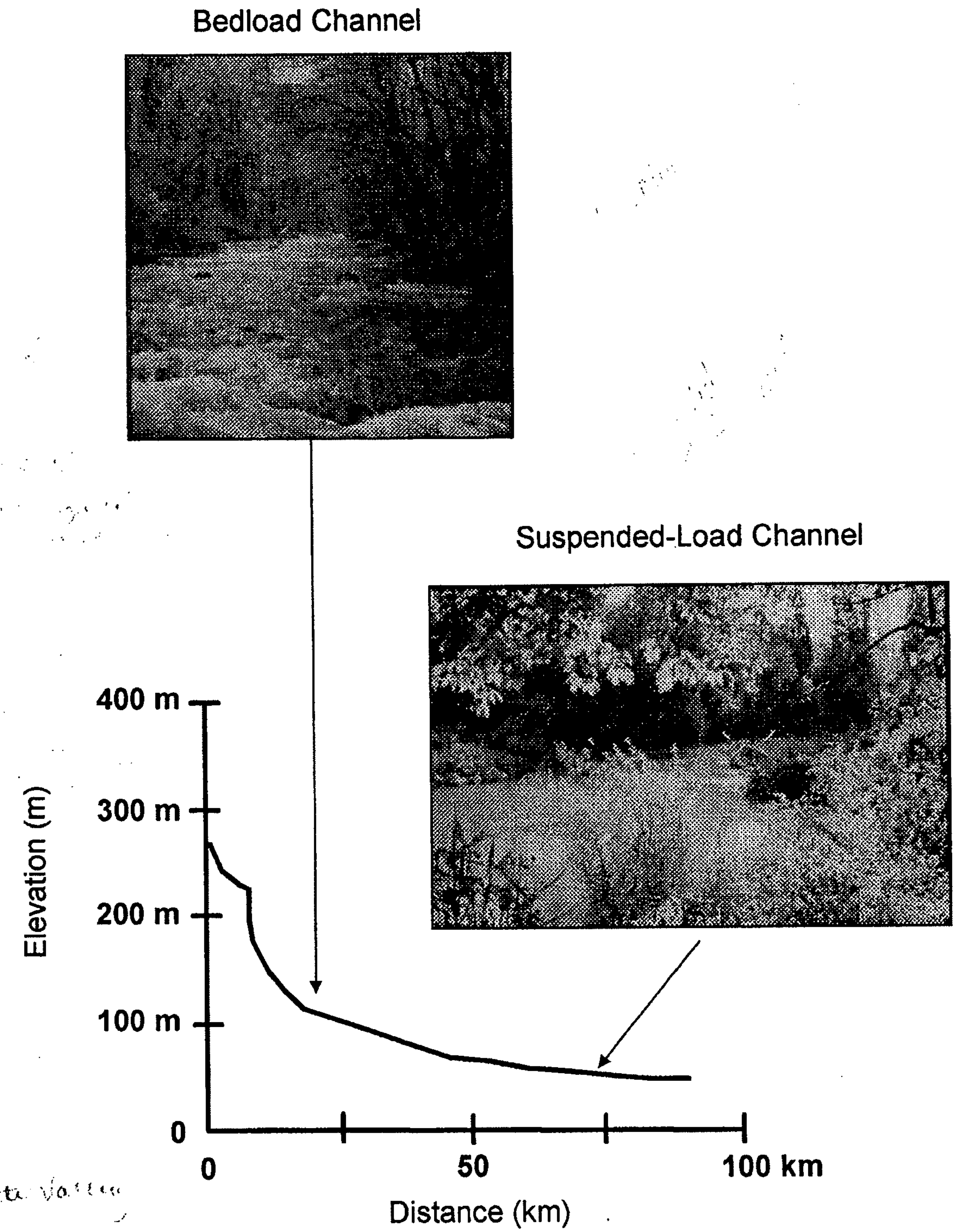
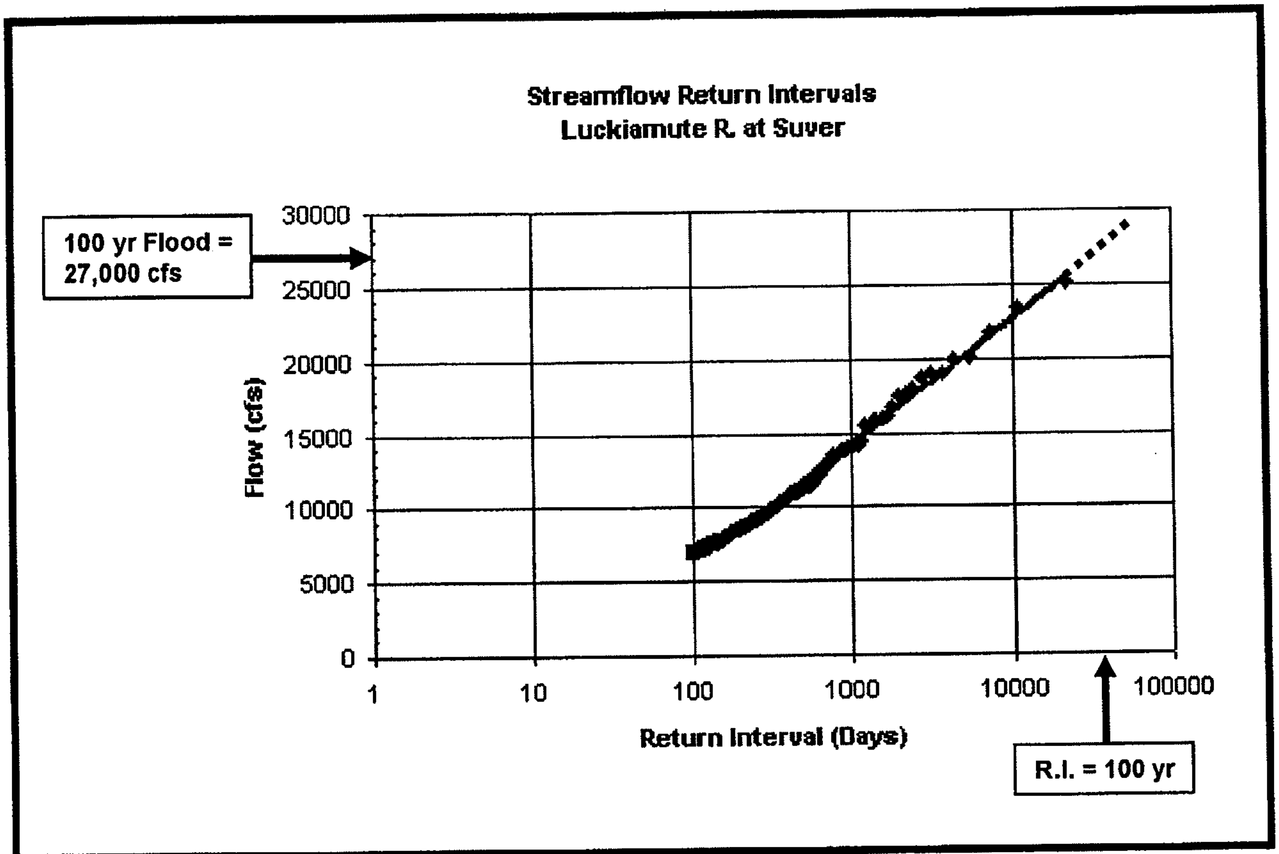
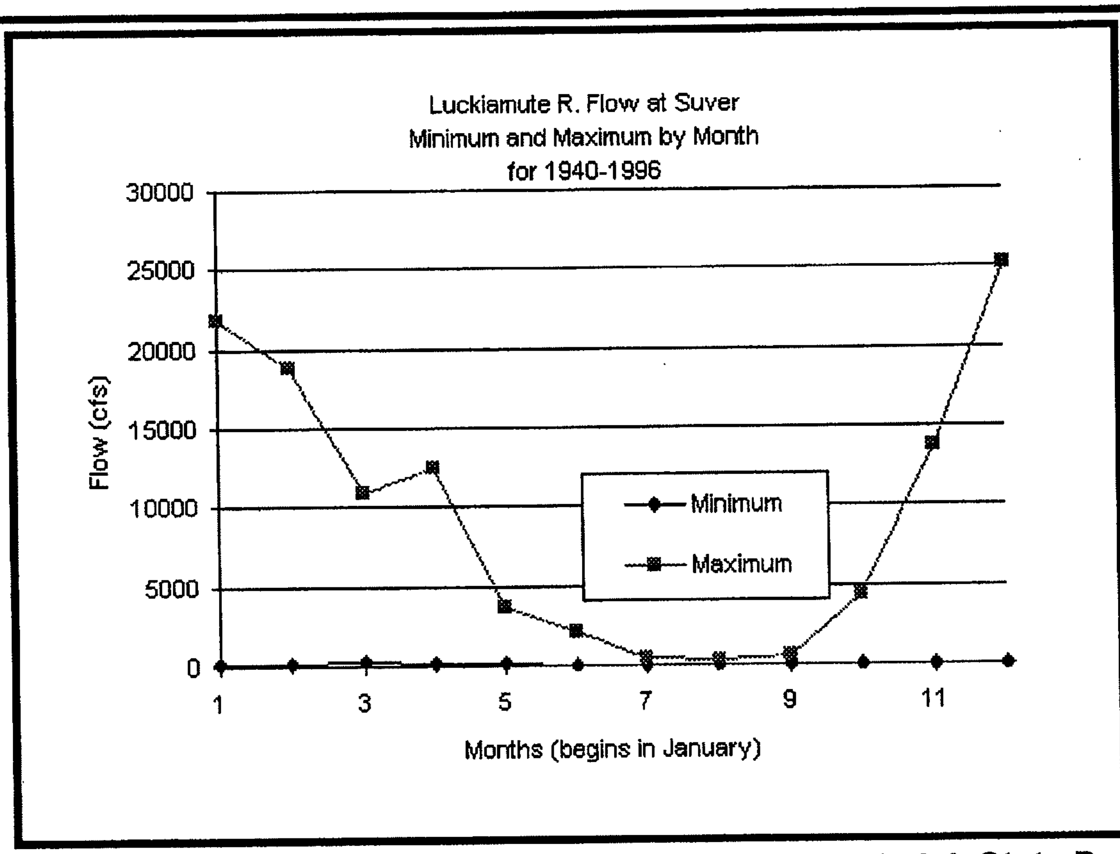


Figure 4. Surficial geology and geomorphology of the Luckiamute River Basin. Surficial map units are modified from O'Connor and others (2001), after Taylor and others (1996). Cross section shown in frame B represents generalized landform elements at Helmick State Park (Stop 6).

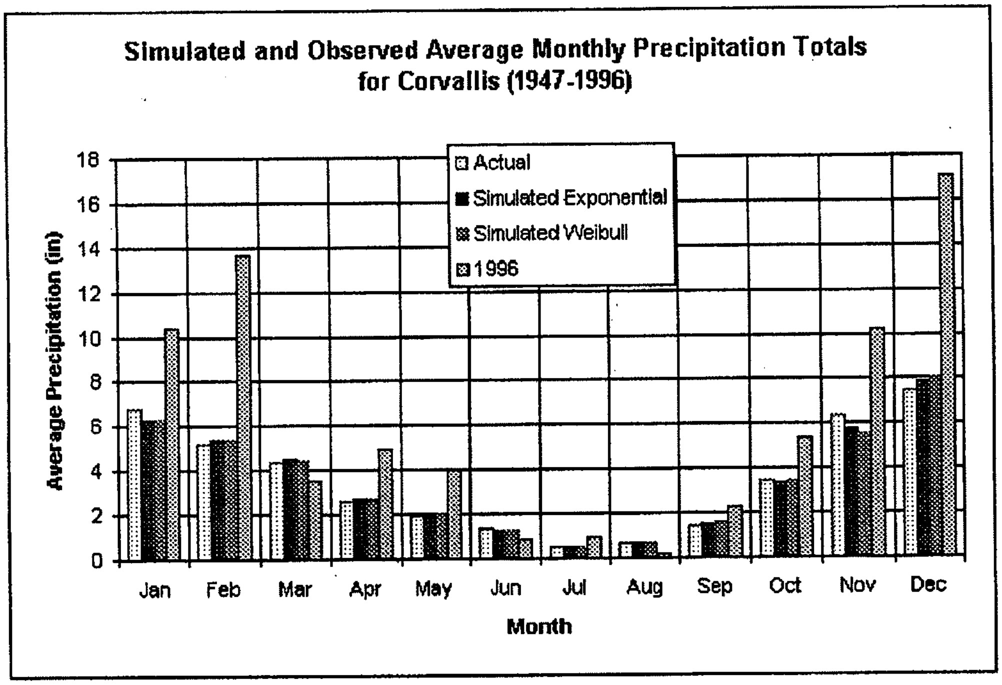


Longitudinal profile along the Luckiamute River (from Rhea, 1993).
Photos from Waichler and others (1997).





Discharge characteristics for Luckiamute River, Helmick State Park (from Waichler and others, 1997).



(Waichler and others, 1997)

Water Balance of Luckiamute Watershed

Period (1961-1990)	Mean Precipitation (mm)	Precip. (Input) (m^3)	Observed Mean Discharge (cfs)	Observed Total Discharge (m^3)	Difference (Precip-Discharge) (m^3)	Difference as % of Precip. ("%LOSS")
Annual	1894	1.23E+09		7.55E+08	4.77E+08	39%
Jan	335	2.18E+08	2232.146	1.69E+08	4.86E+07	22%
Feb	258	1.68E+08	1853.276	1.27E+08	4.09E+07	24%
Mar	216	1.41E+08	1472.097	1.12E+08	2.89E+07	21%
Apr	101	6.57E+07	795.9956	5.84E+07	7.27E+06	11%
May	51.9	3.38E+07	396.072	3.00E+07	3.72E+06	11%
Jun	41.7	2.71E+07	188.61	1.38E+07	1.33E+07	49%
Jul	11.3	7.35E+06	71.32473	5.41E+06	1.94E+06	26%
Aug	23.8	1.55E+07	37.25441	2.83E+06	1.27E+07	82%
Sep	50.3	3.27E+07	49.19311	3.61E+06	2.91E+07	89%
Oct	143	9.30E+07	124.4226	9.44E+06	8.36E+07	90%
Nov	284	1.85E+08	904.1411	6.64E+07	1.18E+08	64%
Dec	378	2.46E+08	2069.228	1.57E+08	8.89E+07	36%

Water budget for Luckiamute Watershed (Waichler and others, 1997)

En Route to Stop 6

- •Drive from Falls City, out of Yamhill-Intrusive Domain, into Spencer Fm-Valley Fill Domain (refer to Figure 3, p. 10)

- •Note change in land use from forestry to agriculture

- •Stop at Western Oregon University, Natural Sciences Building, for brief slide show discussion of the Polk County Flora Project and Interactive Flora Identification Key

Stop 6. Helmick State Park

- •Physiographic Location
  - •Lower Luckiamute River, 18 km upstream from watershed outlet into the Willamette River

- •Bedrock and Surficial Geology
  - •Stop is located in the Spencer Fm-Valley Fill lithospatial domain (Figure 3, p. 10)
  - •Note incised channel characteristics and low terraces

- •Content Piece – Field Botany and Flood Hydrology
  - •Field Botany
    - •Participants are provided an opportunity to use Dutton's interactive flora identification key
  - •Flood Hydrology
    - •USGS Suver Gaging Station
    - •Recurrence intervals and seasonal discharge patterns (p. 32)
    - •Paleoflood hydrology

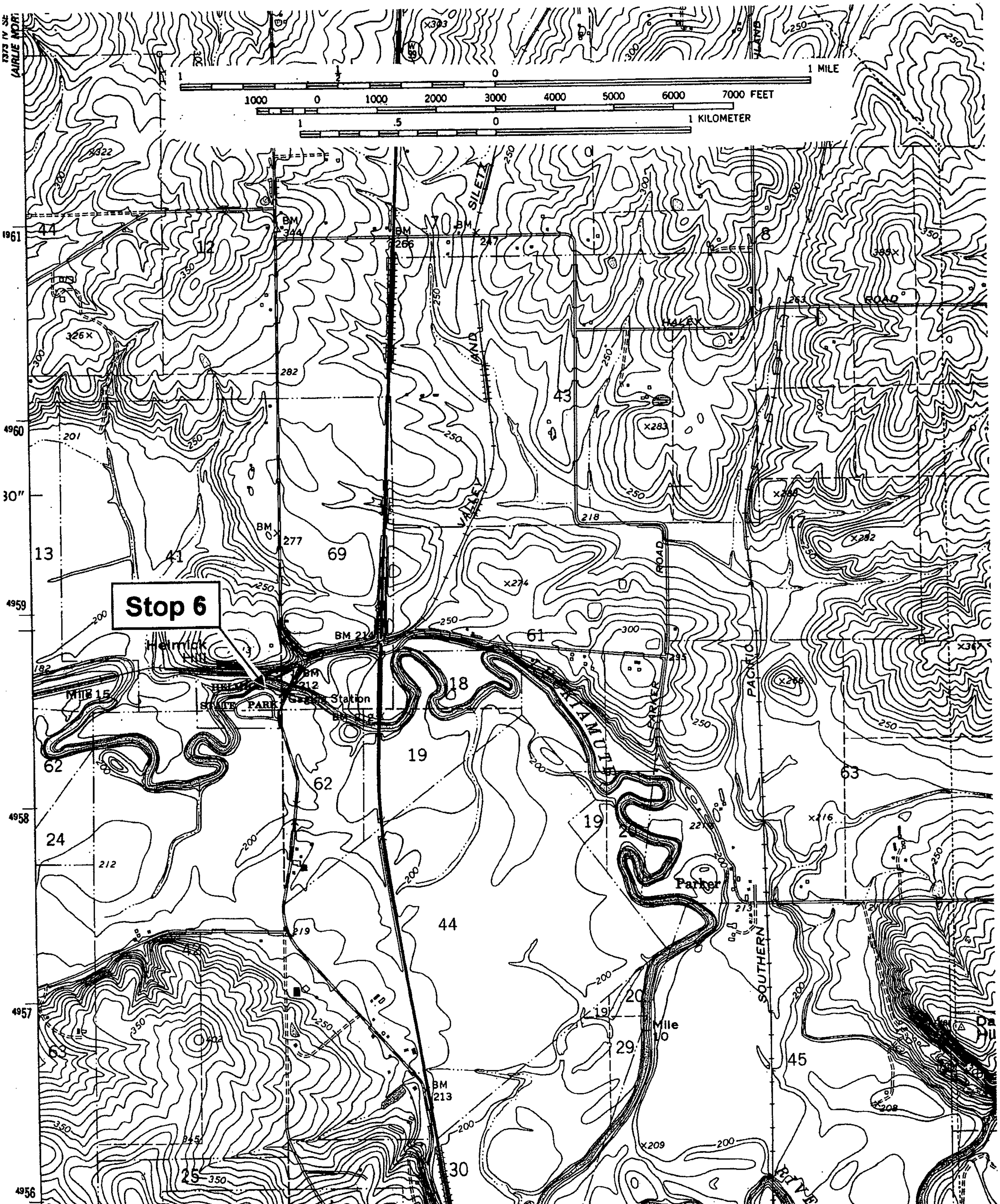
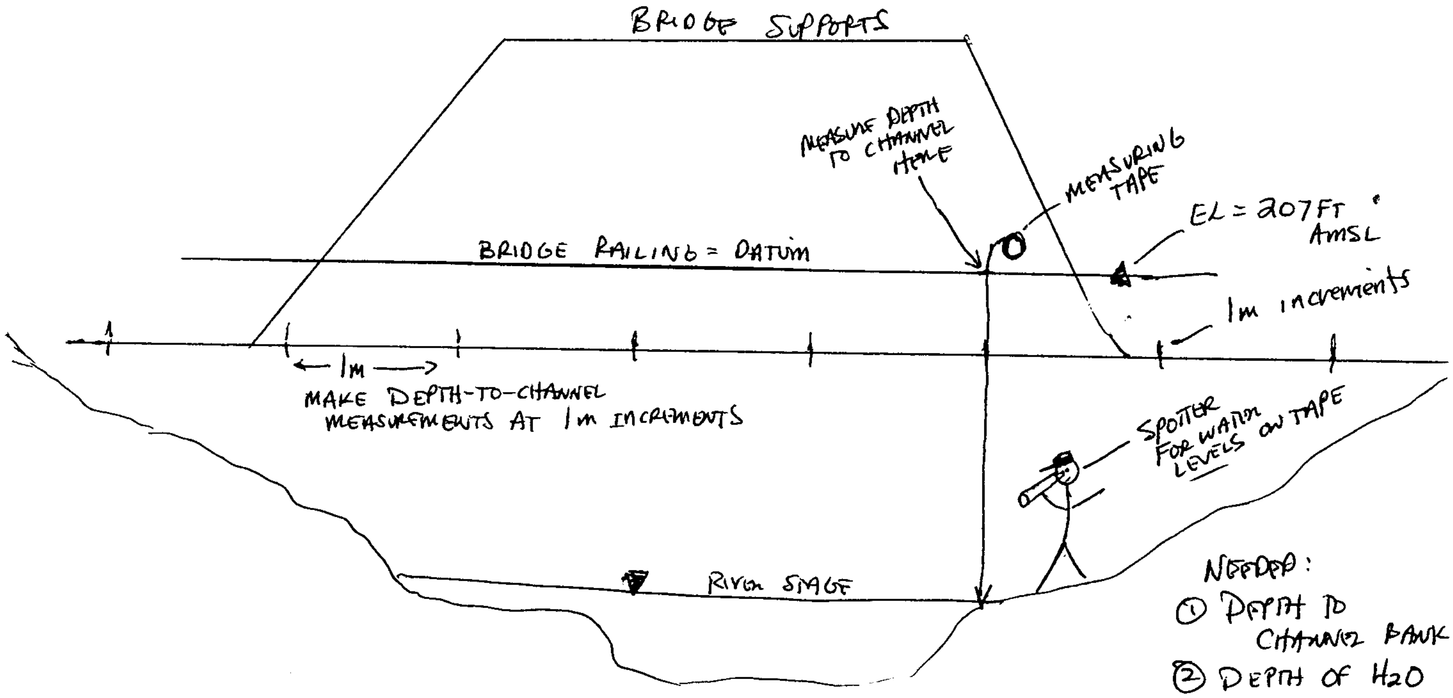
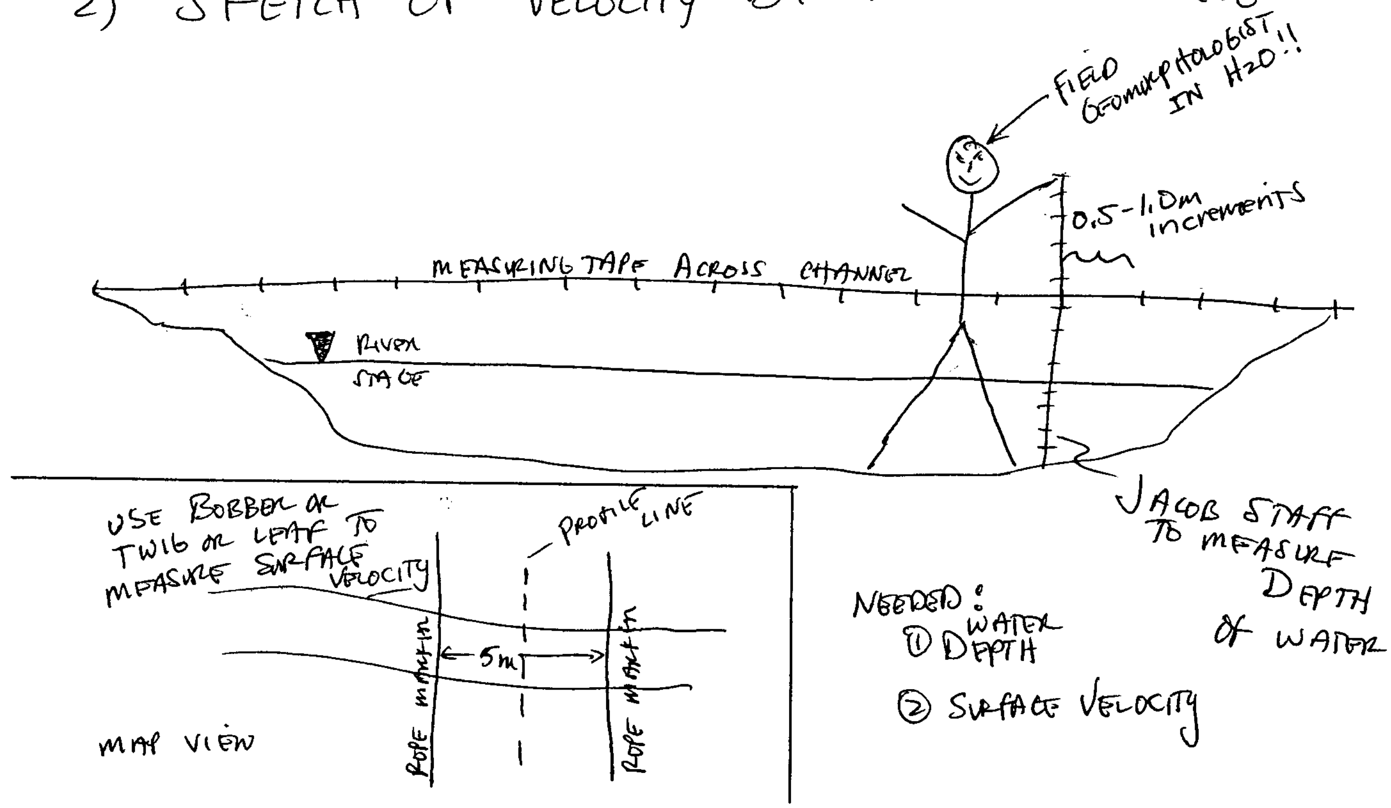

Stop 6
1 MILE
7000 FEET
1 KILOMETER
Helmick Hill
Mile 15
STATE PARK
Parker
SILETZ
VALLEY
ROAD
PARKER
PACIFIC
SOUTHERN
RIVER
Mile 10

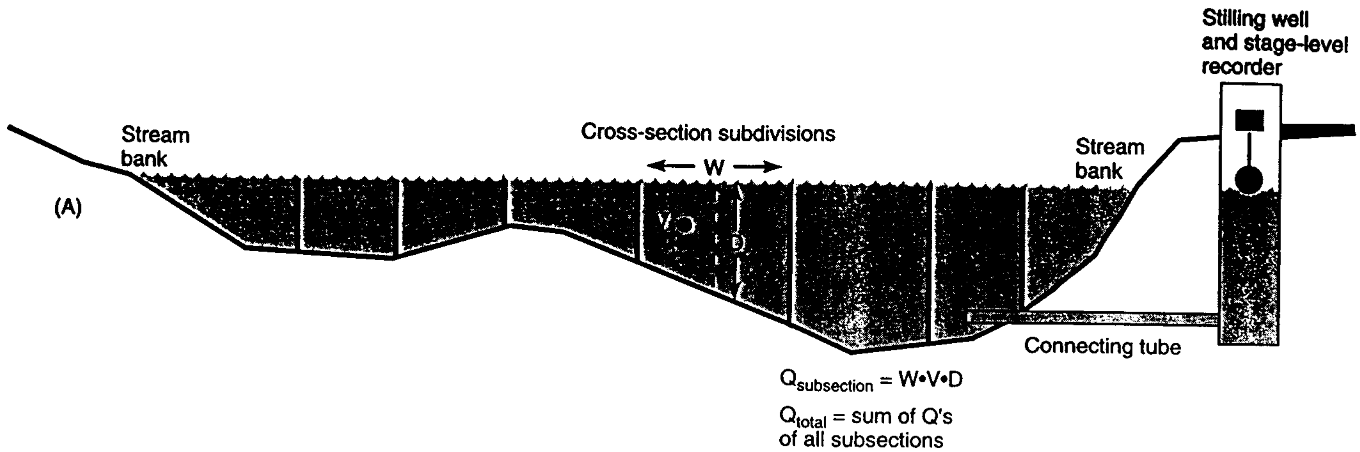
FIGURE 1

1) SKETCH OF VALLEY PROFILE TECHNIQUE



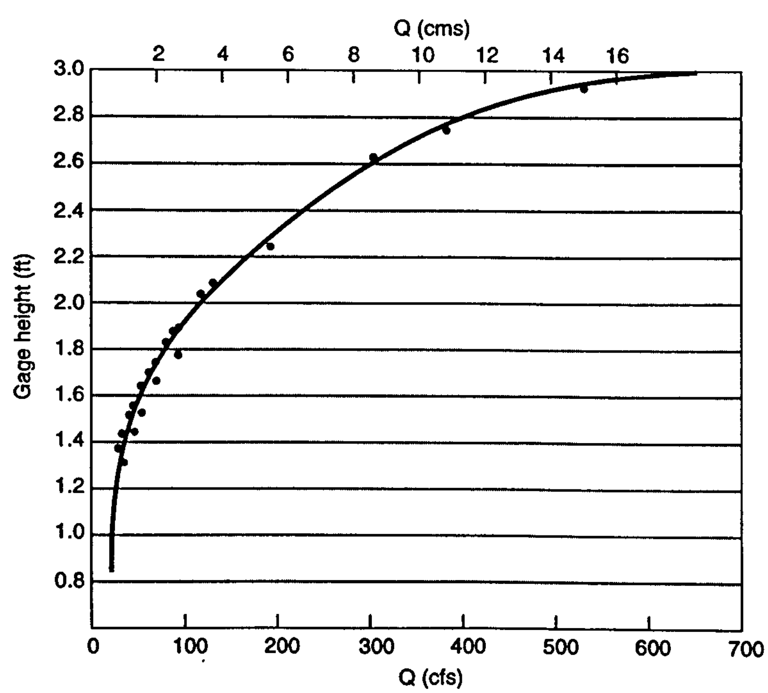
2) SKETCH OF VELOCITY-DISCHARGE TECHNIQUE





(D)

FIGURE 5.33
Rating curve for low flow. Rock Creek near Red Lodge, Mont.



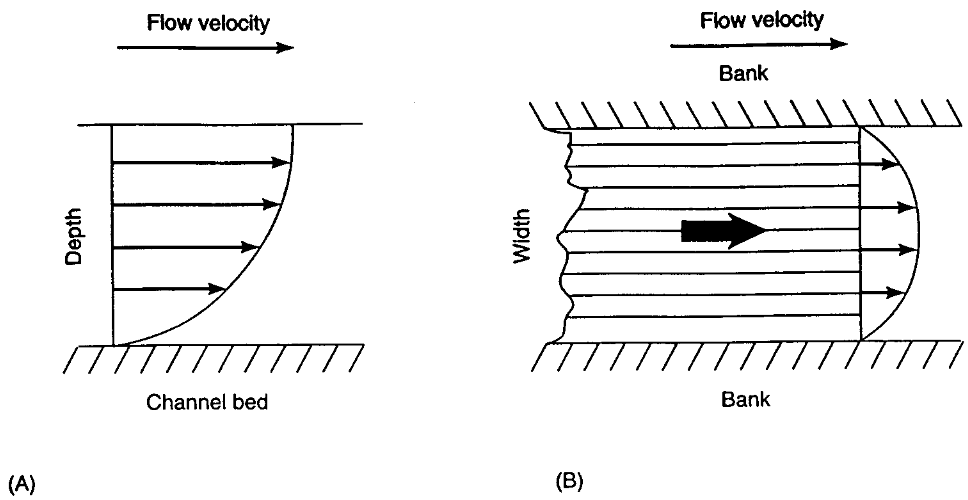
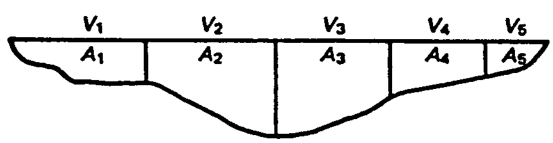


FIGURE 6.1
Diagram showing the changes in flow velocity with (A) flow depth and (B) flow width. Resistance to flow along the bed and banks allows the greatest velocities to occur toward the center of the channel near the water surface.



subareas of velocity domains.

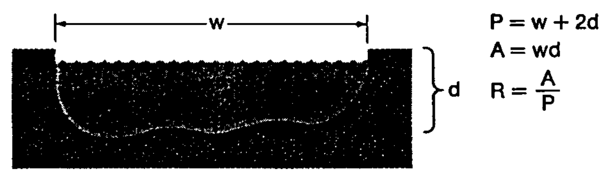


FIGURE 6.2
Cross-sectional measurements of a stream channel: w = width, d = depth, A = area, R = hydraulic radius, P = distance along wetted perimeter.

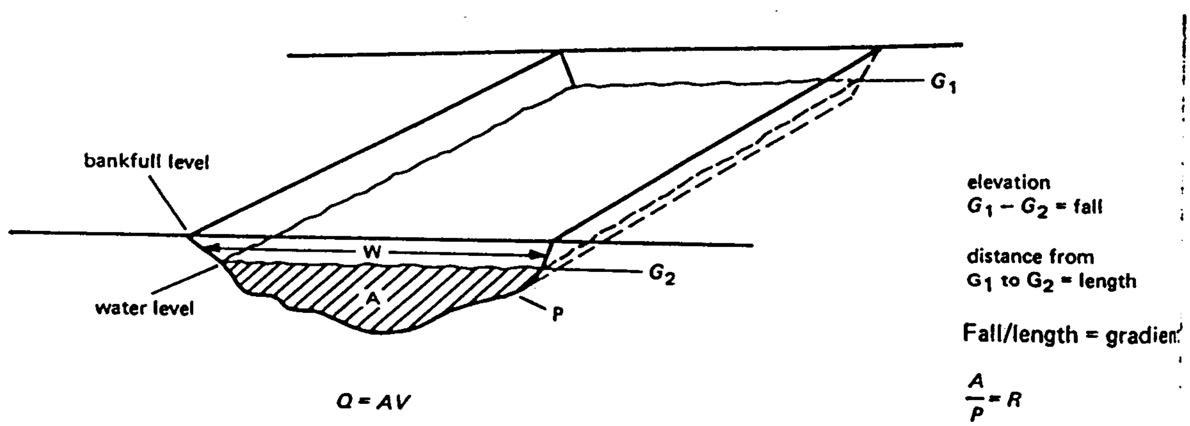


Figure 9.2. Nomenclature of channel morphology.

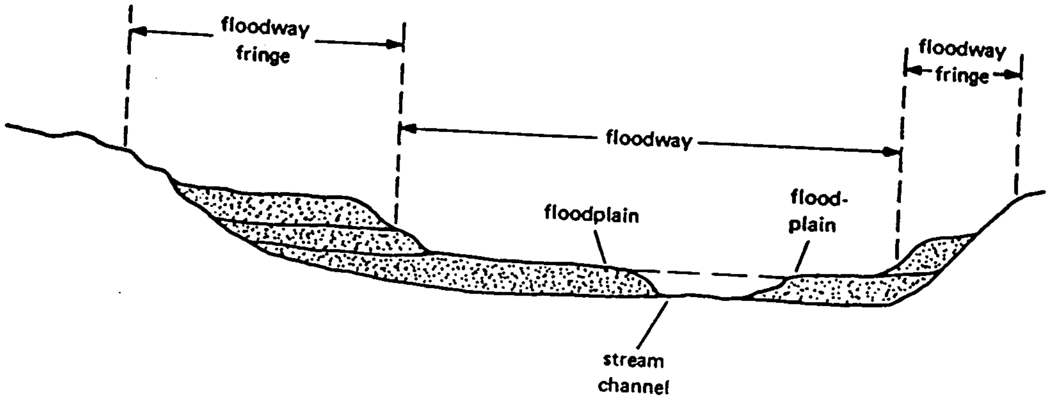


Figure 11.1. View across a river. The floodway is the area along the river which is frequently flooded, an area over which the flood discharge moves with great velocity. The floodway fringe includes areas which are further from the actual channel and which are infrequently flooded by rare events. The floodway fringe is that area flooded by the "100-year" flood.

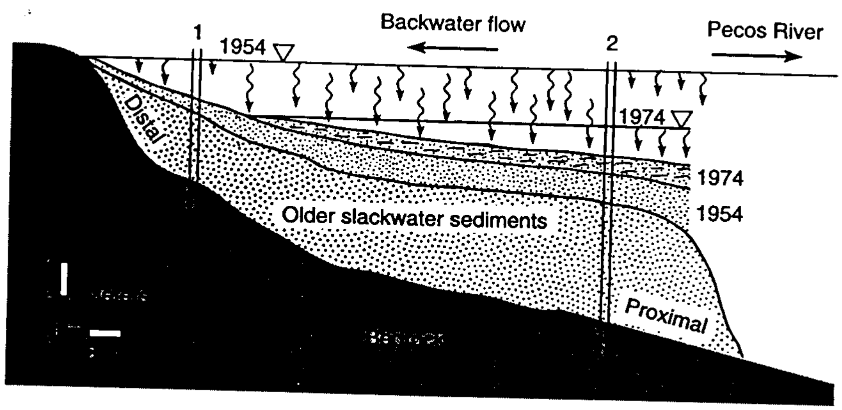


FIGURE 5.37

Schematic of on- and off-lap sequences and peak flood stage in a tributary valley for the 1954 and 1974 floods on the Pecos River, Texas. Sections in the proximal region (area 2) contain both floods, while distal regions (area 1) farther up the tributary record only the larger 1954 flood. Paleostage reconstructions are based on the elevation of the most distal sediments of each flood unit.

(Kochel et al. 1982)

#	Out		Minute (C)	(v)	#	Out		Minute (C)	(v)
1					51				
2					52				
3					53				
4					54				
5					55				
6					56				
7					57				
8					58				
9					59				
10					60				
11					61				
12					62				
13					63				
14					64				
15					65				
16					66				
17					67				
18					68				
19					69				
20					70				
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31					81				
32					82				
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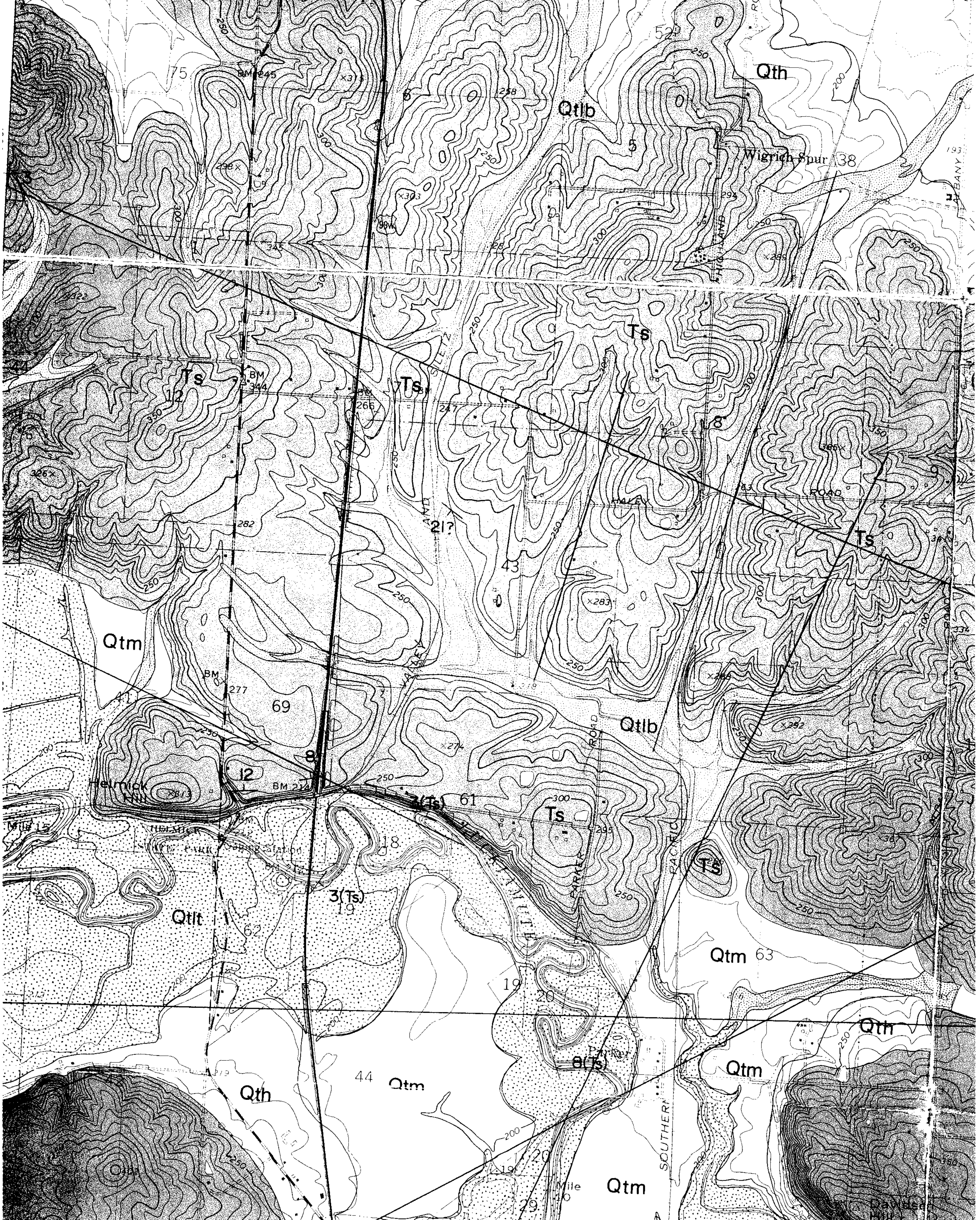
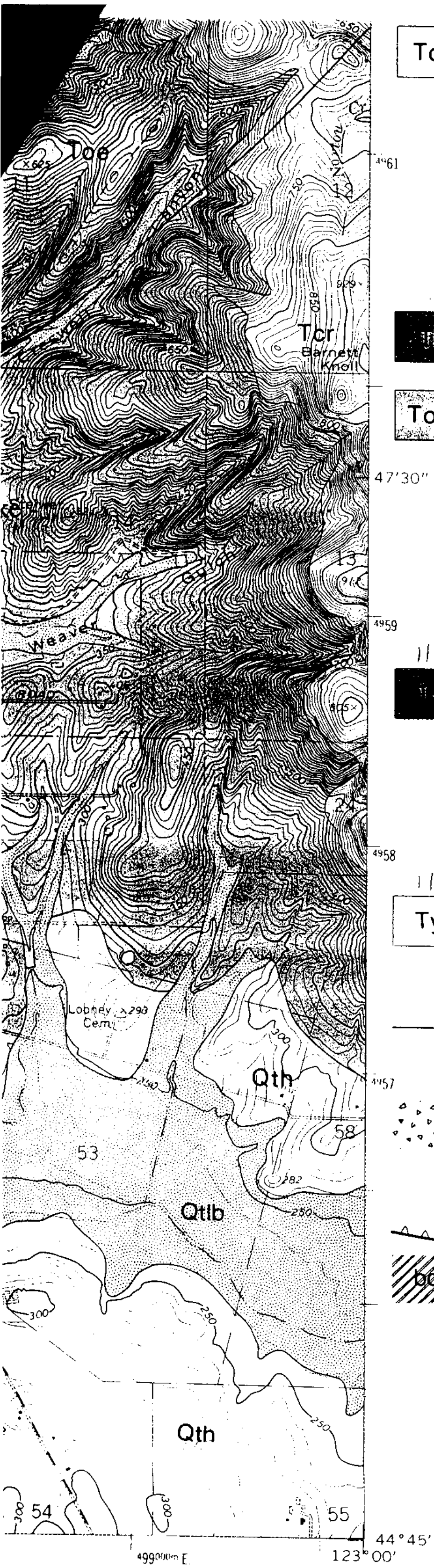
34					84				
35					85				
36					86				
37					87				
38					88				
39					89				
40					90				
41					91				
42					92				
43					93				
44					94				
45					95				
46					96				
47					97				
48					98				
49					99				
50					100				

V.1 For use with the MJP Flowmeter for Stream Velocity
(users may copy this sheet)


Qth
Qtlb
Wigrich Spur
Ts
Qtm
Helmick Hill
Qtlt
Parker
Dawson Hill
SOUTHERN PACIFIC
PARKER ROAD
3(Ts)
8(Ts)
21?



Tcr

Columbia River Basalt Group (Miocene): *Medium-gray to black, fine-grained, even-textured to slightly porphyritic basalt; unweathered flows generally dense, fairly crystalline, exhibiting massive columnar jointing near base to diced or hackly jointing in entablature. Unit consists of weathered and unweathered basaltic lava flows with interflow zones characterized by vesicular flow-top breccia, ash, and baked soils. Maximum thickness generally ranges 400-600 ft, with thickness greatly modified by erosion and weathering in many places; individual flows range from 40 ft to more than 100 ft in thickness.*

Formations recognized within the Yakima Basalt Subgroup (Beeson, 1980, personal communication) include (1) Grande Ronde Basalt: two to four "low Mg" N_2 flows, including one to two "Winter Water" flow(s) at top (typical exposure at Dairy Queen, West Salem); one to two thick "low Mg" flow(s), 100-150 ft thick, extensively quarried throughout map area; one to two flow(s) of "high Mg" N_2 basalt, generally deeply weathered, occurring above the "Winter Water" flow(s); and (2) a thinner layer of younger Wanapum Basalt, represented by one to three flow(s) of the Frenchman Springs Member, observed only in South Salem within the study area, although it also occurs outside the map area in the vicinity of Turner.

Weathered flows consist of reddish-brown to grayish-brown, crumbly to medium-dense basalt. Weathering is variable and believed related to individual basalt flows; some exposures are altered to red clay (laterite) to depths of 30 ft, and occasionally as deep as 60-175 ft, while others are only slightly weathered at surface. Some locations in Salem Hills (generally between 500-900 ft elevation within area bounded by Pringle School-Prospect Hill-Jackson Hill) show extensive laterization which has resulted in deposits of bauxite (Corcoran and Libbey, 1956). Soils are reddish-brown, well-drained silty clay loams and gravelly silty clay loams. Unit yields small to large quantities of ground water from permeable rubbly zones between flows

Intrusive rocks (Oligocene): *Dense basalt, andesite, and gabbro dikes and sills of very limited extent within the map area (Roby Hill, Sidney quadrangle); Roby Hill quarry geochemically not part of Columbia River Basalt Group (Beeson, 1980, personal communication). Another limited exposure of porphyritic intrusive or possibly flow rock, with vertical columns 1-2 ft in diameter in contact with claystone along east bank of Luckiamute River near Buena Vista Road (river mile 3.2). Presumed post-Eocene (Oligocene?) age (Helm and Leonard, 1977)*

Toe

Eocene-Oligocene sedimentary rock (middle and lower Oligocene and upper Eocene): *Equivalent to tuffaceous marine sedimentary rocks (Tts) of Baldwin and others (1955), Illahe tuffs (Tit) of Mundorff (1939), Illahe Formation (Ti) of Thayer (1939), Eocene-Oligocene marine sedimentary rocks (Tm) of Price (1967), and undifferentiated Tertiary rocks (Tu) of Gonthier (in press). Consists of two lithologic and faunal units west of Willamette River (Baldwin and others, 1955) but undifferentiated in this map due to poor exposures. Older unit light-gray to tan sandy tuffaceous siltstone equivalent in age to early Oligocene Keasey Formation; thickest section near border of Amity-Rickreall 7½-minute quadrangles, where approximately 1,000 ft thick; other lower Oligocene strata well exposed in Yamhill River near Yamhill locks, where steeply dipping and complexly faulted. Younger unit is fine- to coarse-grained tuffaceous sandstone equivalent in age to middle Oligocene Pittsburg Bluff Formation; basal stratum approximately 150 ft of dark-gray, coarse-grained, calcareous cemented lithic sandstone, chiefly composed of detrital igneous rock fragments. White, fine-grained, massively bedded phase of pumiceous volcanic glass approximately 250 ft thick exposed for 3 mi along hillside south of Finzer (Salem West quadrangle); good exposures of pebbly tuff, tuffaceous conglomerate, and fine-grained platy tuff along Bunker Hill Road in Sidney 7½-minute quadrangle.*

Tuffaceous marine sandstone and siltstone of Oligocene sedimentary rock correspond to Oligocene Eugene Formation described by Hickman (1969), which contains early to middle Oligocene molluscan faunas. Recent foraminiferal analyses (McKeel, 1980) of oil and gas wells within the study area indicate unit contains almost 2,000 ft of upper Refugian and Refugian strata (Reichhold-Merrill #1, Sidney quadrangle) and 200-1,000 ft of basal siltstone, claystone, and shale of late Narizian (provincial West Coast late Eocene) age (Reserve-Bruer #1 and Reichhold-Merrill #1)

Upper Eocene sandstone: *Equivalent to Helmick beds (Thb) of Mundorff (1939) and Spencer (Ts) of Gonthier (in press); very fine- to medium-grained, thinly laminated (fissile) to thin-bedded, as well as prominently more massive, light-gray to yellowish-brown moderately well-sorted micaceous, calcareous, lithic arkosic marine (tuffaceous) sandstones; frequently interbedded with fine-grained marine tuffaceous siltstone, thinly laminated clay shale, and claystone; comprised of almost equal proportions of quartz, feldspar, and rock fragments cemented with calcite (in concretions); minor constituents include approximately 2% glauconite, 4% mica (biotite, muscovite, and chlorite), and less than 1% authigenic pyrite; well compacted; carbonaceous material consisting of plant stems, leaves, and other organic fragments common; calcareous concretions, fossiliferous or containing carbonaceous material, prominent along Willamette River south of Buena Vista (Monmouth quadrangle); pebbly lenses, abundant organic matter, and paleoecology indicate strandline environment; provenance from chiefly volcanic terrain. Weathered outcrops of massive, very fine- to medium-grained sands, generally friable, ranging in color from white to yellowish-brown, pale-brown, or yellowish-orange.*

According to McKeel (1980), this unit is bracketed by upper Narizian strata in the Reichhold-Finn #1 well (Amity quadrangle), by upper Narizian and Narizian strata in the Reserve-Bruer #1 well (Amity quadrangle), and by upper Narizian strata in the Reichhold-Merrill #1 well (Salem West quadrangle). Average thickness about 800 ft

Ty

Yamhill Formation (middle and upper Eocene): *Medium- to dark-gray, massive to faintly bedded, micaceous, tuffaceous shale and siltstone. Occasional beds of medium-gray to greenish-gray, fossiliferous, calcareous sandstone; minor limestone concretions.*

According to McKeel (1980), this unit contains 2,000-3,000 ft of Narizian and lower Narizian strata in the Reichhold-Finn #1 and Reserve-Bruer #1 wells, located in the Amity quadrangle. Shown only in the cross section

OTHER SYMBOLS

Lineament: *Selected major lineaments identified from 1:76,000 false-color infrared aerial photographs (U.S. Army Corps of Engineers, 1978), orthophotoquads, and topographic maps. Features include aligned ridges, major escarpments, concentric curvilinear drainages, aligned drainages across saddles, and parallelism; omitted are short linear segments along drainages of less than 1 mi length; general trends NE and NW, typical of lineament features observed in western Oregon*

Landslide topography: *Large areas of deep bedrock failure characterized by irregular topography, disrupted stratigraphy, overall anomalous moderate to shallow slope, prominent arcuate headscarps, backward-tilted blocks, springs, sag ponds, and disrupted drainage patterns. Most prominent along west side of Salem Hills and south and west side of Eola Hills, where undercutting of soft marine sediments (Eocene to Oligocene sedimentary rock, unit* **Toe***) has resulted in massive landsliding of blocks of more resistant unit* **Tcr***. Subject to rockfall and debris avalanche along oversteepened escarpments and to slump in some areas (bowed and tipped trees).*

Deep bedrock slides within upper Eocene sedimentary rock **(Ts)** *within Monmouth quadrangle are much smaller than those associated with units* **Tcr/Toe***; characterized by small knobby blocks of sedimentary rock within general hummocky terrain*

Landslide scarp: *Characterized by steep cliff, often arcuate, and backward-tilted block below*

bc

Basaltic colluvium and/or landslide debris: *Generally reddish-yellow or reddish-brown basaltic colluvium and/or landslide debris, deeply weathered, overlying Oligocene sedimentary rock* **(Toe)***, generally within landslide topography or beneath steep cliffs capped by Columbia River Basalt Group* **(Tcr)***; includes alluvial fans and some earthflow and debris-flow topography. Probably generally 6-35 ft thick but may include some blocks of basalt of greater thickness. Soils well-drained silty clay loams and gravelly silty clay loams overlying silty clay and clay*

GEOLOGIC SYMBOLS

Contact

Strike and dip of beds

Abandoned oil and gas well

Abandoned oil and gas well with gas show

REFERENCES CITED

Allison, I. S., 1953, Geology of the Albany quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 37, 18 p.

Baldwin, E. M., Brown, R. D., Jr., Gair, J. E., and Pease, M. H., Jr., 1955, Geology of the Sheridan and McMinnville quadrangles, Oregon: U. S. Geological Survey Map OM-155.

Beaulieu, J. D., Hughes, P. W., and Mathiot, R. K., 1974, Environmental geology of western Linn County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 84, 117 p.

Bela, J. L., 1979, Geologic hazards of eastern Benton County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 98, 122 p.

Corcoran, R. E., and Libbey, F. W., 1956, Ferruginous bauxite deposits in the Salem Hills, Marion County, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 46, 53 p.

Gonthier, J. B., in press, Ground-water resources of the Dallas-Monmouth area, Polk, Benton, and Marion Counties: U. S. Geological Survey Water-Supply Paper.

Helm, D. C., and Leonard, A. R., 1977, Ground-water resources of the lower Santiam River basin, middle Willamette Valley, Oregon: Oregon Water Resources Department Ground-Water Report 25, 75 p.

Hickman, C. J. S., 1969, The Oligocene marine molluscan fauna of the Eugene Formation in Oregon: Oregon Museum of Natural History Bulletin 16, 112 p.

McKeel, D. R., 1980, Micropaleontological study of five wells, western Willamette Valley, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-80-1, 21 p.

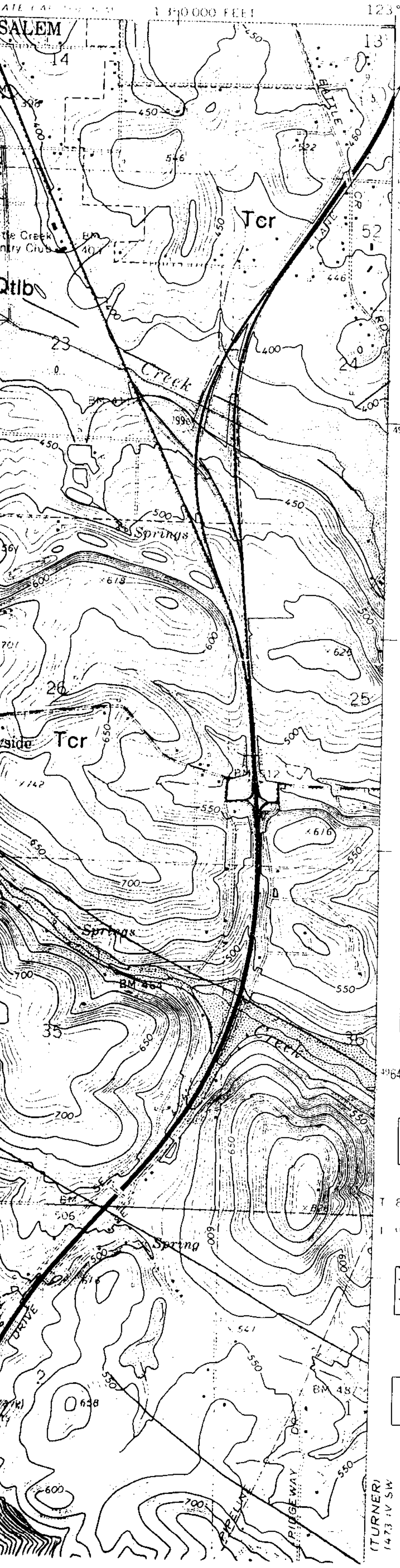
Mundorff, M. J., 1939, The geology of the Salem quadrangle, Oregon: Corvallis, Oreg., Oregon State College master's thesis, 79 p.

Price, D., 1967, Ground water in the Eola-Amity Hills area, northern Willamette Valley, Oregon: U. S. Geological Survey Water-Supply Paper 1847, 66 p.

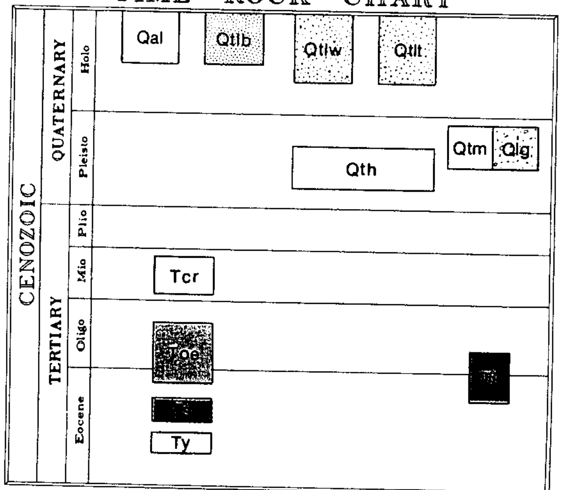
Schlicker, H. G., 1977, Geologic restraints to development in selected areas of Marion County, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-77-4, 41 p.

Thayer, T. P., 1939, Geology of the Salem Hills and North Santiam River basin, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 15, 40 p.

Vokes, H. E., Myers, D. A., and Hoover, L., 1954, Geology of the west-central border area of the Willamette Valley, Oregon: U. S. Geological Survey Map OM-150.



TIME ROCK CHART



Reflects traditional usage in Western Oregon, after: Gonthier, 1980; Bela, 1979; Helm and Leonard, 1977; Beaulieu, 1974; Hickman, 1969; Baldwin and others, 1955; Vokes and others, 1954.

EXPLANATION

SURFICIAL GEOLOGIC UNITS

Qal — **Recent river alluvium**: *Unconsolidated cobbles, coarse gravel, sand, and some silt and clay within active channels of Willamette River. Generally 15-45 ft thick, consisting of stratified sands and well-rounded pebbles, gravels, and cobbles of primarily basaltic and andesitic composition; often overlain by 3-15 ft of light-brown sand and silt overburden. Characterized by low relief, point-bar and channel-bar deposits; many areas unvegetated, others support dense stands of brush and phreatophytes, such as willows and cottonwoods. Subject to major flooding, critical stream-bank erosion, and lateral channel migration; includes many areas located between 1852 meander line and present channel that illustrate possible extent of future changes*

Qtlw — **Lower terrace deposits of the Willamette River (Quaternary)**: *Unconsolidated to semiconsolidated cobbles, gravel, sand, silt, clay, muck, and organic matter of variable thickness (30-50 ft) on the flood plain and lowland terraces immediately above the Recent river alluvium* (**Qal**)*; typically 5-20 ft of light-brown silt and clay or very fine sand overlying 10-45 ft of moderately well-sorted sand and locally cemented gravel. Surface topography characterized by a low, undulating, fluvial surface with abandoned channels, meander scrolls, oxbow lakes, and sloughs; subject to major and local flooding, some catastrophic channel migration of major scale, ponding, and high ground water. Flood-plain soils are predominantly well drained and somewhat excessively drained silty clay loams, silt loams, and sandy loams; good ground-water yields generally of 100-500 gallons per minute*

Qtlt — **Lower terrace deposits of tributary rivers and streams (Quaternary)**: *Unconsolidated to semiconsolidated gravel, sand, silt, clay, and organic matter generally 15-30 ft thick on lowland terraces and flood plains immediately above major tributary rivers of the Willamette River. Gravel deposits are very thin to variable in thickness, according to tributary drainage source, generally limited to active stream beds or former meander channels, and located at or near bed rock beneath 20-30 ft of sand, silt, and clay. Somewhat tortuous meandering streams entrenched 15-45 ft, often flowing on Tertiary sedimentary bed rock or semiconsolidated older valley-fill alluvium. Surface topography characterized by a low, undulating fluvial surface of swell and swale relief, abandoned meander loops, and oxbow lakes; subject to high ground water and ponding and major and local flooding; flood-plain soils are predominantly well drained and somewhat excessively drained silty clay loams, silt loams, and sandy loams. Some soft, compressible organic soils of low shear strength may occur locally, particularly within abandoned channels and oxbows. Major stream-bank erosion commonly occurs at outer bends of meander loops by shallow earthflow and slump due to undercutting. Ground-water yields generally small*

Qtlb — **Lower terrace deposits of alluvial bottomlands (Quaternary)**: *Flat, moderately to poorly drained areas with soft, organic compressible soils of low shear strength locally; characterized by low relief, ponding, and high ground water. Deposits typically consist of somewhat stratified very fine sands, silty sandy clays, silty clays, and silty clay loams, with slight to moderate plasticity (ML-CL); 4-12 ft thick along bottomlands of interior drainages of low, rolling sedimentary bedrock units. Deposits locally may represent somewhat thicker accumulations of silt and silty clay materials of fluviatile and/or loessal origin derived in part from Willamette Silts. Similar deposits along creeks are associated with deposits of units* **Qtm** *and* **Qth** *and are often modified by ditching and field drainage for agriculture; typical examples are deep (more than 60 in.) clay (CH), silty clay (CH), and silty clay loam (CL or ML) black Bashaw clay soils of Baskett Slough (Rickreall quadrangle). Similar thicknesses of reddish-brown sandy silty material (ML-CH) in basaltic terrain* (**Tcr**)

Qtm — **Middle terrace deposits (Quaternary)**: *Semiconsolidated gravel, sand, silt, and clay forming very flat terraces of major extent along the Willamette River. Generally 10-30 ft of light-brown silty clay and interbedded very fine sand and silt (ML or CL-CH) surficial material; believed primarily related to Willamette Silts, including associated glacial erratics consisting of tiny fragments and pebbles up to boulders greater than 4 ft in diameter. Soils somewhat poorly drained and poorly drained silt loams and silty clay loams to moderately well-drained and well-drained silt loams subject to seasonal high ground water and ponding. Sand and gravel (GP, SM), where present, usually occur below 30 ft depth; locally more abundant near Monmouth-Independence and in the lower part of Ash Creek. Total thickness 0-85 ft, but often only 40-50 ft; within Rickreall 7½-minute quadrangle, 15-35 ft of brown clay or silt generally occurs above several to 30 ft of gravelly clay, black sands, and gravels. Generally small ground-water yields, except near Monmouth-Independence, where sand and gravel may yield up to 300 gallons per minute*

Qlg — **Linn gravel (Quaternary-upper Pleistocene)**: *Stratified fine to coarse fluvial gravels deposited as an alluvial fan in the Stayton-Turner-Salem areas during an early stage of the Santiam River; of limited extent within the map area; uppermost few feet of gravels extensively oxidized and weathered, often chalky; thickness ranges from 30-40 ft to possibly as much as 300 ft. Regionally, the upper foot or so of gravel is cemented by an impermeable clay pan locally, which restricts drainage. Composition of gravels (mostly basalt, but also andesite, dacite, rhyolite, quartz, and diorite) essentially uniform. Within map area near Salem, soils are well drained and somewhat poorly drained gravelly silt loam and gravelly loam. Extensively utilized as source of sand and gravel. Good ground-water yields greater than 100 gallons per minute*

Qth — **Higher terrace deposits (Quaternary-middle Pleistocene)**: *Generally semiconsolidated light-brown sand, silt, and clay of variable thickness (3-15 ft) on higher terraces and remnants of old higher terraces adjacent to sedimentary bedrock foothills; mantled by moderately well-drained and well-drained silt loam soils. Includes colluvium, slope wash, and alluvial fan deposits near sedimentary bedrock foothills; deposits thin where transitional with pediments. Material generally similar to unit* **Qtm**, *particularly in West Salem, containing glacial erratics related to Willamette Silt but also some gravelly alluvium. Some higher terrace deposits on west side of Salem Hills between Salem and Illahe Hill not shown due to scale. Also includes weathered (decomposed) cobbles and gravels which extend beyond the study area west of Rickreall (8-10 ft thick) and at southeastern margin of Sidney quadrangle (10-50? ft thick), where they are equivalent to the Leffler gravels of Allison (1953). These deposits also mantled by 3-15 ft of light-brown silt loam and silty clay loam soils. Generally little or no ground-water yield*

BEDRO NITS