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WATERSHEDIPEDIA for Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds

Welcome to this watershedipedia, an alphabetical reference covering topics that can help landowner's understand, use, and manage their lands and waters in ways that are safe, suitable, sustainable, satisfying, and **salmon-friendly** (the Five S's discussed in introductory article 3, listed below). This watershedipedia was developed for landowners in Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds.

This watershedipedia is part of a larger landowner's guide for the watersheds named above. Along with this watershedipedia, the landowner's guide contains an opening section on how to use the guide, followed by four introductory articles, listed below. The entire landowner's guide can be found at Homer Soil and Water's online project portal: http://www.homerswcd.org/ projects/index.php. (Any time you want to find the website of the Homer Soil and Water Conservation District, just do an online search for "Homer Soil and Water.") The four articles in the landowner's guide are:

article 1: *Salmon species and life cycle,*
article 2: *Five S's for landowners,*
article 3: *Exploring your watershed with online tools—two 10-minute tours,* and
article 4: *Research in your watershed.*

What topics are covered in the watershedipedia, and what does the blue and yellow highlighting mean?
Below is an alphabetical list of all topics covered in this watershedipedia. To go to a topic, click on its entry. Wherever you jump to, at the top of each page you'll always find a link back to this list of topics (like at the top of this page). Words or phrases highlighted in blue, like this, have their own entry in the watershedipedia. To go to a blue-highlighted entry, jump back to this list of topics and click on the entry you want to see. Also, if you're looking at this watershedipedia as a pdf, you can click on "Edit" on the Adobe menu bar, choose "Find" or "Search" from the dropdown menu, and then type in any word or phrase you'd like to find. You can do all the other things possible with a pdf and Adobe Reader, like print one or several pages, or have a page read out loud by your computer (click on "View" on the Adobe menu bar, then select "Read Out Loud").

Throughout the watershedipedia, we've highlighted (literally) many suggestions for things landowners can do to help keep their lands, waters, neighborhoods, and watersheds salmon-friendly. Much of that information is highlighted like this paragraph in order to make it easier to find.

This watershedipedia can serve as a portal to many online sources of useful information, and Web links were accurate as of early February 2012. We've written out url addresses for all referenced Web links in case you're using a printed copy of this watershedipedia and want to check out a Web link later on. If you discover that a link no longer works, please let us know by emailing devony@homerswcd.org and describing the nature of the problem. Thanks, and enjoy!

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Agencies with responsibilities for watershed resources

(As appropriate, these are discussed in more detail under their own headings and under other listings in the watershedipedia. A lot of information about these and other entities, along with links to some of their key information resources, map products, etc., can be found in the *Kenai Peninsula Wetland Who's Who*, available at http://www.homerswcd.org/projects/wetlands.php.)

Federal agencies with roles on state, borough, city, private, and Native lands within your watersheds are:

- US Fish and Wildlife Service (USFWS, FWS); USFWS also administers the Kenai National Wildlife Refuge, which overlaps lands in the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds;
- Environmental Protection Agency (EPA);
- Natural Resources Conservation Service (NRCS);
- US Army Corps of Engineers (ACE, USACE, the Corps, COE).

Some of these agencies are focused on research, education, and outreach (e.g., USFWS, NRCS). Some are focused on protecting resources like water quality and wetlands (e.g. EPA and USACE). Some do a bit of both (EPA).

State agencies responsible for managing lands and waters within Alaskan watersheds are:

- Alaska Department of Fish and Game (ADF&G, ADFG, Fish and Game) which has many responsibilities related to protecting salmon;
- Alaska Department of Natural Resources (DNR), particularly the Divisions of Mining, Land and Water (MLW); Parks and Outdoor Recreation (DPOR); and Oil and Gas (DOG). Check out listings under Kenai Area Plan and Oil and gas for some key information;
- Alaska Department of Environmental Conservation (ADEC, DEC), which is primarily concerned with protecting water quality;
- Alaska Department of Transportation and Public Facilities (DOTPF), which constructs and maintains state roads.

Other divisions of state government or state-federal partnerships:

- The Kachemak Bay Research Reserve (KBRR) plays a significant role in research and education in watersheds that drain into Kachemak Bay—which is within the National Estuarine Research Reserve System (NERRS). KBRR is a partnership between the ADF&G and the National Oceanic and Atmospheric Administration (NOAA).
- Homer Soil and Water Conservation District (HSWCD, the District, Homer Soil and Water) is authorized by state law to advise the Department of Natural Resources on land-use-related issues and provides the state and other District partners with input based on local knowledge and experience. The District establishes many kinds of partnerships with agencies, groups, organization, etc. that can help in furthering its mission of promoting wise and sustainable use of soil- and water-related resources. It works closely with a variety of landowners, from state to Native to private, many of whom become District "cooperators."

Kenai Peninsula Borough

- Through its comprehensive planning activities and its administrative and operational roles, the borough makes many kinds of decisions affecting how lands and resources in the borough are used and developed. (The KPB comprehensive plan can be found at: http://www2.borough.kenai.ak.us/planningdept/plan/2005/plan.htm.) The borough also has many responsibilities related to emergency preparedness and response (see http://www2.borough.kenai.ak.us/emergency/). The borough collects many kinds of "geospatial" information useful for its decision making and

operations. Much of this data is available to the public via the borough's online "interactive parcel viewer" (see *introductory article 3: Exploring your watershed with online tools* for step-by-step instructions for using this powerful tool). Finally, the borough limits land use activities within 50 ft of ADF&G-identified anadromous streams (see http://www.kenairivercenter.org/Agencies/kpbhabitat/habitatordinance.htm and http://www2.borough.kenai.ak.us/ AssemblyClerk/Assembly/Ordinances/2011/O2011-12.pdf), and provides tax credits as partial reimbursement for costs of habitat protection and restoration adjacent to anadromous streams http://www2.borough.kenai.ak.us/AssemblyClerk/Assembly/Ordinances/2011/O2011-37.pdf).

Legislation—such as federal laws like the Clean Water Act (http://www.epa.gov/lawsregs/laws/cwa.html), state statutes like "Title 16" (http://touchngo.com/ lglcntr/akstats/statutes/Title16.htm) or borough ordinances like Habitat Protection Ordinance Chapter 21.18 (http://www.kenairivercenter.org/Agencies /kpbhabitat/habitatordinance.htm)—lays out what agencies and governments do to fulfill their responsibilities to society. Watershed landowners may be particularly interested in certain Alaska statutes (AS) and administrative codes (AAC), which provide broad policies and the regulatory scaffolding on which state agencies build their programs. Alaska statutes and Administrative codes are easy to find and look through online. For example, see the link to AS Title 16 (Fish and Game) above, and here's the link to Alaska Administrative Code (AAC) Title 11 (Natural Resources), Chapter 195 (Anadromous Fish Habitat), (which would be written as 11 AAC 195): http://www.touchngo.com/lglcntr/akstats/aac/title11/chapter195.htm.

Alaska Department of Environmental Conservation (ADEC or DEC)

With respect to salmon, DEC, Division of Water is responsible for protecting water quality in state waterbodies. DEC establishes standards for water cleanliness; regulates discharges to waters and wetlands; provides financial assistance for water and wastewater facility construction and waterbody assessment and remediation; trains, certifies and assists water and wastewater system operators; and monitors and reports on water quality. Under Section 401 of the Clean Water Act (CWA), Alaska has legal authority to review applications or projects requiring Section 404 permits. Applicants must obtain a Certificate of Reasonable Assurance from DEC to conduct regulated activities. DEC reviews projects; coordinates with state and federal agencies and local governments; reviews public comments; and approves, approves with conditions, waives, or denies projects based on compliance with CWA, state water quality standards, and other applicable state laws. The DEC, Division of Water website is: http://www.dec.state.ak.us/water/index.htm. Go to that link to find out about DEC wastewater permits, National Pollutant Discharge Elimination Permits (NPDES), or required Stormwater Pollution Prevention Plans (SWPPP). For information about permits you may need from DEC, go to http://www.dec.state.ak.us/water/wwdp/online_permitting/permitentry.htm.)

Alaska Department of Fish and Game (ADFG or ADF&G)

With respect to salmon, ADF&G conducts research in watersheds and regulates many activities that could affect anadromous streams listed in the *Catalog of waters important for the spawning, rearing, and migration of anadromous fish* (Anadromous waters catalog (AWC). Most of its regulations are related to Alaska Statute Title 16 (Fish and Game), and so are called Title 16 regulations. ADF&G also regulates "Special Areas" (see below) under Title 16 (AS 16.20).

(From http://www.kenairivercenter.org/Agencies/adf&g/adf&g.html): Alaska Statute 16.05.841 (Fishway Act) requires that an individual or governmental agency notify and obtain authorization from the ADF&G, Division of Habitat for activities within or across a stream used by fish if the department determines that such uses or activities could represent an impediment to the efficient passage of fish. Culvert installation; stream realignment or diversions; dams; low-water crossings; and construction, placement, deposition, or removal of any material or structure below ordinary high water require approval from the ADF&G.

(From http://www.kenairivercenter.org/Agencies/adf&g/adf&g.html): Alaska Statute 16.05.871 (Anadromous Fish Act) requires that an individual or

governmental agency provide prior notification and obtain approval from the ADF&G "to construct a hydraulic project or use, divert, obstruct, pollute, or change the natural flow or bed" of a specified anadromous waterbody or "to use wheeled, tracked, or excavating equipment or log-dragging equipment in the bed" of a specified anadromous waterbody. All activities within or across a specified anadromous waterbody and all instream activities affecting a specified anadromous waterbody require approval from the ADF&G, Division of Habitat, including construction; road crossings; gravel removal; placer mining; water withdrawals; the use of vehicles or equipment in the waterway; stream realignment or diversion; bank stabilization; blasting; and the placement, excavation, deposition, disposal, or removal of any material. Recreational boating and fishing activities generally do not require a permit.

These statutes mean that if you want to use a vehicle to cross a stream that's listed in the anadromous water catalog, or alter in any way the banks of an anadromous stream "below ordinary high water," you need to obtain a Title 16 permit from the ADF&G, Habitat Division. A list of common activities that require permits is available on the Division of Habitat webpage at: http://www.adfg.alaska.gov/index.cfm?adfg=uselicense.main. This link also gives you access to the forms you need to fill out for Fish Habitat Permits and for Special Area Permits.

ADF&G also has statutory responsibility for managing activities within legislatively designated "Special Areas," such as the Anchor River-Fritz Creek Critical Habitat Area (CHA). Citizens wanting to carry out specified activities within these Special Areas need to get a "Special Area Permit" from ADF&G. (See the paragraph above for a link to the permit form.) Each Special Area has certain allowable uses defined in statute and regulations. A Special Area Permit is required before you can take any action to: construct or place structures, develop natural resources, explore energy opportunities, or use off-road wheeled or tracked vehicles.

ADF&G educational resources: Landowners may also be interested in educational resources provided by ADF&G, which supports a number of programs to help teachers educate students about Alaska's fish, wildlife, and habitats. The home website for these programs is: http://www.adfg.alaska.gov/index.cfm?adfg=educators.teacherresources. Of particular relevance to salmon is the unit on Salmon in the Classroom, found at: http://www.adfg.alaska.gov/index.cfm?adfg=educators.salmonclassroom. As explained at that website, "This innovative, science-based program allows schools to raise salmon from the egg to the fry stage in classroom incubators. Through participation in the project, students learn about the life cycle and biology of Pacific salmon species, their habitat requirements, responsible angling techniques for catching them, and ways to protect Alaska's valuable wild salmon stocks for future generations... State permits are required in advance to receive salmon eggs for the classroom, and each teacher is required to submit progress reports with specific data at two different points in the school year. ADF&G education specialists will assist teachers with the permitting and reporting requirements." Other Fish and Game educational resources are mentioned where appropriate throughout this watershedipedia.

Alaska Department of Natural Resources (ADNR or DNR), Division of Mining, Land and Water (MLW) *(see also Kenai Area Plan, Oil and gas)*

The Division of Mining, Land & Water (http://dnr.alaska.gov/mlw/index.htm) is the primary manager of Alaska's land holdings. MLW's mission is "...to provide for the use and protection of Alaska's state-owned land and water," aiming toward "...maximum use of state lands and waters consistent with the public interest." MLW manages all state-owned land except for trust property and units of the Alaska State Park System (which are managed by the Division of Parks and Outdoor Recreation). Responsibilities include ensuring the state's title; preparing land-use plans and easement atlases; classifying land; leasing and permitting state land for recreation, commercial and industrial uses; and coordinating and overseeing needed authorizations for major development on the North Slope.

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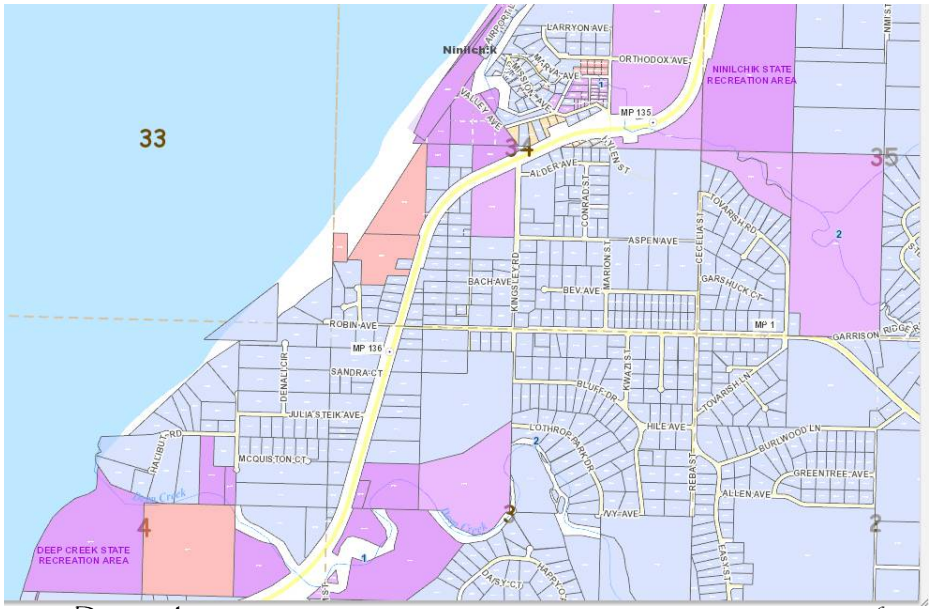
The state develops "area plans" for state lands throughout the state. The state's Kenai Area Plan (KAP) has its own entry in the watershedipedia, focused on sections relevant to Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. (The plan can be accessed at: http://dnr.alaska.gov/mlw/planning/areaplans/kenai/index.htm; our four watersheds are found in Region 7). As an appendix, the KAP incorporates a plan for state lands in the Caribou Hills area (see Caribou Hills Special Use Area and Management Plan or go to http://dnr.alaska.gov/mlw/planning/areaplans/kenai/pdfs/appendc_CaribouHillsMgt.pdf). The state has also developed a plan for state lands making up the Anchor River-Fritz Creek Critical Habitat Area, which is managed jointly by MLW and the ADF&G. (Note that management of oil and gas on state lands (and on private lands where the state owns the "subsurface estate") is handled by DNR's Division of Oil and Gas (DOG). When all land conveyances under the Alaska Statehood Act are complete, the division will be responsible for over 100 million acres of uplands, including non-petroleum minerals in these lands. It also manages Alaska's 65 million acres of tidelands, shorelands, and submerged lands, including some 34,000 miles of coastline. Finally, MLW has jurisdiction over all of the state's water resources, equaling about 40% of the entire nation's stock of fresh water.

Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation (DPOR)

There are four units of the state park system in our four watersheds. These are managed by DPOR and are briefly introduced below. Before fishing at any of these, consult current sport fishing regulations, found at http://www.adfg.alaska.gov/index.cfm?adfg=fishregulations.sc_sportfish.

- **Anchor River State Recreation Area** (SRA), near Anchor Point, offers fishing for king, silver and pink salmon, as well as Dolly Varden and steelhead. There are five campgrounds with a total of 46 campsites. For more information, see http://dnr.alaska.gov/parks/aspunits/kenai/anchorpt.htm and http://dnr.alaska.gov/parks/units/anchoriv.htm.
- **Stariski State Recreation Site** (SRS) is located on a high bluff overlooking Cook Inlet, offering views of Mount Augustine, Iliamna and Redoubt. The park is 5 miles north of Anchor Point, with nine campsites. There is no fishing at Stariski SRS. For more information, see http://dnr.alaska.gov/parks/aspunits/kenai/stariskisrs.htm and http://dnr.alaska.gov/parks/units/anchoriv.htm.
- **Deep Creek State Recreation Area** (SRA), near Ninilchik, has halibut and king salmon fishing, as well as razor clams; it provides 100 campsites. Deep Creek Beach is located at mile 137.3 of the Sterling Highway, near Ninilchik, and offers excellent scenic views of Mount Iliamna and Redoubt. A campground and day use area are located along the beach at the mouth of Deep Creek. The park also offers fishing access to Deep Creek. There are two scenic overlooks: Deep Creek South and North; the north overlook provides access to salmon fishing in Deep Creek. For more information, see http://dnr.alaska.gov/parks/units/deepck.htm.
- **Ninilchik State Recreation Area** (SRA), near Ninilchik, offers salmon and halibut fishing and clamming. Ninilchik View campground is at mile 135.7 Sterling Hwy, on a bluff above Ninilchik Beach. Stairs lead down the bluff to the beach. A scenic overview is found at mile 135.1. For more information, see http://dnr.alaska.gov/parks/units/nilchik.htm.

Map of Deep Creek SRA (bottom-left) and Ninilchik SRA(upper middle).



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Alevin

(see also introductory article 1: Salmon species and life cycle)

These are salmon that have hatched but have not yet completely absorbed their yolk sacs and usually have not yet emerged from the gravel in which they hatched. Alevin live on their yolk sac "lunch bag" for a month or so before emerging from the gravel—at which point they become salmon fry and begin their search for food. (Many become food for other fish, birds, and mammals as soon as they leave the gravel.)

In the **photo at right**, five salmon alevins—recently emerged from their eggs—still have large yolk sacs. After they consume these, they will leave the protection of their gravel nursery and seek slow moving water so they can feed on zooplankton without being washed downstream. (Image from http://www.pixdatabase.com/data/r/o/l/rolljack/medium/3280-salmon-alevin-s3.jpg.)

All-terrain vehicle

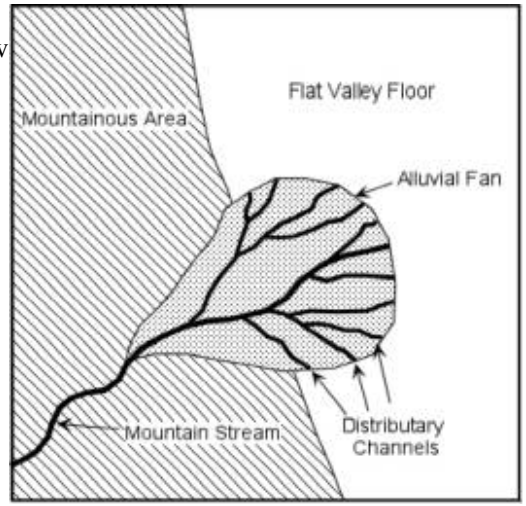
(see ATVs and ORVs)

Alluvial, alluvium

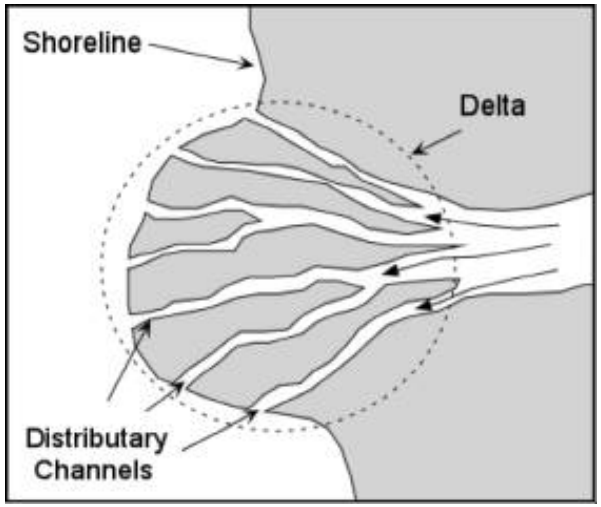
(see also Stream channel "anatomy" and Stream channel processes)

Alluvium is earth material—like rocks, sand, silt, or clay—deposited by flowing water. Alluvial deposits create landforms like alluvial fans, river deltas, and flood plains. Two examples of alluvial landforms are illustrated below, from: http://www.tulane.edu/~sanelson/geol111/ streams.htm).

Alluvial Fans: When a steep mountain stream enters a flat valley, there is a sudden decrease in gradient and streamflow velocity. Slower streamflows can't carry as much sediment as faster flows, so sediments being carried by the stream will be deposited at the edge of the valley in an alluvial fan. As stream velocity slows, the stream channel becomes choked with sediment and breaks up into numerous distributary channels.



Deltas: When a stream enters a standing body of water, such as a lake or bay, there is a sudden decrease in streamflow velocity and the stream deposits its sediment in a deposit called a delta. Deltas build outward from the coastline, but will only survive if currents in the receiving water body are not strong enough to remove deposited



sediments. (Cook Inlet currents are strong enough to prevent the formation of deltas at the mouths of Anchor River, Deep Creek, Ninilchik River, and Stariski Creek—see aerial photos under Estuary.) As the velocity of a stream decreases on entering the delta, the stream may become choked with sediment, leading to conditions favorable for creating a braided channel; alternatively, the main channel may divide into many smaller distributary streams.

Anadromous

(see also introductory article 1: Salmon species and life cycle)

This is an adjective that describes fish, such as salmon, that migrate from the ocean into freshwater habitats to breed and lay eggs. Juvenile anadromous salmon migrate to the ocean to feed and grow (see Smolts). Pink salmon may outmigrate to sea shortly after they hatch; chinook and coho rear in freshwater habitats for from one to several years, depending on species.

Anadromous waters catalog (AWC)

(see also Headwater streams)

As noted under Alaska Department of Fish and Game, the state maintains a catalog of waters that have been identified as important for spawning, rearing, or migration of anadromous fish. The catalog is accompanied by maps that show which waters have been identified for particular fish species. Many activities within these waters require permits (see the entry for Alaska Department of Fish and Game or go to ADF&G, Land and Water Use Habitat Permits: http://www.adfg.alaska.gov/index.cfm?adfg=uselicense.main). The catalog and atlas are important because waterbodies that are "specified" in the AWC are afforded protection under AS 16.05.871; waterbodies that are not specified, are not. The catalog can be found at: http://www.adfg.alaska.gov/sf/SARR/AWC/.

The catalog and atlas currently list over 17,000 streams, rivers, or lakes around the state important for anadromous fish. Based on thorough surveys of a few drainages, ADF&G biologists believe that this number probably represents less than 50 percent of the waterbodies actually used by anadromous species. Due to timing, water clarity, temperature, survey method, or other factors, a survey for a particular fish species may fail to a) gather complete life phase information, b) observe juvenile fish or non-targeted anadromous species, or c) identify the actual upper limit of anadromous fish use. Therefore, the upper points of stream reaches listed in the AWC usually reflect the extent of fish surveys or known anadromous fish use in a particular waterbody rather than actual limits of anadromous fish occurrence or habitat use. In addition, only a limited number of waterbodies in Alaska have actually been surveyed. Virtually all coastal waters in the state provide important habitat for anadromous fish, as do many unsurveyed tributaries to known anadromous fish-bearing waters. Anadromous fish often rear in small tributaries, flood channels, intermittent streams, and beaver ponds. Due to the remote location, small size, or ephemeral nature of these systems, however, most have not been surveyed and are not included in the catalog or atlas.

Waterbodies are added to the catalog when anadromous fish have been seen or collected and identified by a qualified observer. Most nominations for additions to the catalog come from ADF&G fisheries biologists, but others are received from private individuals, companies, and biologists from other agencies or organizations. You can request a change to the catalog and atlas using the nomination form see http://www.adfg.alaska.gov/sf/SARR/AWC/index.cfm?ADFG=noms.home.

The following maps from the 2011 anadromous waters catalog show where chinook, coho, and pink salmon are known to occur in the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. (Maps also provide a good way to get familiar with watershed topography.) These maps are based on available information and no doubt **underrepresent** anadromous streams in these watersheds. You'll notice that coho are the "gypsies" of your watershed.

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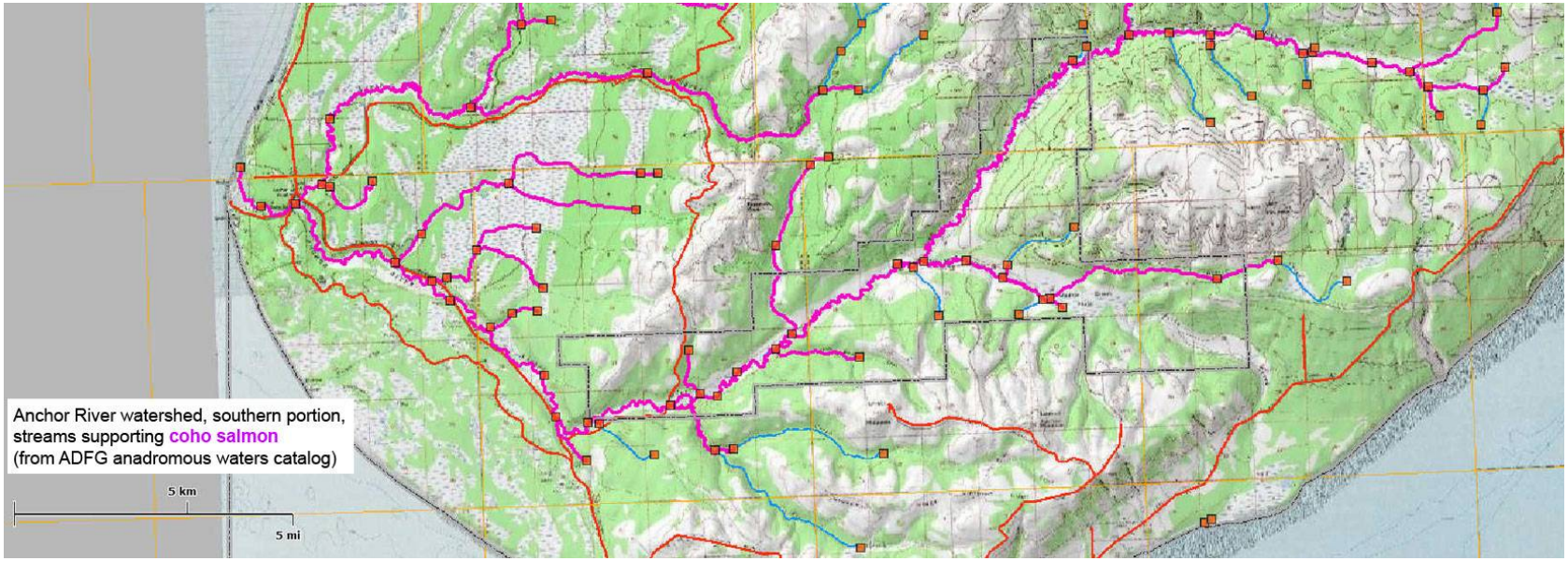
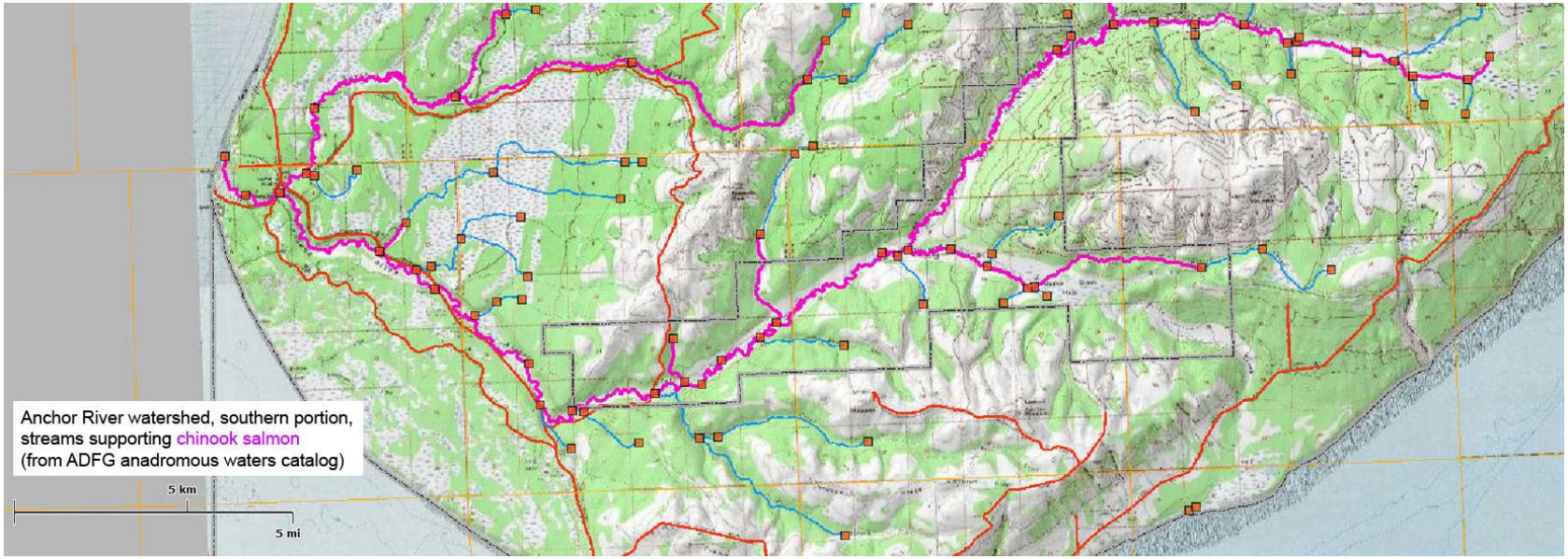
ANCHOR RIVER—southern stream channels identified in the AWC for coho and chinook salmon.





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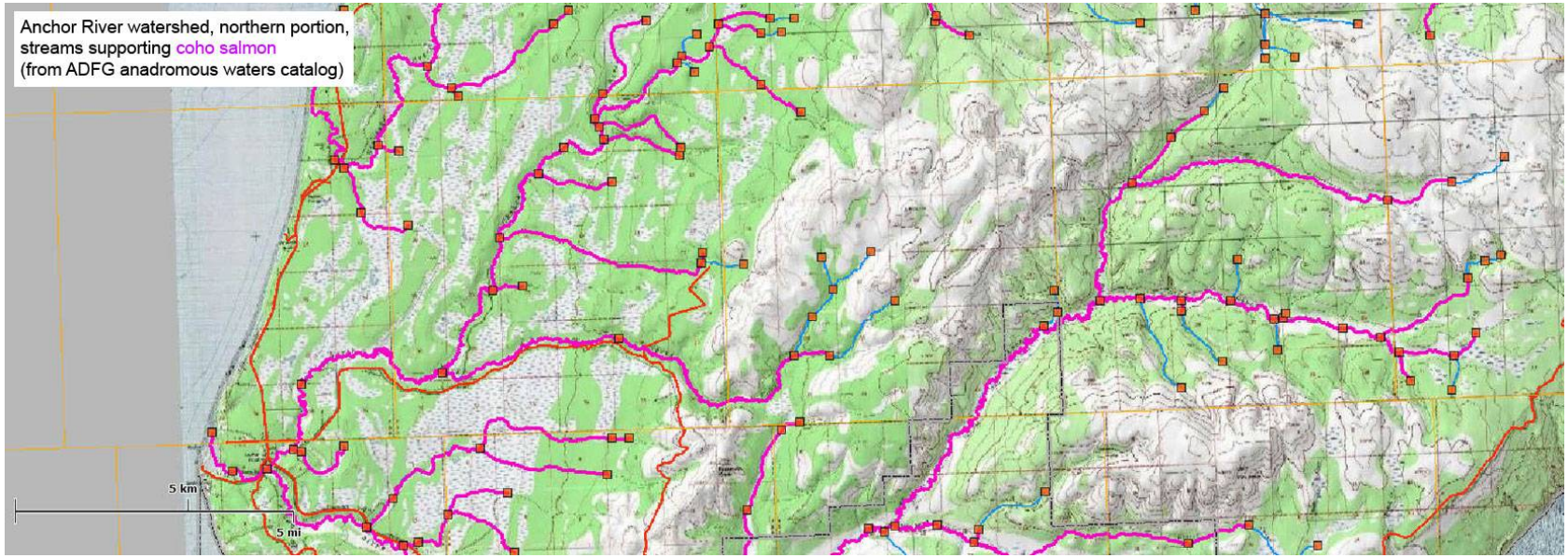
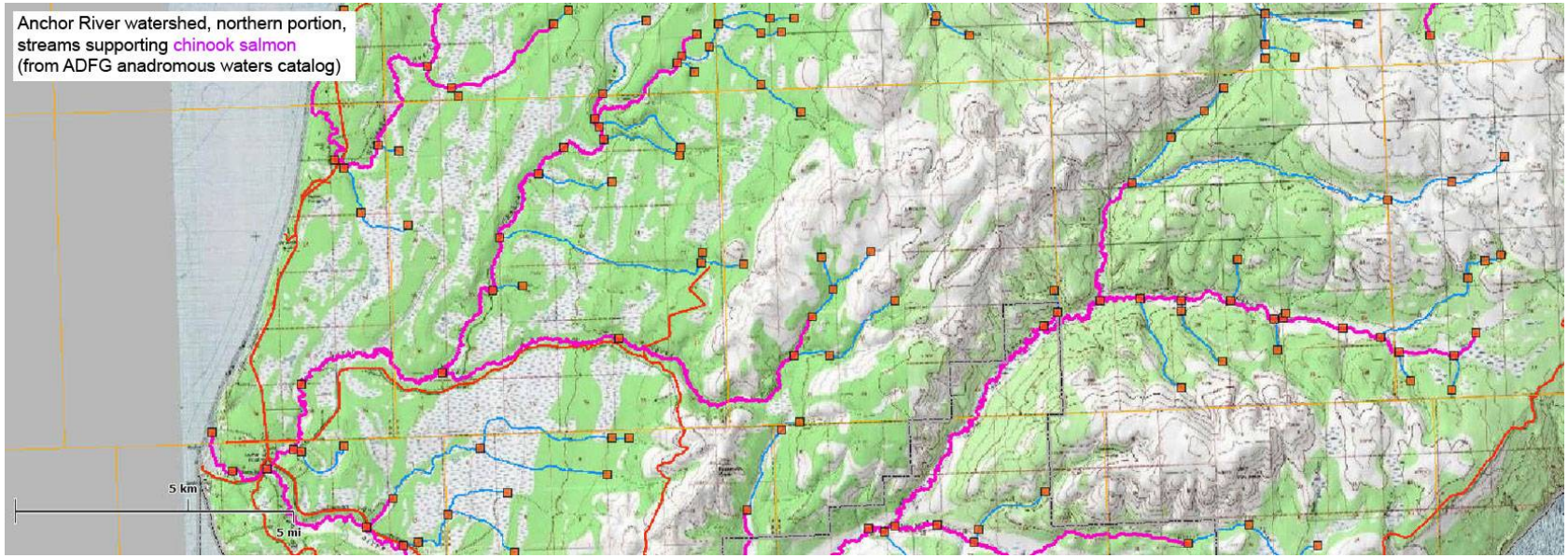
ANCHOR RIVER—northern stream channels identified in the AWC for coho and chinook salmon.





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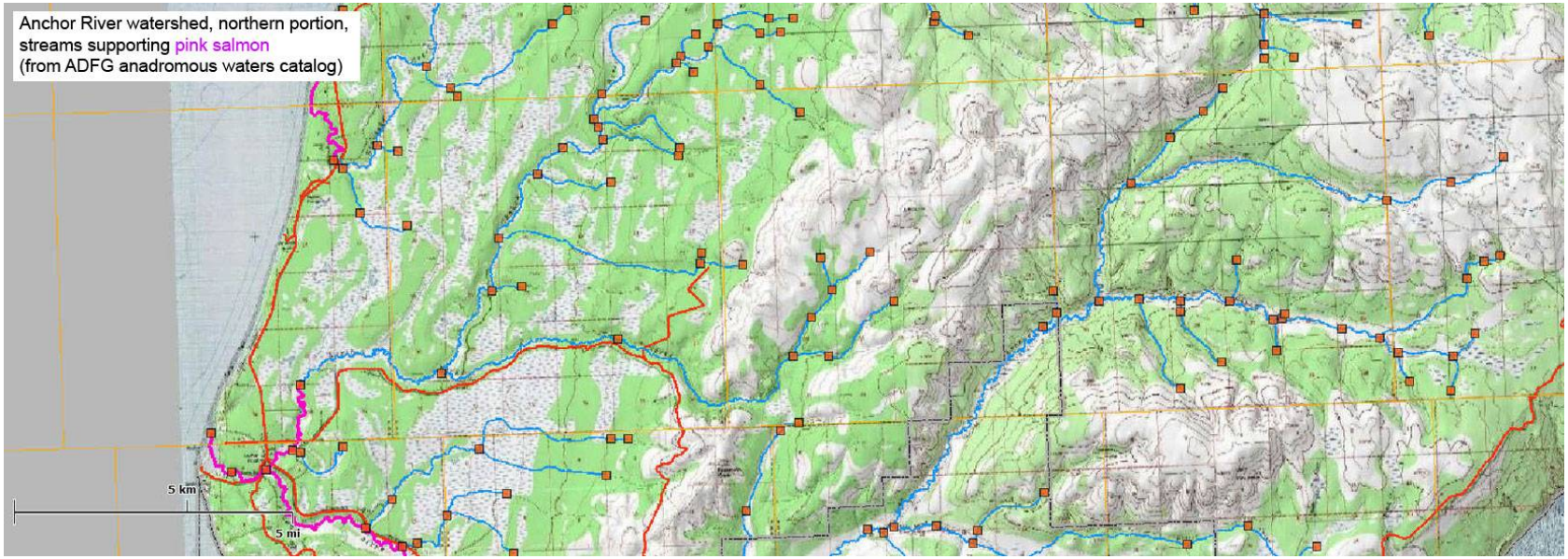
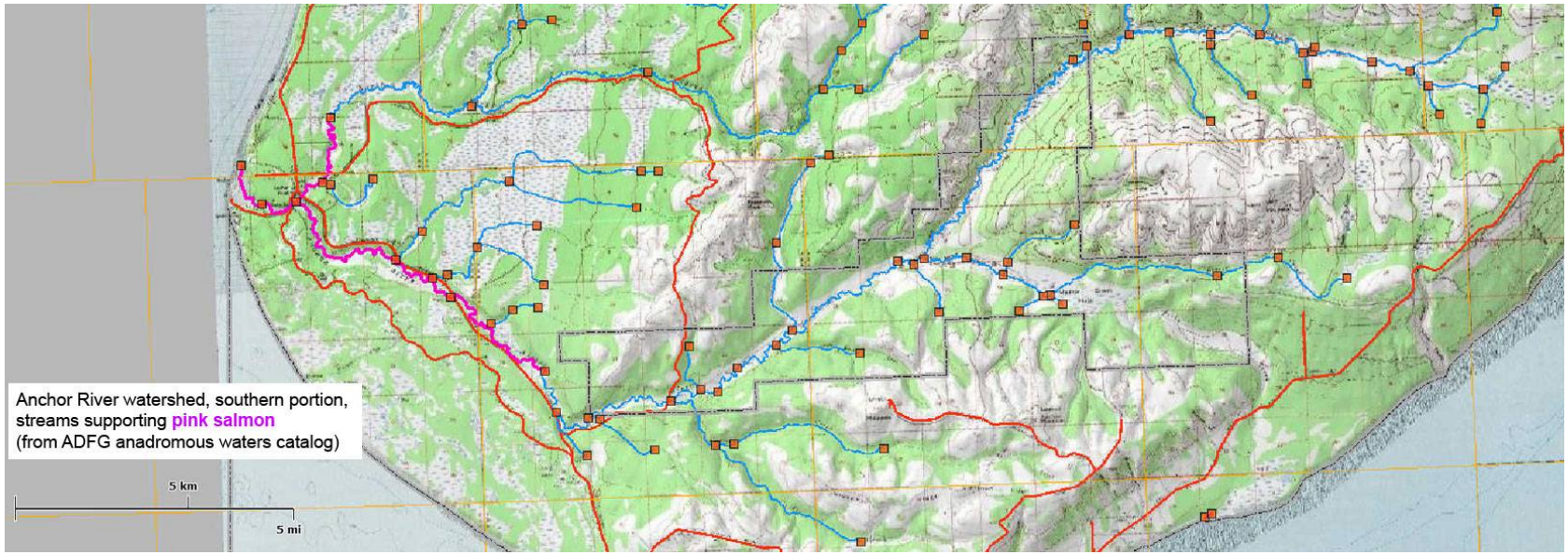
ANCHOR RIVER—northern (top) and southern (bottom) stream channels identified in the AWC for pink salmon.





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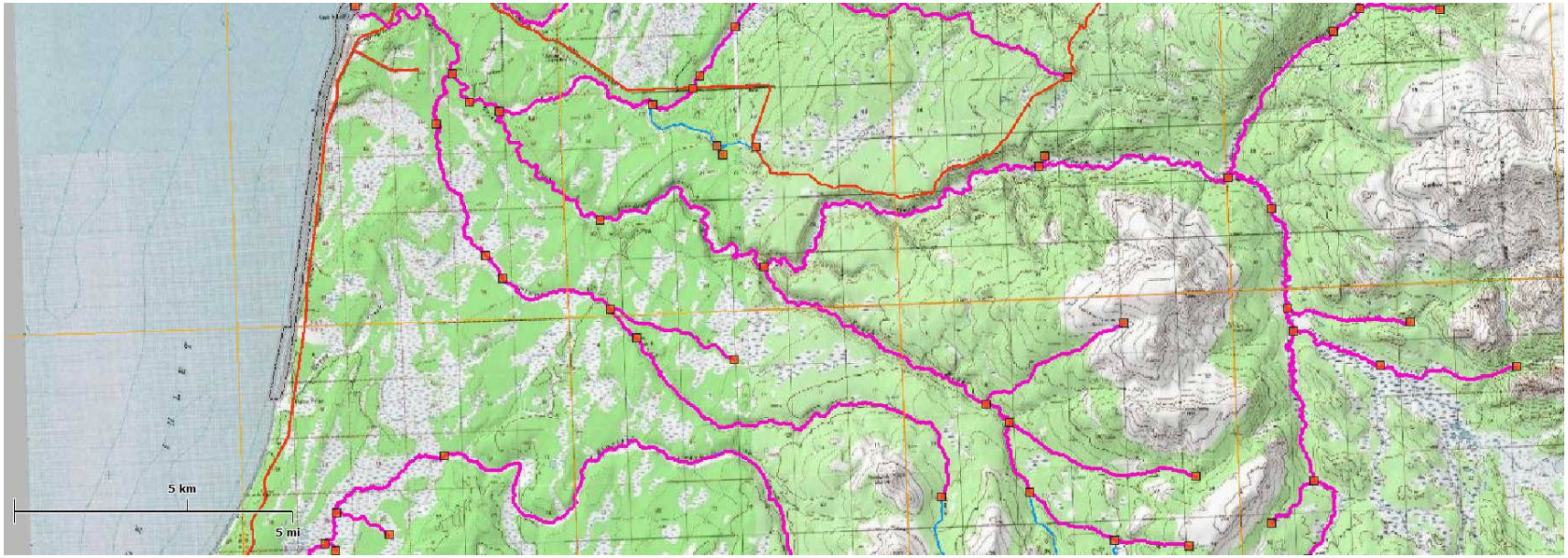
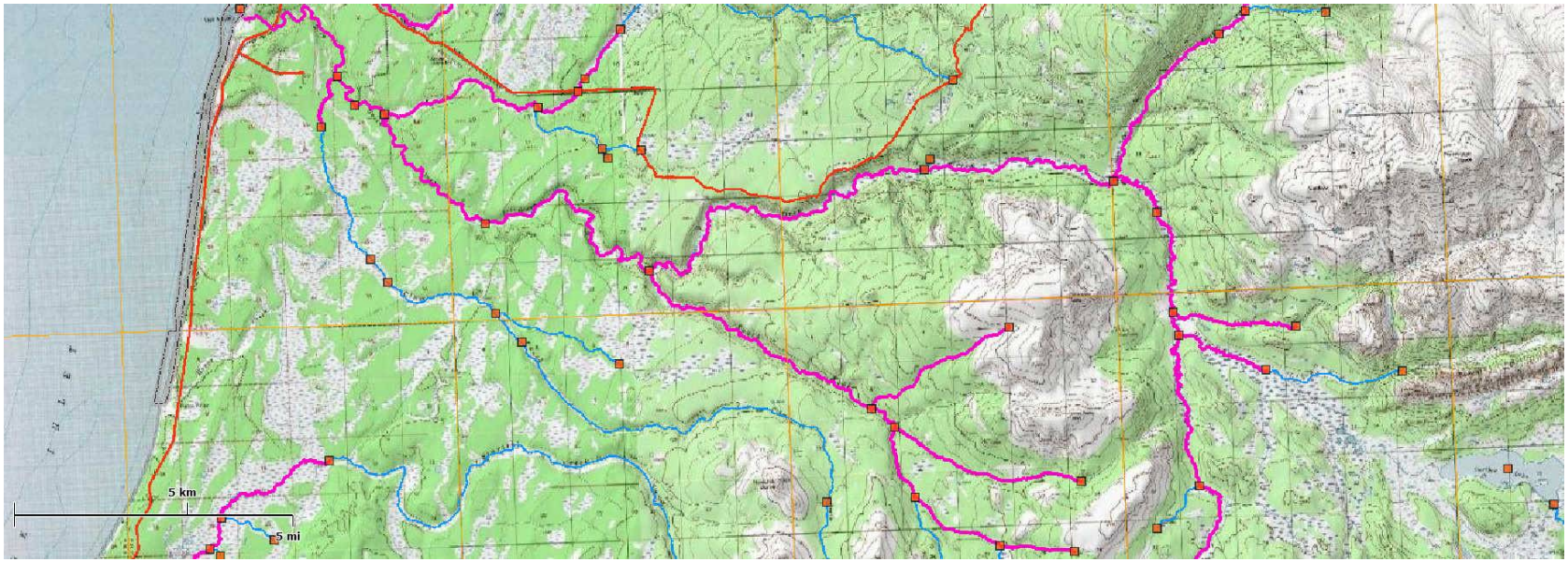
DEEP CREEK—stream channels identified in the AWC for coho salmon (top) and chinook salmon (bottom).





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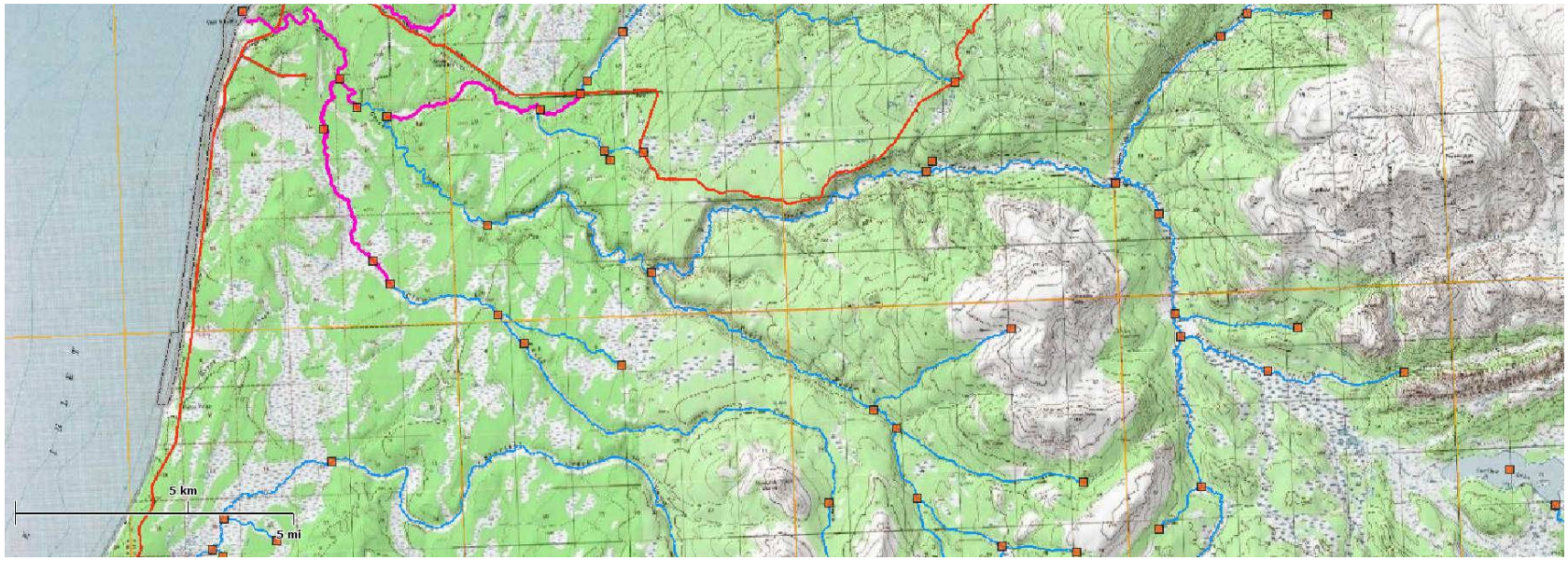
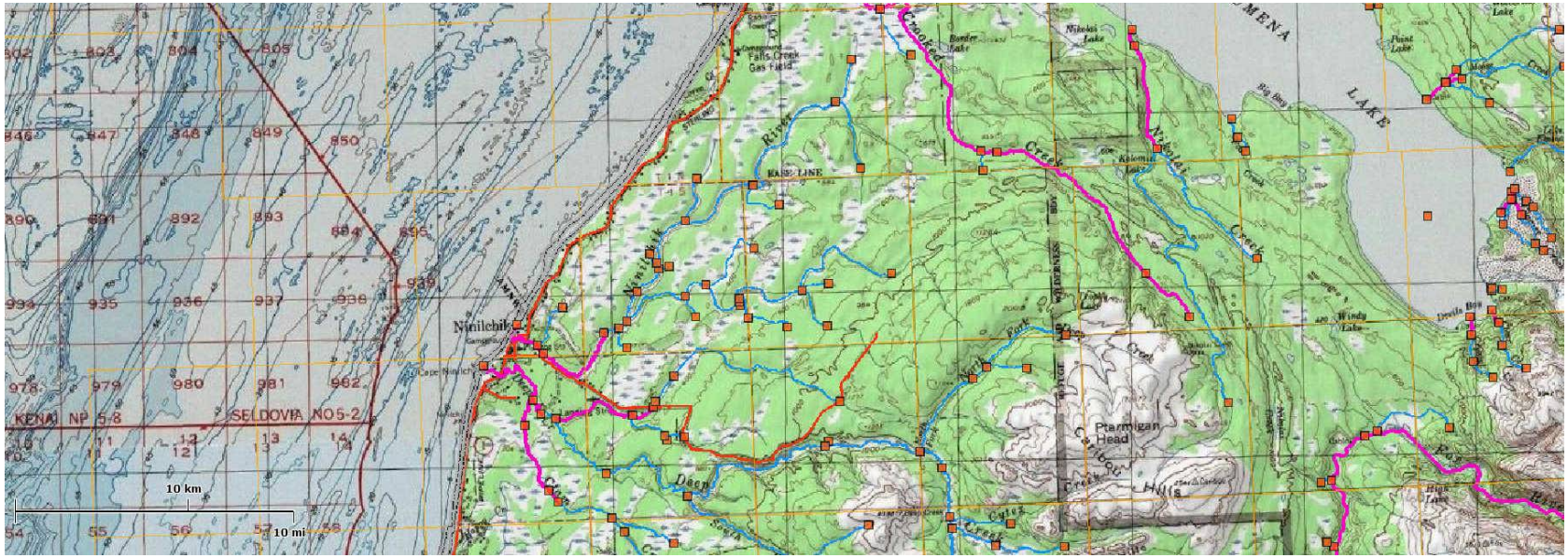
DEEP CREEK (top) and **NINILCHIK RIVER** (bottom)—stream channels identified in the AWC for pink salmon.





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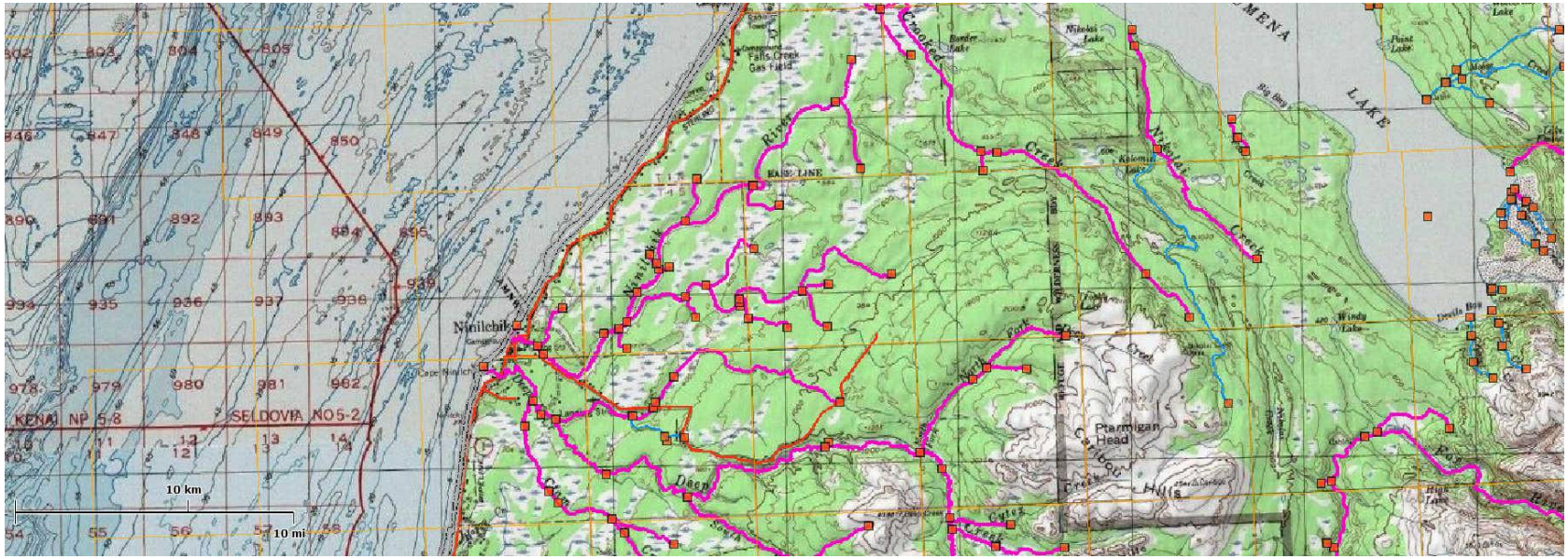
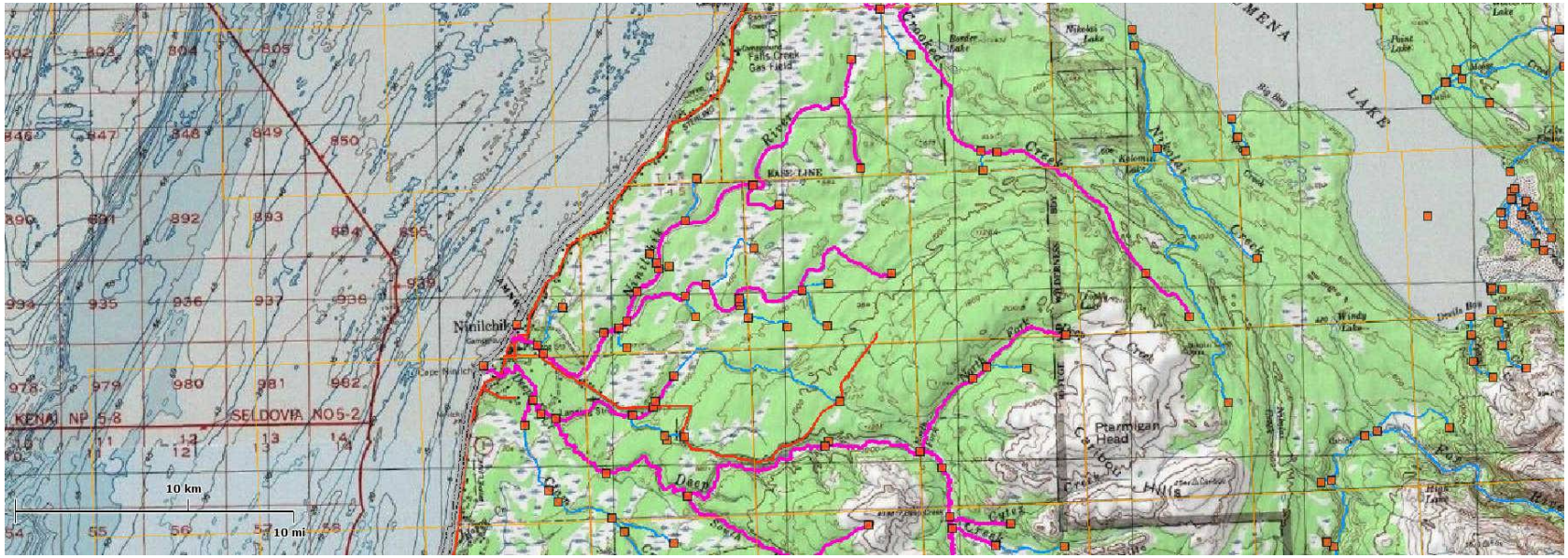
NINILCHIK RIVER—stream channels identified in the AWC for coho (top) and chinook (bottom).





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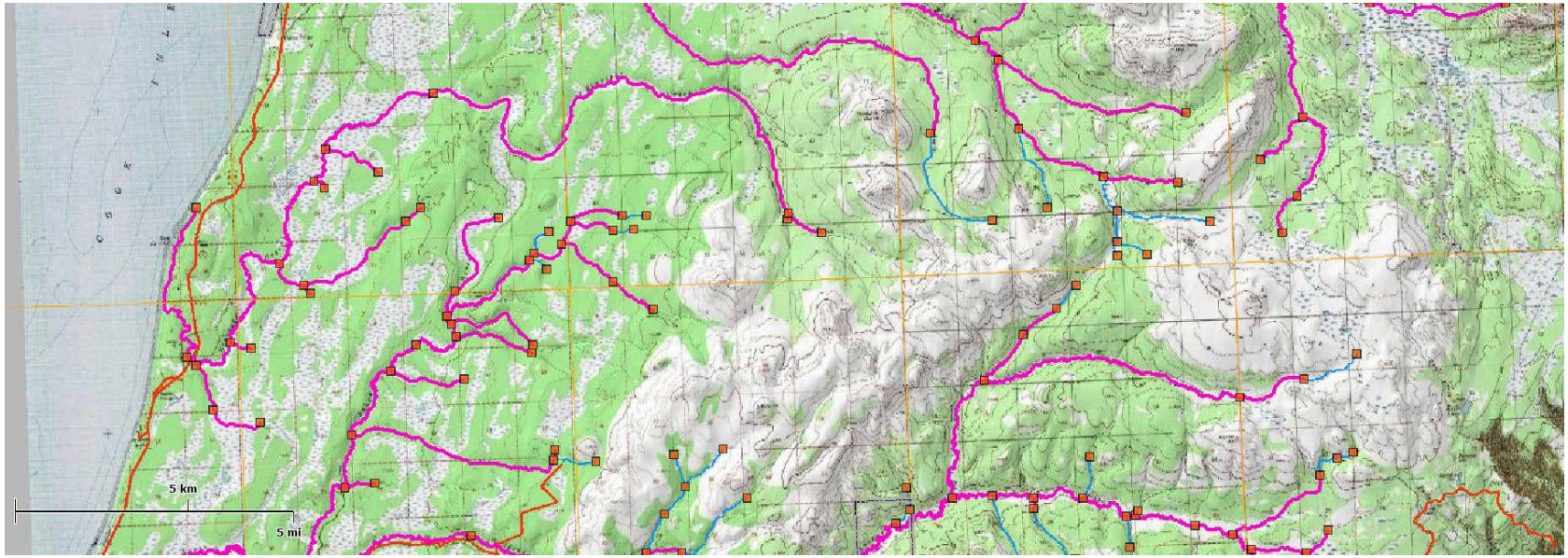
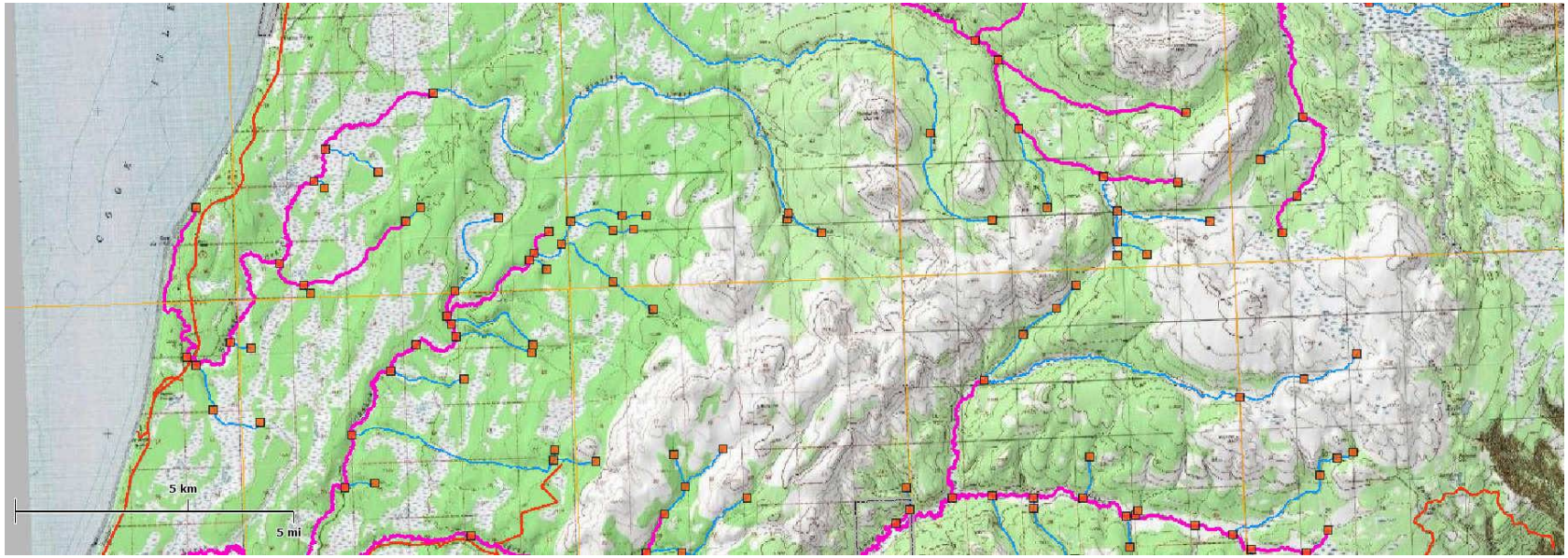
STARISKI CREEK—stream channels identified in the AWC for coho (top) and chinook (bottom).





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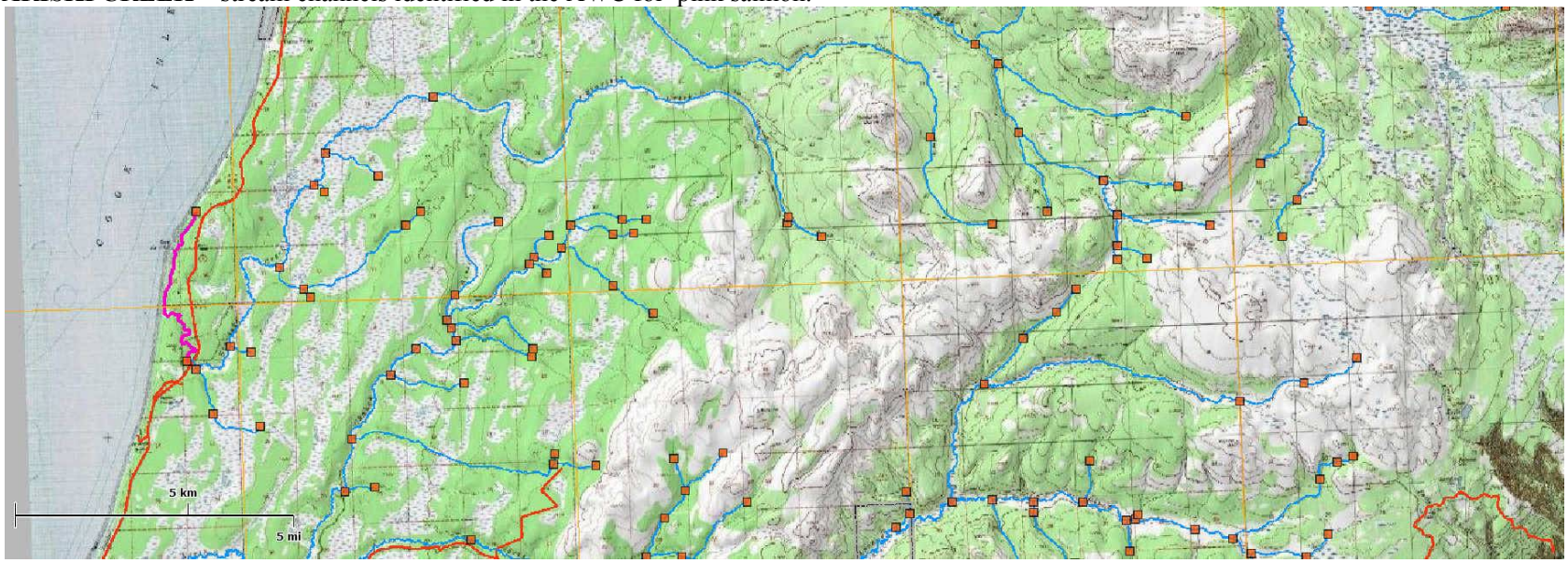
STARISKI CREEK—stream channels identified in the AWC for pink salmon.



Anchor River

(see also Anchor River watershed, Anchor River Restoration Project, and Estuary; as well as entries on Stream channel processes, Wetlands, and other topics related to streams and rivers)

If you are a landowner along the Anchor River, you know what a remarkable river it is. As the table below shows, the Anchor River is the largest of the four watersheds south of Kasilof River and north of Kachemak Bay. Draining a watershed of about 225 square miles (roughly 144,000 acres), the Anchor River supports healthy populations of three salmon species—chinook (king), coho (silver) and pink, as well as Dolly Varden, steelhead trout, and resident fish such as sticklebacks and sculpin. (Steelhead are rainbow trout that leave freshwater to mature at sea and then return to freshwater to spawn; but unlike salmon, many steelhead survive after spawning and migrate back to sea.) Chinook salmon escapement in the Anchor River watershed has ranged from about 3,500 to 12,000 from 2003 to 2009, and coho escapement, from about 2,700 to 19,000 from 2004 to 2009. The South Fork watershed (which is about twice the size of the North Fork watershed) supports about 84% of the chinook and 88% of the coho salmon escapement (http://alaska.fws.gov/fisheries/fish/Data_Series/d_2011_8.pdf). The Anchor River is believed to support the largest native chinook salmon run in ADF&G's Lower Cook Inlet Management Area.

The Anchor River provides a variety of salmon habitats, from tiny headwater streams where juvenile coho can be found feeding on aquatic insects, to gravel streambeds where chinook return to spawn, to its estuary—where the Anchor River mixes with saltwater from Cook Inlet, and where salmon smolts undergo complex physical and behavioral changes to get ready for life at sea. Researchers estimate that roughly 75,000 chinook and 51,000 coho smolts outmigrated from the Anchor River during June and July 2010 (http://alaska.fws.gov/fisheries/fish/Data_Series/d_2011_8.pdf). When adult salmon return, the estuary becomes their staging area as they prepare for their upstream journey to spawning grounds.

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Because of the great productivity and complexity of Anchor River salmon habitats, a number of studies are now underway to better understand how and when different salmon life stages use the Anchor River system. Some of these studies are mentioned elsewhere in this watershedipedia, for example, studies of stream temperatures, headwaters, and the Anchor River estuary. For a fascinating compilation of ongoing studies, look at "What's New in the Bay" (WNITB) online at: http://www.guru.uaf.edu/kbay/2010%20KBAY%20Research%20Overviews.pdf. WNITB provides short summaries, most with illustrations, of salmon-related research projects and ongoing management activities related to the Anchor River. Another interesting project on the Anchor River was the restoration of a segment of river channel that had been diverted into a gravel pit by 2002 flooding, see Anchor River Restoration Project. Much of the research going on in the Anchor River watershed is summarized in *introductory article 4: Research in your watershed*. A webcam of the Anchor River can be found at http://www.anchorriverinn.com/lgcam.htm.

The table below provides general statistics about the Anchor River and neighboring river systems (which makes it easy to compare them); the table includes watershed size, length of river mainstem, and total length of mainstem plus tributaries. Remember that determining watershed area or river length is somewhat subjective and depends on the scale and resolution of maps or images being used. With respect to river length, even if you can find the channel that defines the river's longest segment, you may not be able to find where that channel really starts, since headwater streams can be tiny and hidden deep under a layer of peat or beneath overhanging vegetation. Information in the table below is from the Kenai Watershed Forum's excellent atlas, which includes a wealth of information about every watershed on the Kenai Peninsula, see (http://www.kenaiwatershed.org/Atlas/index.html). The KWF atlas is described in *introductory article 3: Exploring your watershed with online tools*.

The landscape through which the Anchor River flows is characterized by landforms profoundly shaped by glaciers, earthquakes, fires, and flooding. Some of these processes are discussed in this watershedipedia. Equally important to salmon are more subtle natural processes, like interception, infiltration, and stream channel processes that create and maintain productive salmon habitats. Landowners can take many actions to maintain these more subtle natural processes in salmon friendly ways, as discussed throughout this watershedipedia (see, for example, Best Management Practices, Buffers, Low Impact Development, and Raingardens).

A photo of the Anchor River (source: http://www.alaskaanchorriverland.com/).

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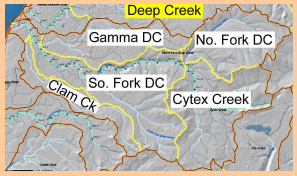
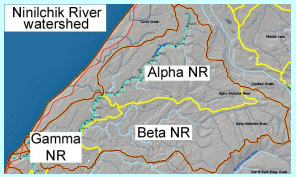
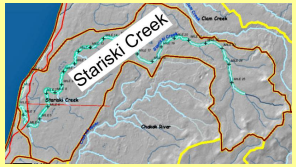
Comparison of five Kenai Peninsula watersheds and rivers.

(Really big rivers like the Yukon have immense watersheds—the Yukon drains about 225,000 sq mi.)

If you're looking at this table as a pdf, you can zoom in to see the thumbnail maps in more detail.

Source for maps and all information summarized below is the Kenai Watershed Forum atlas: www.kenaiwatershed.org/atlas.html.

	Anchor River (AR)	Deep Creek (DC)	Ninilchik River (NR)	Stariski Creek (SC)	Kenai River
Watershed length: Rough length as the crow files **Watershed Area:** Areas are shown in sq miles. To calculate acres, multiply sq mi by 640 (1 sq mi = 640 ac). Area changes with more detailed mapping.	 Watershed length ≈ 29 mi	 Watershed length ≈ 26 mi	 Watershed length ≈ 22 mi	 Watershed length ≈ 14 mi	 Watershed length ≈ 80 mi
Total watershed area: sq mi	**About 225 sq mi**	**About 218 sq mi**	**About 137 sq mi**	**About 52 sq mi**	**About 2,119 sq mi**
Subwatershed 1 area	North Fork AR 31	North Fork DC 38	Alpha-NR 53		(43 subwatersheds are mapped in the KWF atlas, http://www.kenaiwatershed.org/Atlas/index.html#.)
Subwatershed 2 area	West Anchor R 55	South Fork DC 67	Beta-NR 62		
Subwatershed 3 area	East Anchor R 65	Gamma-DC 34	Gamma-NR 22		
Subwatershed 4 area	Chakok River 38	Cytex Creek 58			
Subwatershed 5 area	Beaver Creek 20	Clam Creek 21			
Subwatershed 6 area	Twitter Creek 16				
River mainstem length "as-the-boat-floats" miles*	**About 62 miles**	**About 40 miles**	**About 26 miles**	**About 26 miles**	**About 81 mi to Kenai Lake**
Combined length of main-stem and tributaries	308 miles	270 miles	162 miles	67 miles	1,648 river miles
Subwatershed 1 length	North Fork AR 39	North Fork DC 56	Alpha-NR 52		(43 subwatersheds are mapped in the KWF atlas, http://www.kenaiwatershed.org/Atlas/index.html#.)
Subwatershed 2 length	West Anchor R 84	South Fork DC 83	Beta-NR 82		
Subwatershed 3 length	East Anchor 78	Gamma-DC 35	Gamma-NR 28		
Subwatershed 4 length	Chakok River 54	Cytex Creek 72			
Subwatershed 5 length	Beaver Creek 31	Clam Creek 24			
Subwatershed 6 length	Twitter Creek 22				

* River length information is from the National Hydrography Dataset (NHD) at a map scale of 1:63,360; measurements will change as more detailed maps are generated.

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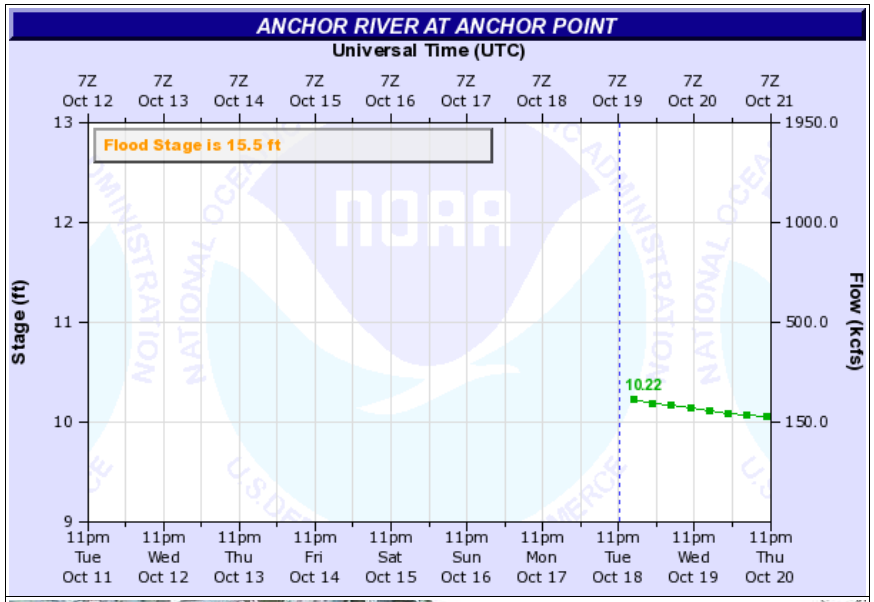
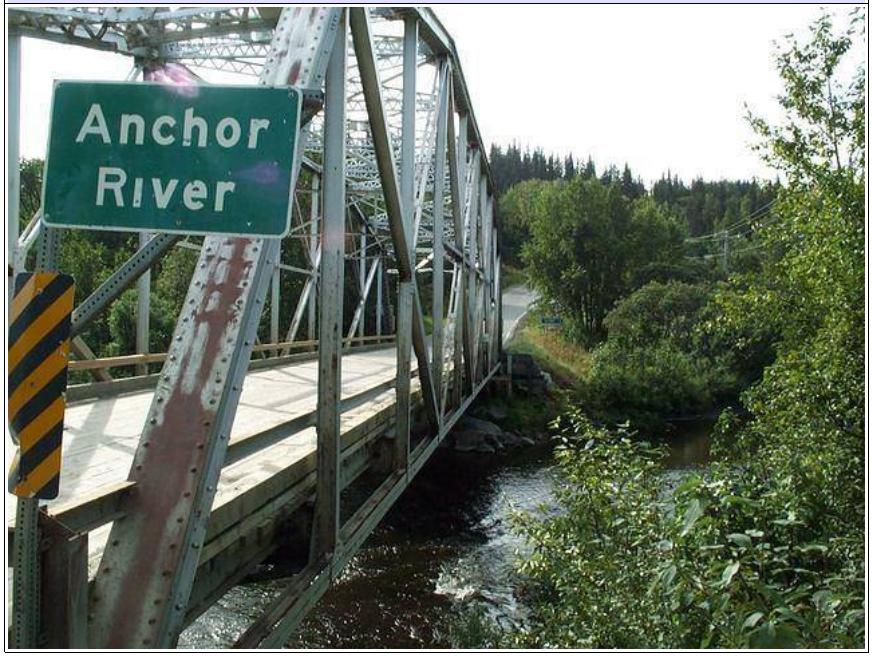
Alaska's Advanced Hydrologic Prediction Service collects flow information on the Anchor River (see http://water.weather.gov/ahps2/ hydrograph.php?wfo=pafc&gage=apba2). Data and photos below are from that site.

Historical Flood Crests	Low Water Records
(1) 19.15 ft on 10/24/2002	(1) 8.32 ft on 08/17/1984
(2) 18.50 ft on 01/20/1961	(2) 8.50 ft on 07/22/1960
(3) 16.90 ft on 03/07/1963	(3) 8.56 ft on 08/21/1955
(4) 15.50 ft on 04/20/1996	

Selected flood categories at National Weather Service gage
18 ft: Major flood stage. Water floods entire campground and several cabins downstream (DS) of the gage.
17 ft: Moderate flood stage. Highways in the area will start to have problems. New Sterling Hwy near mile 160 usually washes out above this stage.
15.5 ft: Minor flood stage. Width of river is 75 feet. Water starts to flood state campgrounds DS of bridge.
14.5 ft: Bankfull stage.

National Weather Service stream gage = 0 ft, the gage is located on the Old Sterling Highway bridge. Photo below is looking upstream from the bridge.





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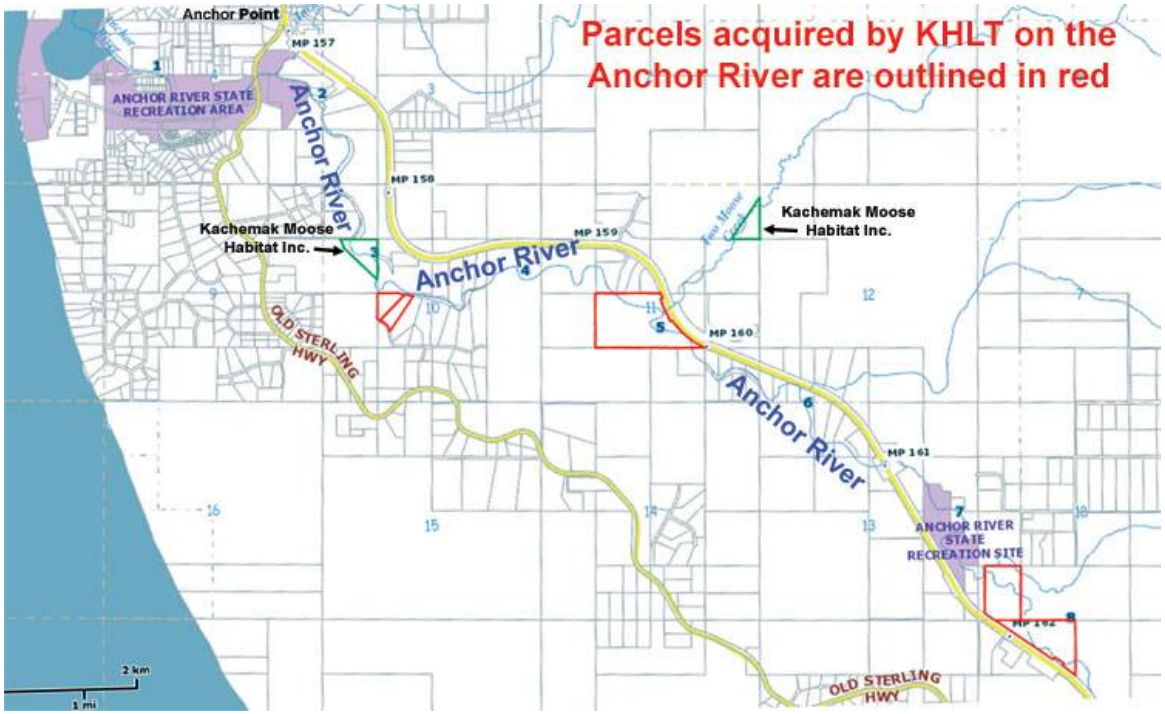
Anchor River Conservation Corridor

As part of its "connecting the dots" initiative (http://kachemaklandtrust.org/pages/protecting-land.php), Kachemak Heritage Land Trust is working to create an Anchor River conservation corridor connecting as many conservation units as possible. KHLT works with willing landowners who want to pass on a legacy for future generations. KHLT now owns a total of 131 acres that together preserve 2 miles of the Anchor River; it has also helped other conservation organizations acquire 68 acres that span an additional mile of river and contain wetlands important to the river's health. These acquisitions help fill gaps in the river corridor protected by the Alaska Department of Natural Resources and the State Parks system.

KHLT's most recent purchase was the 11.76–acre Martin property, located off the Old Sterling Highway in Anchor Point. This property is the first acquired for permanent conservation through KHLT's Lower Peninsula Wetlands Fund. Its selection as a priority parcel was based on its proximity to existing conservation units and on research by Kachemak Bay Research Reserve, Homer Soil and Water Conservation District, and Cook Inletkeeper. Initial assessment of the habitat values of the Martin property, and prioritization of parcels along the Anchor River, were supported through a cooperative agreement between the U.S. Fish and Wildlife Service Coastal Program and KHLT. In addition, KHLT, working with Homer Soil and Water and Cook Inletkeeper, overlaid previously mapped Anchor River priority areas with river reaches more recently identified as providing cool water habitats. Areas of cooler water are becoming increasingly important to salmon as stream temperatures rise in response to climate change. KHLT uses information about priority areas to identify which Anchor River landowners to contact.

The Martin property contains Anchor River frontage and side channels, with 9 acres of discharge slope wetlands, all important for salmon and water quality. Research by Kachemak Bay Research Reserve, in collaboration with Baylor University and the Smithsonian Environmental Research Center, found that it is important to maintain a diversity of habitats for juvenile salmon that spend at least a year in freshwater. The Anchor River bottomland also provides winter moose browse and functions as part of a wildlife corridor from moose wintering grounds on the North Fork.



Purchase of the Martin parcel shows how landowners can work with KHLT to protect habitat for salmon and other wildlife. The Martin parcel is near the 64-acre Pate property, owned by the land trust, the 12-acre Clark property, owned by Kachemak Moose Habitat Inc., and across the river from state-owned land designated for moose habitat and public use by the state's Kenai Area Plan.

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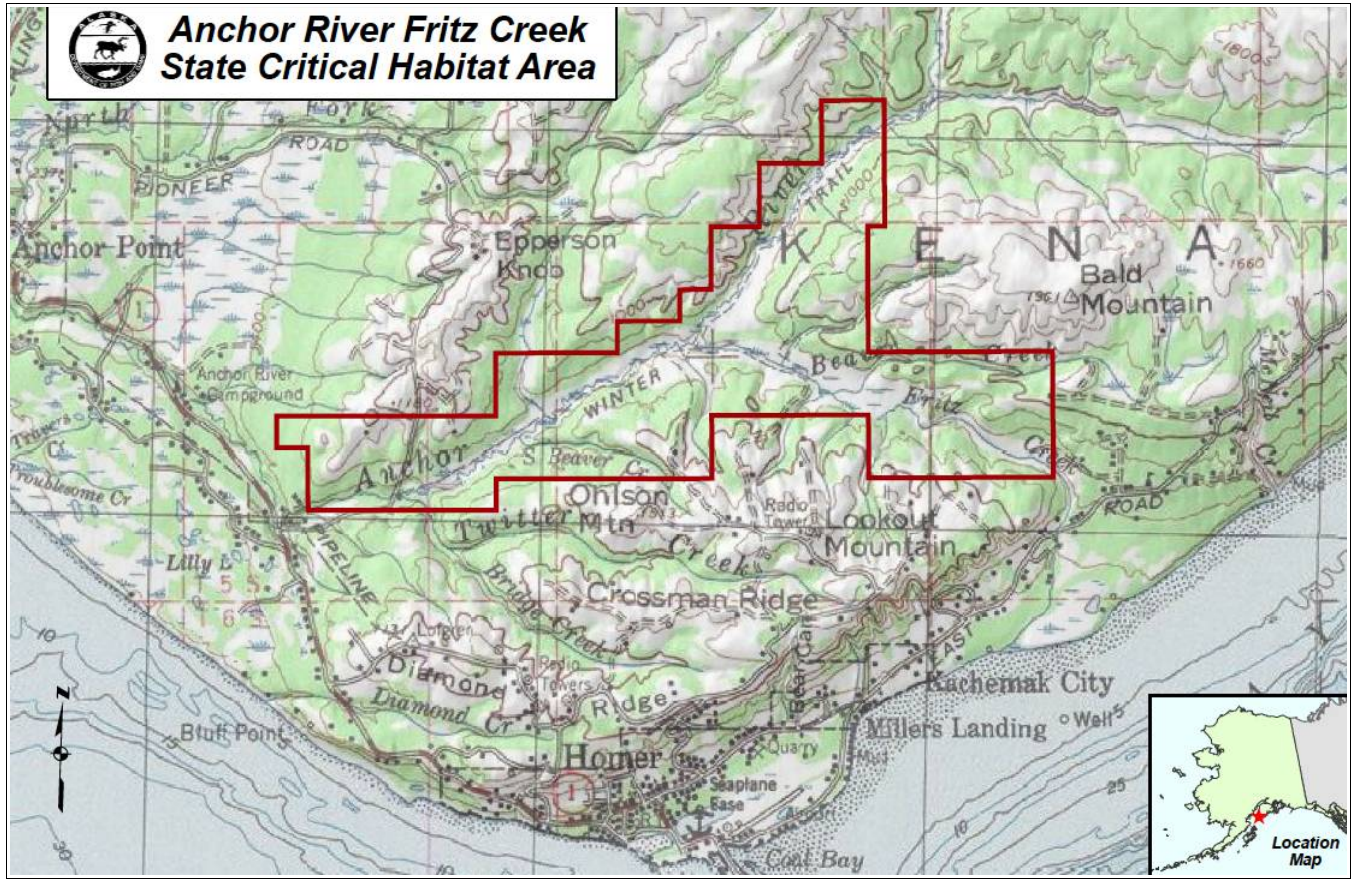
Anchor River-Fritz Creek Critical Habitat Area (CHA)

(see also ATVs and ORVs)

The Alaska legislature created the Anchor River-Fritz Creek Critical Habitat Area in 1985 to protect natural habitat critical to perpetuating fish and wildlife, especially moose; the area is one of the only major moose overwintering areas on the southern Kenai Peninsula. ADF&G oversees CHA management, and you can download the 1989 management plan at http://www.adfg.alaska.gov/static/lands/protectedareas/_management_plans/anchor_river.pdf. Trail access to the critical habitat area can be gained from the west via the North Fork Road loop, from the south via Ohlson Mountain Road and the Watermelon Trail, and from the southeast via the Lookout Mountain Trail. The Watermelon Trail and its relationship to salmon streams is discussed below. For more information about the CHA and for access to the map printed below, visit: http://www.adfg.alaska.gov/index.cfm?adfg=anchorriver.managementplan.

(Slightly modified from: http://dnr.alaska.gov/parks/misc/orv/appenda.pdf.) A popular trail into and through the Anchor River-Fritz Creek CHA is the Watermelon Trail. The Watermelon Trail is approximately 14.3 miles long and crosses six streams, four of which are cataloged as anadromous by ADF&G (see Anadromous Waters Catalog). The Watermelon Trail begins off Ohlson Mountain Road, north of Homer, and enters the critical habitat area after approximately 2 miles. The trail continues through the CHA, crossing Beaver Creek at a permitted location (FG Permit FG 05-II-GP12) at which Homer Soil and Water has installed an ATV bridge (crossing **through** the stream damages salmon habitats, see ATVs and ORVs). The trail exits the CHA approximately 2 miles past the Beaver Creek crossing. The trail generally follows ridgelines and high ground, however, watersheds in this area often run perpendicular to the trail, forcing trail users into low, wet, riparian areas and stream crossings. Most of the trail is located on state or borough land, however one section crosses private land. A project is underway to reroute the trail onto state land to resolve the trespass issue. (Contact Homer Soil and Water Conservation District for information about the planned trail re-route.)



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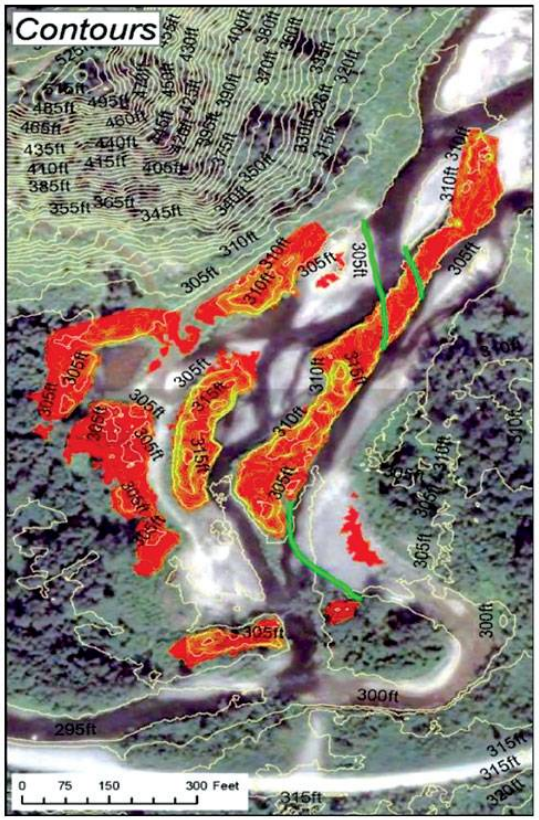
Anchor River Restoration Project

In the summer of 2011, the Kenai Watershed Forum (KWF) restored salmon habitats and natural conditions to a segment of the Anchor River. The river 's natural channel—which had supported chinook salmon spawning, Dolly Varden, and rainbow trout, as well as passage of coho salmon—had been degraded as a result of gravel mining and flooding. During extreme flood flows in 2002, this portion of river channel rerouted itself into and through a gravel pit and could no longer meander back into its natural channel. Funding for restoration was provided by the American Recovery and Reinvestment Act and involved moving more than 22,000 yards of material. For more information, see http://www.kenaiwatershed.org/currents/KWF_Spring2011_Currents_small.pdf. In addition, KWF has produced A 6-minute video of their restoration work:http://www.youtube.com/watch?v=tIDSufAH4L4. The video includes interviews about the project, as well as examples of streambank stabilization and restoration work KWF accomplished using soil bioengineering techniques.

Flooding had moved a segment of the Anchor River into a gravel pit, where berms left by gravel mining (shown in orange) altered streamflows and degraded salmon habitat (source: Kenai Watershed Forum).



The gravel pit opened in 1984—before borough regulations protected anadromous streams—and eventually covered 6 acres, with one edge less than 100 feet from the river. During gravel mining, several berms were constructed by piling overburden and vegetation stripped off to get to underlying gravel layers. Berms as high as 15 feet covered about 4 acres. Until 2002, the largest berm acted as a levee that kept the Anchor River out of the gravel pit. The river breached this berm during 2002 flooding and created a new channel. In 2007 an upstream logjam created during another flood redirected most of the river's flow into what had been a small side-channel. This channel funneled the thalwag (the deepest part of a river where water flows fastest and has the most force) directly at the large berm, causing erosion that washed sediments into the river.

As these changes occurred, stream channel "anatomy" became less and less suited for salmon. The river grew more braided. Increased sediment loads threatened to bury spawning gravels, abrade fish gills, and reduce feeding success of juvenile salmon (juvenile salmon hunt by sight and have trouble finding food in water with increased turbidity. Other impacts included potential stranding of juvenile fish in braided channels during low flows, loss of riverbank vegetation needed by juvenile fish for food and cover, and changes in streamflows and stream temperatures, which could reduce survival of eggs and rearing juvenile salmon. To top it off, this stretch of the Anchor River was no longer connected to its natural floodplain. In 2002, the Alaska Department of Natural Resources had purchased this gravel pit with Exxon Valdez Oil Spill money to prevent further degradation. As a result, KWF, working with ADF&G and the USFWS, was able to determine how best to restore natural channel conditions so that the river could once again function within its natural range of variability.

Restoration was designed to (1) level the berms that were preventing the river from returning to its historic, natural course; (2) lower channel gradient to pre-flood levels; and (3) stabilize the channel by reinforcing its banks with rock, vegetation, and root wads. Work was done during low flows in late June and early July of 2011. Almost immediately after project completion, schools of juvenile fish were observed in re-established pools, and chinook salmon were seen preparing to spawn in recreated riffles (see Pool and riffle channel pattern). By enabling the river once again to function as it had before the gravel pit "captured" the channel, KWF and its partners were able to restore salmon habitat in this stretch of river.

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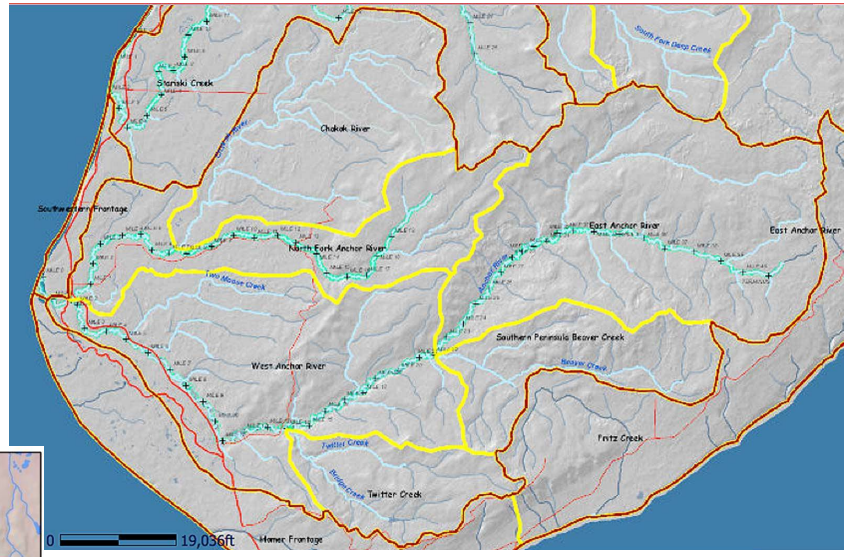
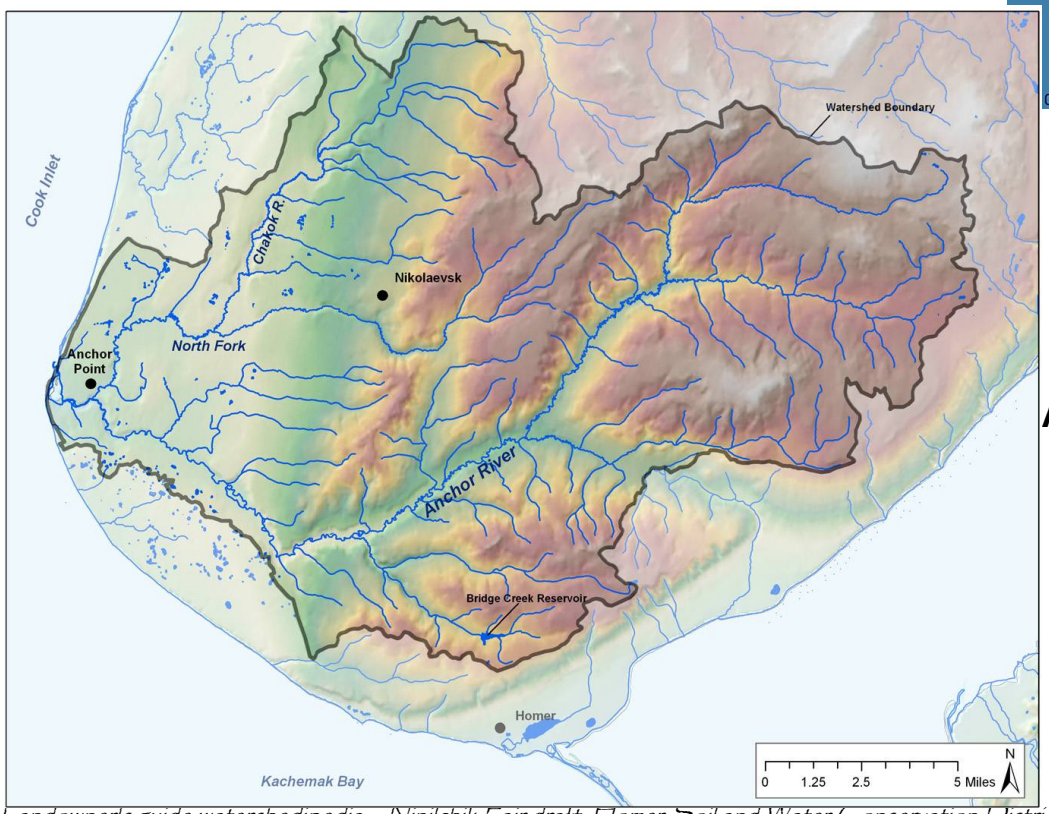
Anchor River watershed

(see also Anchor River)

The Anchor River watershed consists of all areas from which surface and subsurface waters (rainfall, snowmelt, groundwater, etc.) flow into the Anchor River, and from there out to Cook Inlet. The watershed encompasses about 225 square miles (roughly 144,000 acres). About half of this is below 1000 ft in elevation (73,000 ac), and about half is above (71,000 ac). The watershed has headwaters in the Caribou Hills and includes at least 164 miles of anadromous (salmon-bearing) streams (see Kenai Watershed Atlas). About 48% of the watershed has been mapped as wetlands.

The Kenai Watershed Atlas divides the Anchor River watershed into six subwatersheds: Chakok River, North Fork Anchor River, West Anchor River, East Anchor River, Beaver Creek, and Twitter Creek. These are shown outlined in yellow on the **map above,** which can be viewed with maps showing many other kinds of information at: http://www.kenaiwatershed.org/Atlas/index.html#) (see *introductory article 3: Exploring your watershed with online tools*). The **map at left** shows shaded topographic relief in the watershed (source: Kachemak Bay Research Reserve).





Aquifer

(see also Baseflow, Groundwater, Hyporheic flow and zone, Water cycle)

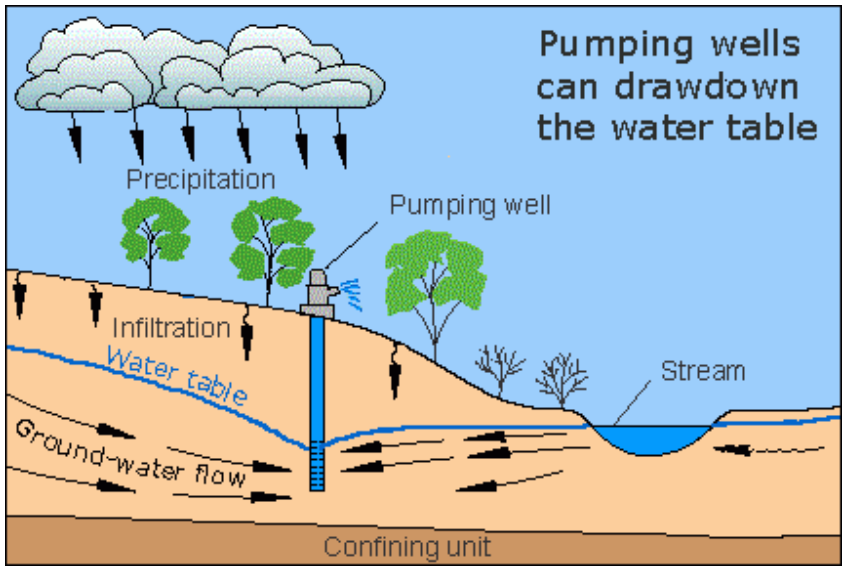
An aquifer is a layer of rock, sediment, or soil that can store water. Rock and sediment layers have different porosities and permeabilities, which means that below ground, water does not move around in all rocks the same way. The term *groundwater aquifer* refers to underground layers that are saturated; that is, all available spaces and pores are filled with water. The upper surface of this zone of saturation is called the *water table*. The level of the water table can rise and fall due to changes in weather cycles, precipitation patterns, streamflow, geologic changes (e.g., earthquakes),

and human activities (e.g., increases in impervious surfaces on the landscape or in pumping of water out of wells, see below). Depending on an aquifer's geologic and hydrologic conditions, the impact of such changes on the level of the water table can be short lived or long term, and the water table can change a small amount or hundreds of feet. Aquifers are very important to salmon and other fish that use freshwater habitats because during dry seasons, the water flowing in a stream (its *base flow*) may come entirely from groundwater flowing out of an aquifer.

Water movement in aquifers is very dependent on the *permeability* of aquifer material. Permeable material contains interconnected cracks or spaces that are both numerous enough and large enough to allow water to move freely. In highly permeable materials (like sand and gravel), groundwater may move several feet in a day; in material with low permeability (like clay), it may move a fraction of an inch a century. But even permeable materials can perch a water table (that is, block the downward percolation of groundwater). This can happen where a *textural discontinuity* occurs, meaning, a layer of one texture overlies a layer with a different texture. A discontinuity like this will perch a water table even if the underlying layer is MORE permeable than the layer above, like where sand overlies gravel. This is because, before water can begin to flow into the gravel below, the sand must become completely saturated. This surprising phenomenon has been shown many times by layering sand and gravel between two panes of glass, then pouring water on top and observing the resulting saturation pattern.

(The rest of this entry is modified from: http://ga.water.usgs.gov/edu/earthgwaquifer.html.) The **photo at left** shows a "well" that exposes the water table, with an aquifer beneath it. At the beach —where this hole was dug—the top of the water table is always the same level as the ocean.

Wells can be drilled into aquifers and water can be pumped out. Precipitation eventually adds water (recharge) into the porous rock of the aquifer. The recharge rate (how fast water soaks into the ground and reaches the aquifer) is not the same for all aquifers and affects what happens when pumping water from a well. Pumping too much water too fast draws down the water in the aquifer, as shown in the **drawing at right**. This can cause a well to yield less and less water over time and even to run dry. Pumping a well too fast can also cause a neighbor's well to drop or run dry too if both wells are pumping from the same aquifer.



Note in the **drawing at right** that as the water table is drawn down by pumping the well, the water table in the nearby stream may also drop. This reduction in streamflow can reduce the health and numbers of fish in the stream. Obviously, as more wells are installed and pump more water out of aquifers that feed salmon streams, streamflows will show more change and salmon populations will show more impacts.

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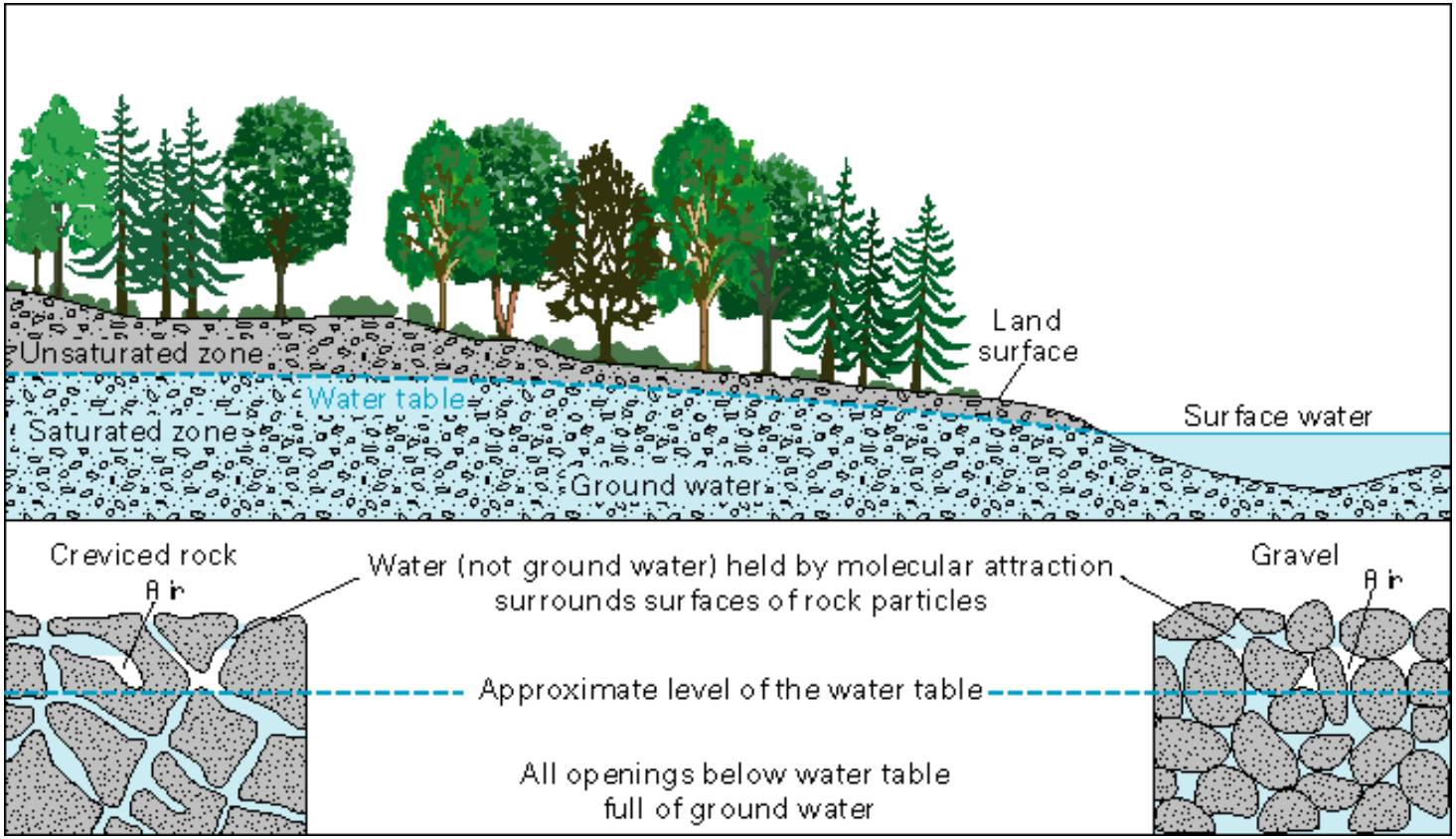
In the **drawing below**, you can see how the ground below the water table (the blue area) is saturated with water. The "unsaturated zone" above the water table (the gray area) still contains water (after all, plants' roots live in this area), but it is not totally saturated with water. You can see this in the **two drawings at the bottom of the diagram**, which show a close-up of how water is stored between underground rock particles.

Sometimes porous rock layers become tilted in the earth. There might be a *confining* layer of less porous rock both above and below the porous layer that stores water. This is an example of a *confined aquifer*. If a well is drilled into this "pressurized" aquifer, the internal pressure might (depending on the ability of the rock to transport water) be enough to push the water up the well, and even up to the surface, without the aid of a pump. If water from the well flows up to the surface, the well is called *artesian*. The pressure of water from an artesian well can be quite dramatic.

A relationship does not necessarily exist between the water-bearing capacity of rocks and the depth at which they are found. A very dense granite that will yield little or no water to a well may be at the land surface; a porous sandstone may be hundreds or thousands of feet below the land surface and may yield hundreds of gallons per minute of water (although the water may have taken many years to reach this aquifer from the recharge areas connected to it). On average, however, the porosity and permeability of rocks decrease as the depth below land surface increases; the pores and cracks in rocks at great depths are closed or greatly reduced in size because of the weight and pressure of overlying rocks.



This image, along with the related discussion above, is from http://ga.water.usgs.gov/edu/earthgwaquifer.html.

Army Corps of Engineers (ACE, ACOE, COE, the Corps)

(see also Agencies with responsibilities for watershed resources, Wetland permits)

The US Army Corps of Engineers performs many roles, including design, engineering, and construction of many kinds of structures , as well as planning and conducting environmental clean-up. The Alaska District of the Corps summarizes its activities on its homepage: http://www.poa.usace.army.mil/hm/default.htm. Here we'll focus only on the Corps' role in reviewing and granting (or denying) permits for certain kinds of activities in wetlands. Many landowners have heard of "Corps wetland permits" or just "wetland permits," and probably most think that getting a permit from the Corps will be complicated and intimidating. That doesn't need to be the case, as is outlined below. But first a little background is useful: Dredge and fill activities in waters of the United States, including wetlands, are regulated under Section 404 of the 1972 Clean Water Act. This is because wetlands perform many important environmental functions and provide many values. Supporting salmon habitat, as discussed under wetland functions and values, is one example of what wetlands do that are important to us all. Digging in wetlands (dredging, trenching, ditching, etc.) or dumping material on top of them (filling) disrupts or destroys wetland functions and values. To prevent (or sometimes mitigate) this kind of damage, the US Army Corps of Engineers, along with the Environmental Protection Agency (EPA), implements Section 404 by requiring "404 permits" for activities involving dredge and/or fill in "jurisdictional wetlands" (see wetlands). The Corps encourages other agencies, local governments, and the public to comment on 404 applications. Agencies that frequently review these applications include the Alaska Departments of Fish and Game, Environmental Conservation, and Natural Resources, Mining, Land and Water; the US Fish and Wildlife Service (USFWS), and the National Marine Fisheries Services (NMFS), along with local governments like the Kenai Peninsula Borough.

How do you get a Corps wetland permit?

The Alaska District of the Corps maintains a website with all the information you need to figure out how to complete an application to build something—like a driveway—in a wetland on your property: http://www.poa.usace.army.mil/reg/Permits.htm. If what you plan to do will result in only minor disturbance to the wetland (e.g., you'll disturb less than ½ acre of wetland and your project is more than 500 ft from an anadromous stream or lake), you will probably be eligible for what's called a "nationwide permit" (NWP), which is usually approved in 30-45 days (see http://www.poa.usace.army.mil/reg/Permits.htm#Nationwide%20Permits). If all you plan to do is install a soil bioengineering practice, for example to stabilize a stretch of streambank, you may only need to provide the Corps with a "preconstruction notification" (PCN); see http://www.poa.usace.army.mil/reg/permits/Nationwide%20Permits/Pre-Construction%20Notifications.pdf. Regardless, if your project is on the Kenai Peninsula, the Kenai office of the Alaska District can answer questions that arise as you work through the information on the Corps' website. The Kenai office is located at 805 Frontage Rd., #200C, Kenai, 99611; the phone number is: 907-283-3519; and the email address is CEPOA-RD-KFO.

Ash (volcanic)

(see also Erosion, Soil, Stormwater runoff)

Regular eruptions of volcanoes across Cook Inlet have deposited numerous ash layers on areas in the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. As a result, local soils are characterized by ash layers of varying thickness. Ash is highly susceptible to wind and water erosion if exposed, and erosion of ash sediments can reduce water quality and harm salmon.

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ATVs and ORVs (all-terrain and off-road vehicles) *(see also Caribou Hills trails)*

ATVs and ORVs are popular modes of travel for reaching backcountry areas for recreation, hunting, access to cabins, and other purposes. Many individuals who would not otherwise be able or likely to experience areas of remote beauty do so by accessing them on ATVs or ORVs.

As ATV and ORV use increases in our watersheds, however, landowners and ORV users need to understand the impacts these vehicles can have, particularly on streams and wetlands and the salmon that depend on them. Better understanding and management of ORV impacts are becoming increasingly important in keeping watersheds salmon friendly. The re-routed and largely boardwalk-covered Caribou Lake trail northeast of Homer is one example of how it's possible for community groups and agencies to work together to minimize ATV impacts on wetlands, but addressing such impacts will be a challenge given the increasing popularity and widespread use of ATVs and ORVs. (Contact Homer Soil and Water Conservation District for more background on the boardwalk on the Caribou Lake trail.)

Problems for salmon can become significant when users of ATVs and ORVs fail to understand or care how traveling over sensitive habitats, like across streams or through wetlands, can affect salmon habitats or the salmon living there. As the **photo at right** shows, ATV use can cause a variety of changes that harm salmon habitats and populations, as well as other fish and wildlife (photo source: Homer Soil and Water Conservation District). Problems for salmon can arise when ORV use causes:

- **increased erosion and sedimentation** along corridors where ORV use has destroyed plants and churned up soils (like in the photo above);
- **localized increases in sedimentation**, for example where ORVs cross stream channels and disturb sediments, which can then flow downstream and settle into nearby spawning gravels and redds. (Fine sediments can settle into the spaces between streambed gravels—the interstitial spaces—which prevents the flow of water between gravel particles. The free flow of water between particles is essential in order to surround incubating salmon eggs and emerging alevins with oxygen-rich water and to carry away metabolic wastes.)
- **alterations to streambanks** where bankside vegetation has been destroyed and bank shape has been altered;
- **alterations to stream channel "anatomy"** where ORV crossing has eroded back streambanks, creating a wider, shallower channel at the crossing location;
- **alterations to stream temperatures** in areas where overhanging vegetation or other shade from plants has been destroyed, particularly when combined with channel widening where ORVs cross through streams;
- **areas where ruts and quagmires alter natural surface flow patterns**, for example, ruts can intercept and divert surface flows, and both ruts and quagmires can intersect shallow groundwater, potentially altering water tables in nearby areas;

- **habitat destruction** where natural plants and terrain features are altered or destroyed;
- **habitat fragmentation** where undisturbed habitats are bifurcated by heavily disturbed and largely impassable ORV travel corridors (which can extend for considerable distances); and
- **active disturbance of streambeds and alterations of streambed conditions** where ORVs travel upstream or downstream within shallow stream channels themselves, using the channels as travel corridors (see the middle photo below).

ORV use (ATVs and other ORVs) has been surveyed in Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. For example, in 2004 ADF&G and the Division of Parks assessed four ORV trails in Anchor River and Deep Creek watersheds (http://dnr.alaska.gov/parks/misc/orv/indexorv.htm). In 2002 ADF&G surveyed conditions of ORV-trail stream crossings on the Lower Kenai Peninsula (Wiedmer, 2002, ADF&G, Habitat Division, available at http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/02_02_draft.pdf). Within the Lower Kenai Peninsula study area (shown in maps that follow), ADF&G identified 324 ORV stream crossings, 56 of which had multiple channel crossings. Most crossings (63%) were in upper watersheds, above 1000 ft elevation. The majority of crossings (290 sites or 61% of the total) were on state land, followed by Native land (65 crossings, 14% of the total). The study found that crossing impacts were concentrated spatially, with 72% of all sites that scored 5 (the most severely damaged) located within only 12% of the study area, much of this is in the upper watersheds of Deep Creek and Anchor River. **Photos below** are from that study and show impacts related to ORV use.

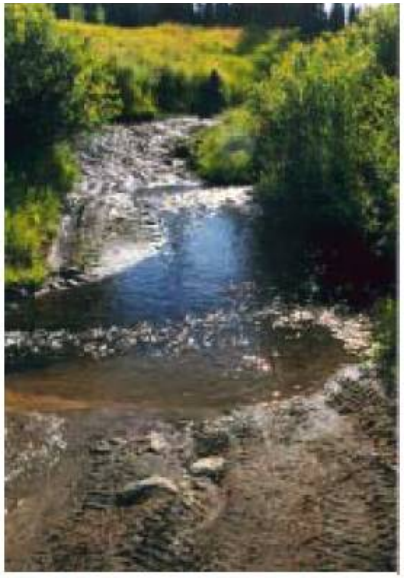

Figure 3.-Sediment entry into coho salmon spawning and rearing habitat in the Upper Anchor River.

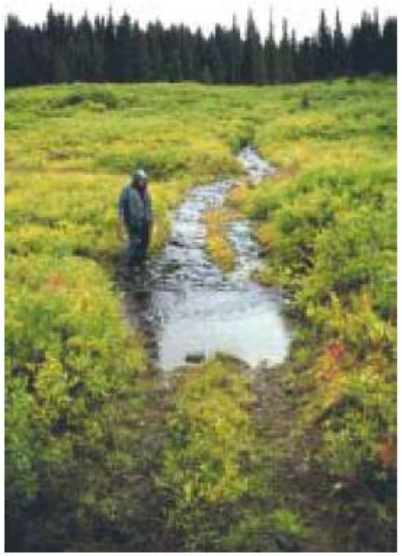

Figure 4.-Stream channel used as ORV trail, Upper Deep Creek watershed.

Figure 5.-ORV trail system paralleling South Fork Deep Creek.

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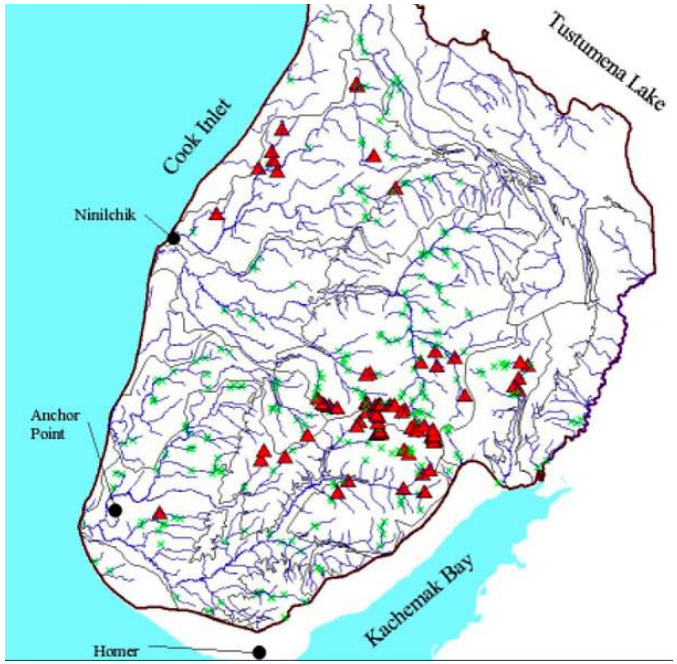
Figure 6.-High crossing densities across Deep Creek headwaters.

Figure 7.-ORV trail fanning in wetland adjacent to the Anchor River.

The **map at right** shows the study area (outlined in black) in which the ADF&G assessed ORV-trail stream crossings in 2002.

During the ORV trail study, ADF&G biologists also identified non-riparian wetlands adjacent to stream crossings that had been impacted (degraded) by ORV use. ADF&G observed impacts to non-riparian wetlands at 76 sites (23%), representing 174 crossings (37% of all identified crossings). As the author of the study, Michael Wiedmer, notes: "These sites were not randomly distributed, but were concentrated at the high elevation headwaters of Deep Creek and the Anchor River and mid-elevation tributaries of the Ninilchik River. The **map at right** shows these 76 impacted wetland sites in red triangles.



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These photos from the ADF&G ORV study described above illustrate the system used to score ORV trails at stream crossings.

Top left	Score 0
Middle left	Score 1
Bottom left	Score 2
Top right	Score 3
Middle right	Score 4
Bottom right	Score 5

The higher the score, the more severe the damage from ORV use.

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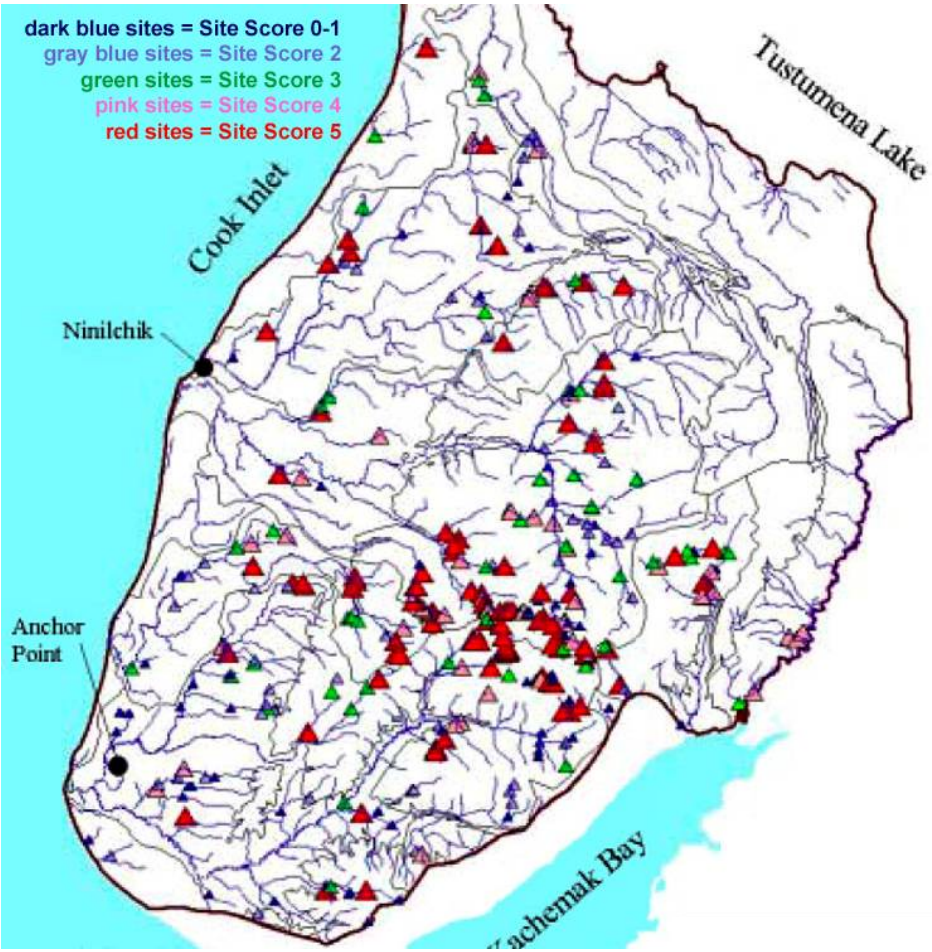
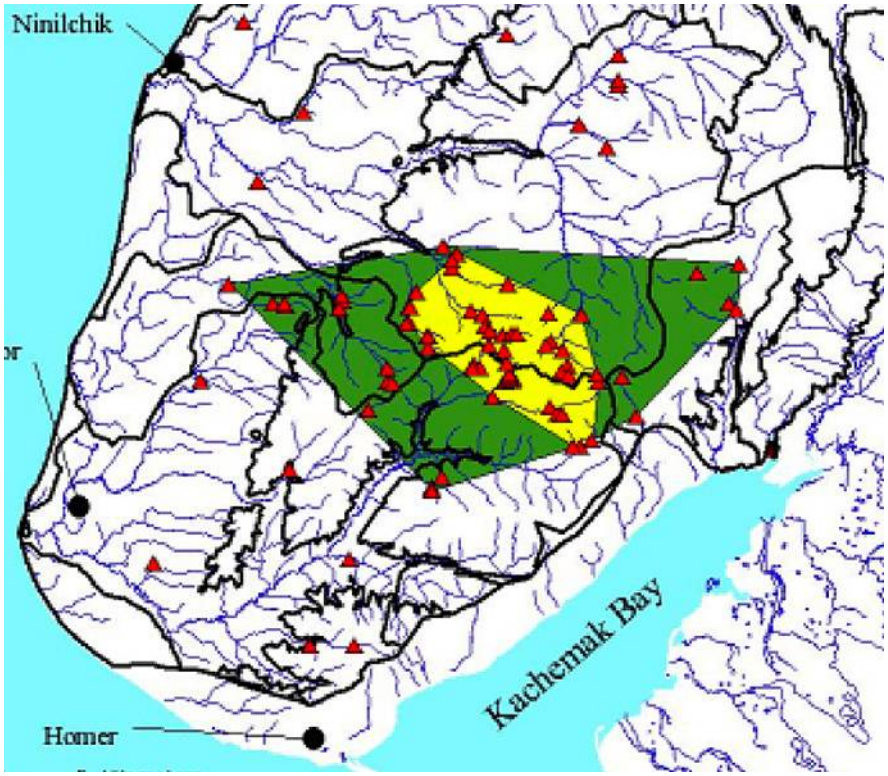
These maps show where impacts from ORV stream crossings are located (map on left) and concentrated (map on right)..The higher the Site Score, the more damage was observed at the stream crossing. (See discussion above for the source of these maps.)





The map on the left shows the location and score of each identified ORV-trail stream crossing.

The map above shows where 71% of all crossings with a score of 5 were located (green polygon) and where 50% of all crossings with a score of 5 were located (yellow polygon). These are the areas where it makes the most sense to concentrate work on re-routing and improving trails.

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Bankfull stage and discharge

Bankfull stage and discharge are, respectively, the water *level* and the flow *volume per unit of time* that come to the top of a stream channel but just remain within its banks. Any more water height or discharge would overtop the streambanks and start flooding adjacent areas (see Floodplain). Bankfull flows generally occur roughly every 1.5 to 3 years, depending on area climate.

Bankfull flows are major determinants of stream channel size and shape and of streambed materials (see Stream channel anatomy and Stream channel processes). Despite the relative effective power of bankfull flow, channels are formed by the integration of all flows up through bankfull and even flood flows (see Flooding).

An illustration of the edge of bankfull flows on this stream (source: http://www.fgmorph.com/fg_3_5.php).

Signs you can use to determine where bankfull flows come up to on your streambanks include:

- deposits of sand or silt at an active scour mark,
- a break in streambank slope,
- the lower limit of perennial vegetation,
- rock discoloration
- roots exposed where soils have been washed away.

Because bankfull discharge is so important in determining stream channel conditions, maintaining "natural" patterns of bankfull flows is fundamental to maintaining salmon habitats. Activities that alter these flows can alter salmon habitats. This means that for landowners, doing things to minimize impacts of land uses and activities on natural streamflows (both volumes and timing) are key to keeping their lands and waters salmon friendly. Landowners can do things like maintaining effective stream and wetland buffers; reducing impervious surfaces; minimizing the amount of water withdrawn from streams, wells, springs, and lakes; and other activities discussed throughout this guide.

Baseflow

(see also Aquifer, Hyporheic flow and zone)

Baseflow, or base runoff, is the long-term supply of water that keeps at least some water in the stream even during extended dry periods. Baseflow comes from water that percolated down into deep storage. Baseflow is the water within a stream that comes from groundwater sources instead of from water flowing on the surface of the land (runoff and flows from tributaries and other channels). Baseflow is also called *drought flow* because it is the streamflow that continues even during dry seasons, when no precipitation or runoff is occurring.

Baseflow is very important to salmon because it determines how much water a stream carries when **no** surface runoff is flowing in. If baseflow decreases (for example, if wells pump out so much water that groundwater levels drop), instream habitats that fish depend on can change in ways that harm salmon.

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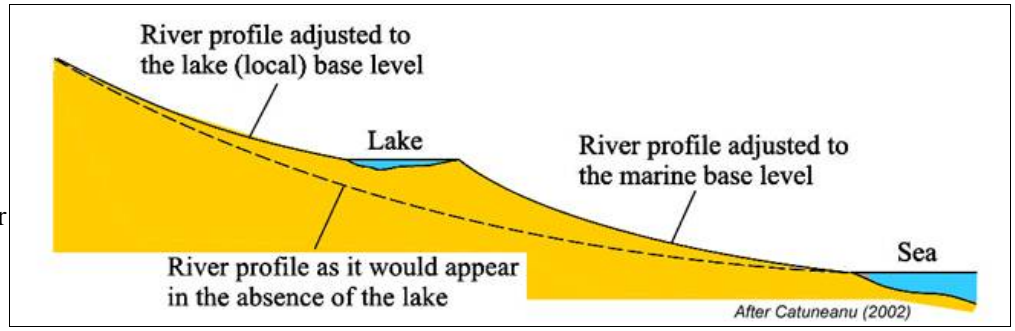
Base level

(see also Stream channel "anatomy")

Water can only flow downhill (duh!). Base level is the level at which a particular stream or river runs out of any more slope to flow down (its water surface is at the same elevation as the water surface it's flowing into). The ultimate base level for flowing water is the ocean. For your watershed, the ultimate base level is Cook Inlet, but a lake or river can represent the base level for a stream that flows into it.



Base level for a river channel as created by a lake and by the sea
(source: http://sepmstrata.org/terminology/baselevel.html.)

Blocking a stream (e.g., with a dam) so that water builds up behind the blockage creates a new base level for some distance upstream of the blockage. Where the upstream channel gradient becomes less steep, flow velocities will slow down, which in turn leads to deposition of some of the stream load. Both the blockage itself and the changes it causes in upslope channel conditions are likely to create altered habitats less suitable for salmon. That's one reason the ADF&G requires permits for any activity below ordinary high water within a salmon stream.

Best Management Practices (BMPs)

(see also Buffers, Low Impact Development, Raingardens, introductory article 2: Five S's for Landowners)

Here we use the term best management practices (BMPs) in its broadest sense, as things you can do—practices, methods, actions, etc.—to protect a natural resource of interest, whether water quality or salmon habitat or views. These are also sometimes called "best stewardship practices" or "conservation practices" (though conservation practices also has a more specific meaning as used by the Natural Resources Conservation Service). Originally, BMPs were focused on protecting water quality by reducing pollution, particularly pollution carried in stormwater runoff. Stormwater runoff (and in northern climates, also meltwater from snowmelt) can pick up and carry sediments, pollutants, and contaminants from one area and deposit them in another area where they do damage or harm. For example, runoff from residential and commercial developments, roads, construction sites, industrial parks, logging areas, and the like can carry sediments from exposed soils or hydrocarbons from fuel leaks into nearby streams, thus harming fish and other aquatic life. Over the years, usage of the term BMP has become more general; and the term is now often used for any practice or method that helps protect a resource of interest, for example, BMPs to protect salmon and their habitats. Reducing runoff, however, remains a focus of many BMPs because water is so good at carrying things from here to there, including things that do harm when carried over there. That's certainly true for salmon and their habitats when it comes to things like sediments, pollutants, and contaminants.

Despite the use of the word "best" for BMPs, these practices are generally much more effective when used in combination. With respect to salmon, for example, preventing stormwater runoff and its load from reaching a stream won't be enough to protect salmon if stream temperatures get too warm because all the trees and overhanging vegetation that used to help reduce water temperatures are replaced with plants that provide no shade.

Best management practices can be divided into two basic categories, **non-structural** and **structural**. **Non-structural** BMPs tend to be

- good decisions that protect a site (e.g., limit vegetation clearing, soil compaction, and impervious surfaces; site buildings on suitable soils);
- plant-based practices that improve sites (e.g., soil bioengineering techniques to stabilize a streambank; a raingarden to catch roof and driveway runoff);

- temporary measures taken while a project is underway (e.g., using straw or a geotextile fabric to cover exposed soils or dirt piles until they can be planted with permanent cover); or
- behavioral changes resulting from improved knowledge or understanding (e.g., avoiding crossing salmon streams where crossing will damage salmon eggs incubating in redds, rinsing rented equipment before bringing it onsite so as to avoid transporting seeds of invasive plants).

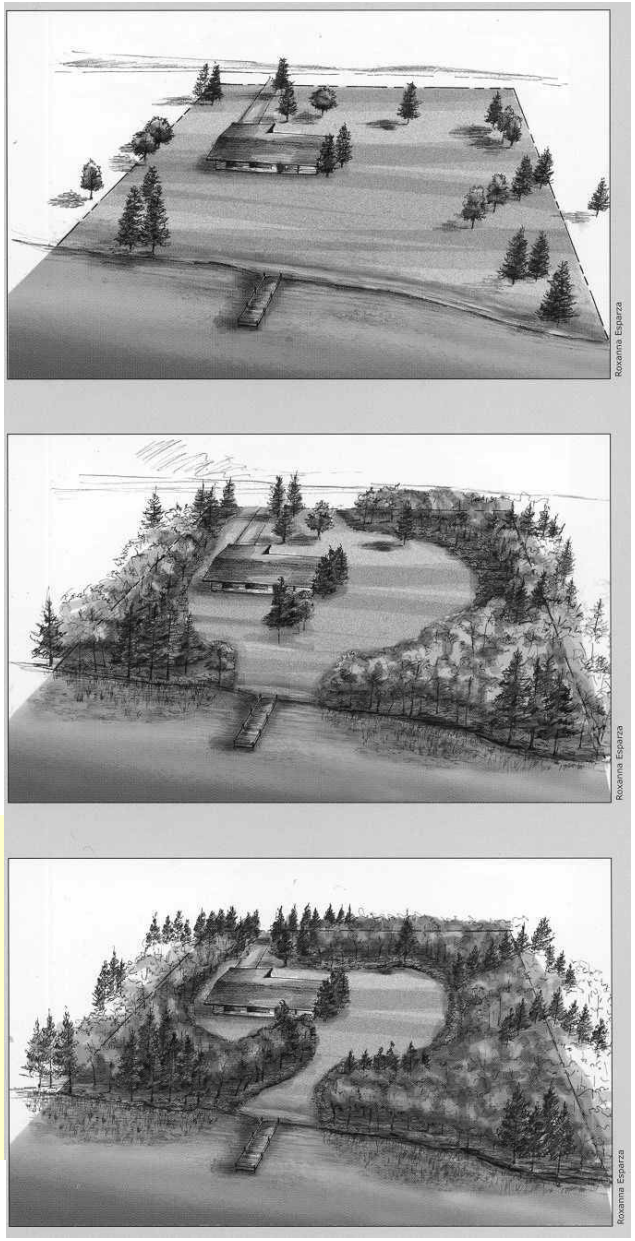
Structural BMPs, on the other hand, are engineered or more highly designed installations that generally mitigate damage caused by changing the land use from its natural state (pre-development or pre-settlement) to other uses. Structural BMPs tend to be expensive and are rarely as effective as the natural state for maintaining high-functioning drainage systems, plant communities, and fish and wildlife habitats.

Different BMPs will apply to different activities (construction, agriculture, recreation, logging, etc.), and the choice of which BMPs to use where will depend on site conditions and on each land developer's goals. In addition, different practices may be needed during different phases of a project. For example, just saving a stand of trees while building a house may require:

- a site layout in the planning phase that considers the trees;
- a development plan that is mindful of how to protect the trees during excavation, grading, installation of utilities, construction, and other phases of site preparation and development;
- a general contractor who respects the tree protection zone identified during the design phase and who knows when to call an arborist (e.g., if tree roots must be cut); and
- long-term maintenance practices that support the health of the trees (e.g., appropriate pruning and thinning, watering, fertilizing, integrated pest management, and limiting of soil compaction in the root zone).

Choosing the right BMP for a particular situation can seem complicated, and lists of BMPs for different activities can seem overwhelming. (We provide links to some of these below, as well as to several excellent BMP references, which CAN make interesting reading.) To keep things simple, we've come up with a basic, simple BMP that will do a lot to keep your property salmon friendly. Any landowner with whatever skills can apply this BMP all over his or her property with just a little forethought and almost no expense. The simple, salmon friendly **BMP** is: **B**uffer and **M**aximize **P**lants.

Buffers are discussed more in their own watershedipedia entry, but here we're referring to generally linear areas with dense vegetation (remember: **M**aximize **P**lants). Dense vegetation includes plant communities that have lots of ground-covering plants to slow surface runoff and promote infiltration, as well as lots of shrubs and/or trees to provide interception (catch and slow precipitation).



To right, a parcel where the landowner has **B**uffered and **M**aximized **P**lants
http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/01_03.pdf

Create buffers around and along areas you want to **protect**—such as streams and wetlands—and around or along areas you want to **protect from**, such as driveways, outdoor work areas, and even lawns. Even a 10-to-20-ft-wide buffer along a driveway can significantly reduce the amount of water running offsite from this impervious surface (gravel driveways aren't as impervious as paved driveways, but they tend to release more sediments). Even a 6-to-10-ft unmowed buffer allowed to "grow wild" between a lawn and a nearby road ditch will reduce the amount of stormwater runoff and pet waste running off the lawn and into the ditch, to be carried off to who-knows-where. If you cooperate with your neighbors to connect buffers, buffers on individual parcels can combine into corridors along significant stretches of stream or around whole wetland complexes, and these linear corridors can provide important habitats and movement corridors for wildlife. When in doubt as to what to grow in your buffers or what plants to maximize, just look at nearby natural areas with similar conditions to those on your land, and **copy Nature**! After all, Nature is what gave us salmon in these watersheds, so the more successfully we copy Nature, the more salmon friendly we're likely to be. (As someone from the Corps once said: "Vegetation is Nature's way of protecting a streambank.")

For those who want to explore the topic of BMPs in more detail, here are some links to good resources. This is just a small sampling; by "googling" the words Best Management Practices and a particular land use or resource, you'll find much more information. (For example, do an online search for "Best Management Practices for salmon" and see what comes up.)

Links to some good compilations and discussions of various kinds of BMPs are provided below.

EPA's National Menu of Stormwater Best Management Practices: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
Low Impact Development Center: http://www.lowimpactdevelopment.org/links.htm
This site has many excellent links to a variety of sources of information on BMPs and LID; two examples are:

- http://www.lowimpactdevelopment.org/links.htm#top10 (Top 10 Internet Resources for Low Impact Development)
- http://www.lowimpactdevelopment.org/links.htm#bmp_gen

Lower Columbia River Field Guide to Water Quality Friendly Development: http://www.lcrep.org/sites/default/files/fieldguide/index.htm See for example Techniques and Examples: http://www.lcrep.org/sites/default/files/fieldguide/techniques.htm

"Welcome to the Lower Columbia River Estuary Partnership's celebration of innovative, water quality friendly development throughout the Lower Columbia River area. Browse these pages and find pictures, addresses, and contact information for local sites that utilize ecoroofs, permeable pavers and 22 other water quality friendly development techniques, as well as detailed technical information on how each practice works and where you can use it."

Landowner's Guide to Watershed Friendly Living: http://www.spawnusa.org/pages/page-134
Landowners Guide to Fish Habitat Conservation and Restoration Practices http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/01_03.pdf
Ten Tips for Fish-Friendly Living, Ten Tips for Forest Landowners http://www.salmonnation.com/10tips/foresters.html

"These suggestions are practical changes we can consider making in our daily lives to help salmon."

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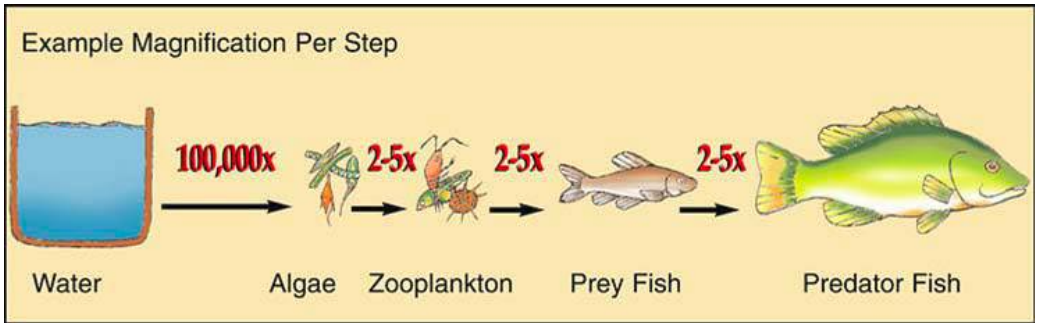
Bioaccumulation

One reason to keep watersheds salmon friendly is because of bioaccumulation. This is the process by which certain toxic substances (such as heavy metals and polychlorinated biphenyls) build up and keep on accumulating in living organisms, posing a threat to the health (and sometimes life) of humans and other animals that eat those organisms. In particular, toxic concentrations can increase dramatically up a food chain, as shown in the **image at right**. (Also called bioconcentration, biological concentration, or biological magnification.)

from: Santa Clara Valley Streambank manual (add citation)



The following comments about various pollutants are from http://www.epi.hss.state.ak.us/eh/fish/#facts.

Mercury: The Alaska Department of Environmental Conservation has an ongoing Fish Monitoring Program that has sampled thousands of fish. ADEC observed a wide variation of mercury content among the 23 species of fish sampled from Alaska waters between 2001 and 2006. All species of Alaska wild salmon have very low levels of mercury.

Based on the Fish Monitoring Program mercury data, the Alaska Division of Public Health has developed fish consumption guidelines for women who are or can become pregnant, nursing mothers and young children. The benefits of eating fish far outweigh any potential health risks as long as these guidelines are followed.

Persistent Organic Pollutants (POPs) include polychlorinated biphenyls (PCBs), dioxins, and organochlorine pesticides such as DDT. When these chemicals are released into the environment, it takes a long time for them to break down. When POPs get into an animal or a human they are concentrated in fatty tissues and stay there for a long time, instead of getting metabolized or excreted from the body. Thus while POPs concentrations in fish may be very low, ongoing frequent fish consumption can lead to an accumulation of POPs over time in human tissue. Because POPs are so persistent, they biomagnify in food chains and can reach high concentrations in the fat of top predators such as polar bears.

All Alaskan fish species tested have either non-detectible or very low concentrations of POPs. No POPs were detected at levels of health concern in any fish species tested, and no limitations in Alaska fish consumption are warranted or recommended based on POP levels.

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Biodiversity

"At its simplest level, biodiversity is the sum total of all the plants, animals, fungi and microorganisms in... a particular area; all of their individual variation; and all the interactions between them." [Peter H. Raven, "Defining Biodiversity," Nature Conservancy (Jan.-Feb. 1994) 44(1): p. 11]. Biodiversity is a fundamental attribute of any ecosystem, including those occurring in your watershed. Changes to natural patterns of biodiversity can have unforeseen consequences on ecosystems, rippling out through food webs, populations of organisms, predator/prey relationships, and other kinds of species interactions. Many of us saw these kinds of changes as the effects of the spruce bark beetle epidemic rippled out through peninsula spruce forests. Additional background on biodiversity is provided below in a discussion modified from http://www.naturescapebc.ca/naturescape/Provincal_Guide_2003.pdf.

Diversity occurs at three different levels of biological organization:

- ***Genetic diversity*** refers to the variation in genetic makeup of individuals within each species. Populations with high genetic diversity—like populations of wild salmon in Alaska—have a greater ability to adapt to environmental change.

- ***Species diversity*** refers to the number of different species within a given ecosystem. Within a stream, for example, you'll find many kinds of aquatic insects, terrestrial insects, streamside plants, fish, birds, and mammals. Ecosystems with high species diversity are generally more resilient to environmental stress than ecosystems with few species.

- ***Ecosystem diversity*** refers to the number and extent of dissimilar ecosystems within a given area like a watershed. Spruce forests, birch woodlands, bluejoint grasslands, peat wetlands, meandering rivers, estuaries are all familiar examples of ecosystems found in your watershed. But ecosystems occur at smaller scales too: a downed, moss-covered log; a stand of willows along a stream, a gravel stream channel itself, are also examples of ecosystems. Within each of these ecosystems—large or small—are countless different habitats, each occupied by its own variety of organisms that find food, shelter, and other

An example of a landscape with high biodiversity
(from http://www.naturescapebc.ca/naturescape/Provincal_Guide_2003.pdf).

necessities there. This biodiversity is essential to the health of all the species in the watershed. Without a complete, functioning system—with all its habitats and all its inhabitants—the needs of many watershed species, including salmon, can't be fully met. Maintaining biodiversity at all scales throughout the watershed is the surest way to make sure that the species we really care about—like salmon—will have what they need to survive and reproduce.

What landowners can do to maintain neighborhood and watershed biodiversity
What each of us does on his or her land can either contribute to or subtract from the biodiversity in our neighborhood and watershed. In particular, the things we do that reduce habitat complexity and connectivity will also tend to reduce biodiversity. We do many such things when we settle onto a piece of property—we remove some of the native plant species; we reduce the variety of plant forms—such as tree, shrub, or grass growth forms, as well as the numbers of snags and amount woody debris along streams or falling into them; we fragment ecosystems with clearings for buildings, lawns, roads, trails, and other purposes—and these actions lead to declines in biodiversity. This can be particularly true in riparian areas so critical to salmon because these areas often tend to have inherently very high and easily altered spatial and temporal diversity. When hundreds or thousands of landowners reduce biodiversity and alter natural functions on thousands of acres, the effects accumulate into big changes for watersheds and for species, like salmon, that need watersheds to function as they have for thousands of years.

Watershedipedia entries on impervious surfaces, culverts, erosion, invasive species, and many others are designed to alert you to the kinds of seemingly small actions that can add up to big cumulative consequences to watershed plants and animals. Landowners can take many actions to reduce the impacts of their developments and activities on biodiversity. Watershedipedia entries on topics like Best Management Practices, elevated light penetrating boardwalks, raingardens, Low Impact Development, soils for salmon, soil bioengineering, and others offer ideas on the kinds of things you can do to help protect the biodiversity on which our salmon depend.

ADF&G's Wildlife Diversity Program
To help maintain biodiversity throughout the state, in 2002 the Alaska Department of Fish and Game established a wildlife diversity program (see http://www.adfg.alaska.gov/index.cfm?adfg=wildlifediversity.main). Program staff are surveying, monitoring, and studying biodiversity in terms of many species and in a number of ways. A brochure at the following link provides background on the program: http://www.adfg.alaska.gov/static/home/about/management/wildlifemanagement/wildlifediversity/pdfs/wd_brochure.pdf).

In cooperation with the Division of Sport Fish, the Wildlife Diversity Program also initiated efforts to identify fish and wildlife with conservation needs and developed a statewide conservation strategy. The statewide strategy is outlined in: *Alaska's Wildlife Action Plan*, online at http://www.adfg.alaska.gov/index.cfm?adfg=species.wapabout. The Plan discusses conservation needs in terms of featured species and featured habitats (featured species in this case are "non-game" fish and wildlife, since game species are already actively managed). Among the featured habitats of concern that the strategy identifies are two habitat types critical to salmon—wetlands and freshwater aquatic habitats. The habitat-related concerns for those two habitats are shown in the table below. That means that anything you do to help minimize these concerns and to maintain natural conditions and biodiversity in these two habitat types will be particularly beneficial to salmon. All of these concerns are discussed in this watershedipedia.

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Concerns identified by ADF&G related to maintaining biodiversity (see above discussion)

Habitat-related concerns for freshwater aquatic habitats:	**Habitat-related concerns for wetlands:**
• increased temperatures and altered flow regimes due to warming climate (see Stream temperature)	• desiccation, inundation, and vegetation changes due to warming climate (see Climate change)
• decreased instream flow and connectivity of waterways	• nonpoint source pollution
• nonpoint source pollution and stormwater runoff	• dredge and fill activities (see Army Corps of Engineers)
• streambank erosion from illegal fords and inadequate crossing sites	• habitat alteration and ATV use/ (see ATVs and ORVs)
• invasive species (see also Reed canary grass)	

The Wildlife Diversity Program hopes to work with a variety of partners to fill information gaps and meet the conservation needs of wildlife and fish in Alaska. With updated information on species distribution and abundance, ADF&G can begin to evaluate trends and population changes and work to keep populations at healthy and sustainable levels. This will ensure that the state's full biological diversity will be enjoyed by future generations with opportunities for harvest, economic benefit, and personal viewing and recreation.

Landowners can help study biodiversity by becoming "citizen scientists"
Alaska is a huge state with few scientists and limited funds available to study the many different species of wildlife that live here. The A**laska Citizen Science Program** is a partnership between members of the public and professional scientists. The program provides opportunities for private citizens to assist wildlife biologists in collecting important data as part of ongoing research projects and conservation planning. Information will be used to support future research and conservation planning. With the help of local residents, ADF&G is able to expand its efforts and do more with limited resources. The Citizen Science Program allows individuals, families, community organizations, and school groups—anyone interested in learning more about local wildlife—a chance to get involved. For information about opportunities in Southcentral Alaska, including wood frog and bat monitoring programs, go to: http://www.adfg.alaska.gov/index.cfm?adfg=citizenscience.southcentral. To find out more about the Citizen Science Program, visit http://www.adfg.alaska.gov/index.cfm?adfg=citizenscience.main.

Bioengineering
(see Soil bioengineering)

Bluff erosion
(see also Meanders, Meander belt or zone, On the Coast, On the River)
Bluffs in your watershed are composed of poorly consolidated (poorly "lithified") sediments, so they're very susceptible to erosion. If you're dealing with a bluff that's currently well vegetated and relatively stable, you'll save yourself a lot of headaches by doing everything in your power to protect the status quo, particularly existing plant communities. If you're dealing with a bluff that's on the outside bend of a river meander, your bluff will be particularly erosion-prone because the stream will continually eat away at the toe of the bluff, leading to the collapse of overlying materials. It's important to get professional advice before building structures near the edge of an eroding bluff.

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If you'd like to see coastal bluff erosion in action on the Kenai Peninsula, Northwest Research Associates, Inc. maintains an Argus Beach Monitoring Station (ABMS) at Bishop's Beach in Homer**.** This station was installed in February 2003. Use of the ABMS for monitoring the nearshore environment of Homer is part of a cooperative research agreement between NorthWest Research Associates (NWRA), the US Geological Survey Coastal and Marine Geology Program (CMGP), and the Kachemak Bay Research Reserve. For real time images from ABMS cameras, go to: http://www.planetargus.com/homer/

BMP
(*see Best Management Practices*)

[add suitable illustration]

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Braided channel

(see also Stream channel "anatomy" and Stream channel processes)

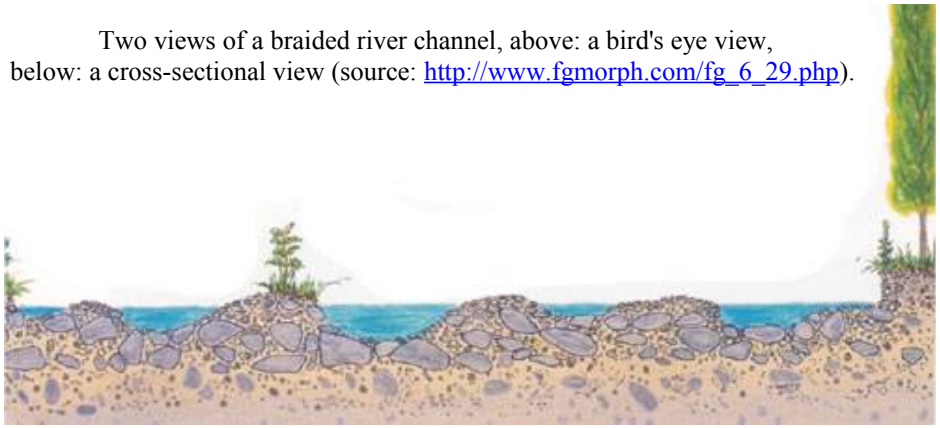
A braided river contains many channels separated by small islands and bars (called braid bars). The channels and braid bars are usually highly mobile, with channel patterns shifting with high flows. These shifts may be dramatic during flooding.

Like meanders, each channel tends to move laterally because of differential flow velocities: on the outsides of curves, deeper, swifter water picks up and carries away sediments, causing erosion; on the inside of channel bends, water velocities slow down, and sediments settle out and are redeposited.

Conditions that promote the formation of braided channels are:

- an abundant supply of sediment,
- rapid and frequent variations in water discharge, and
- erodible streambank and bed materials.

These conditions are common in glacier-fed streams, such as Fox River and Sheep Creek, at the head of Kachemak Bay, and Resurrection River in Seward. Although Anchor River, Deep Creek, Ninilchik River, and Stariski Creek may create side channels as they meander, they are not braided (although at low flows, some segments may develop minor braiding).



Two views of a braided river channel, above: a bird's eye view, below: a cross-sectional view (source: http://www.fgmorph.com/fg_6_29.php).

Buffers

(see also Best Management Practices)

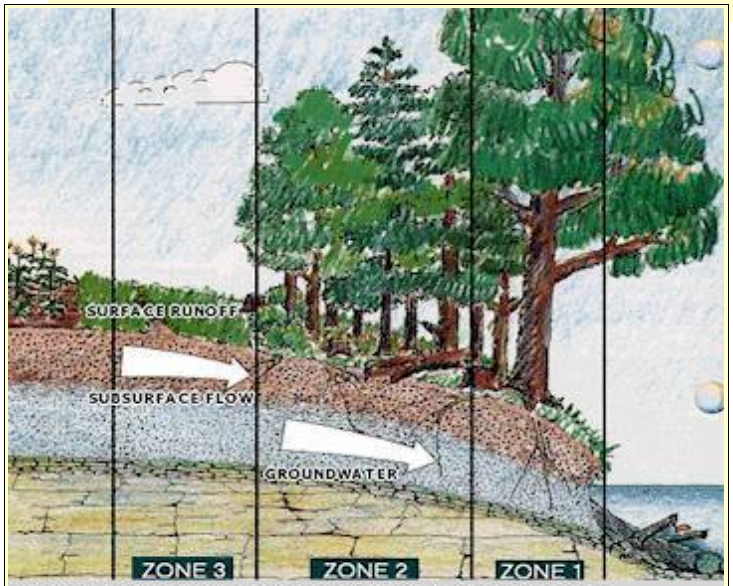
A buffer is a vegetated linear feature managed to separate (and often protect) one kind of landscape element (like a stream or wetland) from another (like residential development, forestry, or agriculture). Location and design of buffers depend on what kind of landscape elements and processes are being protected and what kind are being protected from. Buffers can be used to protect water quality, maintain biodiversity and particular species—like salmon, protect soils, provide economic opportunities (like marketable plant products), increase safety (e.g., from wind and snow or floodwaters), provide recreation, and improve aesthetics.

Well-vegetated stream buffers that protect natural conditions and processes also protect salmon habitats and populations. The Kenai Peninsula Borough acknowledges this in KPB 21.18, which limits land use activities within 50 ft of ADF&G-identified anadromous streams (see http://www2.borough.kenai.ak.us/AssemblyClerk/Assembly/Ordinances/2011/O2011-12.pdf), and KPB 5.14.010, which provides tax credits as partial reimbursement for costs of habitat

protection and restoration on and adjacent to anadromous streams (see http://www2.borough.kenai.ak.us/AssemblyClerk/Assembly/Ordinances/2011/O2011-37.pdf; see also Anadromous waters catalog). Fifty feet is a minimum width; in forested stream corridors, a rule of thumb is to make buffers at least as wide as the height of the tallest trees growing along the stream. (You'll notice that the three-zone buffer below is 100 ft wide.) The entire width of meander belts should be protected, since streams will tend to meander throughout this width.

A number of questions should be considered when designing and creating effective stream buffers to protect salmon habitats. These include:

- What is the minimum total buffer width that will be effective in meeting the landowner's buffer objectives? This depends on site conditions like soils, slopes, plant communities, upslope land uses, etc.
- What buffer design will be most effective given landowner goals? An example three-zone riparian forested buffer system is illustrated below.
- What plant communities will be maintained or established in the buffer? Along salmon streams, well-vegetated buffers that provide a high coverage of groundcover plants, shrubs, AND trees are most beneficial. By looking at plant communities along nearby undisturbed stream reaches with similar conditions, landowners can see plant communities likely to be ideal for salmon. If a natural plant community already exists on your property along the stream you're protecting, you need only protect what's already there. (An undisturbed stream reach used as a model is called a "reference reach.")
- What allowances should be made for expanding (or contracting) the buffer. For example, erosion along an outside meander bend will tend to shift the stream channel sideways and downstream (see diagram on next page). Buffer width should take into account long-term processes like this.
- Where, when, and how will the buffer be crossed? (A permit is required from Alaska Department of Fish and Game to cross anadromous streams.)
- Can practices be incorporated into the buffer to reduce stormwater volumes and velocities? For example, can vegetated depressions, such as raingardens or bioswales, be incorporated to slow down stormwater and allow it more time to infiltrate?
- How will the buffer be maintained?



Sketch of a typical riparian forest buffer (Source: Chesapeake Bay Program, 2000)

An example of a three-zone riparian forested buffer
(Slightly modified from http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=82&minmeasure=5.)

The three-zone buffer system at left consists of an inner, middle, and outer zone. The zones are distinguished by function, width, vegetative target (long-term goal), and allowable uses.

The **inner zone** protects the stream's physical and ecological integrity. It consists of a minimum of 25-feet plus wetland and critical habitats. The vegetative target consists of mature forest. Allowable uses are very restricted (flood control, utility right-of-ways, footpaths, etc.).

The **middle zone** provides distance between upland development and the inner zone. It is typically 50 to 100, feet depending on stream order, slope, and 100-year floodplain. The vegetative target for this zone is natural or managed forest. Usage includes some recreational activities, stormwater BMPs, and bike paths.

The **outer zone** is the first zone to encounter runoff. It prevents encroachment into the buffer while slowing and filtering backyard runoff. The outer zone width is at least 25 feet, and while forest is encouraged, turf-grasses can be a vegetative target. Outer zone's uses are unrestricted. They can include lawn, garden, compost, yard wastes, and most stormwater BMPs.

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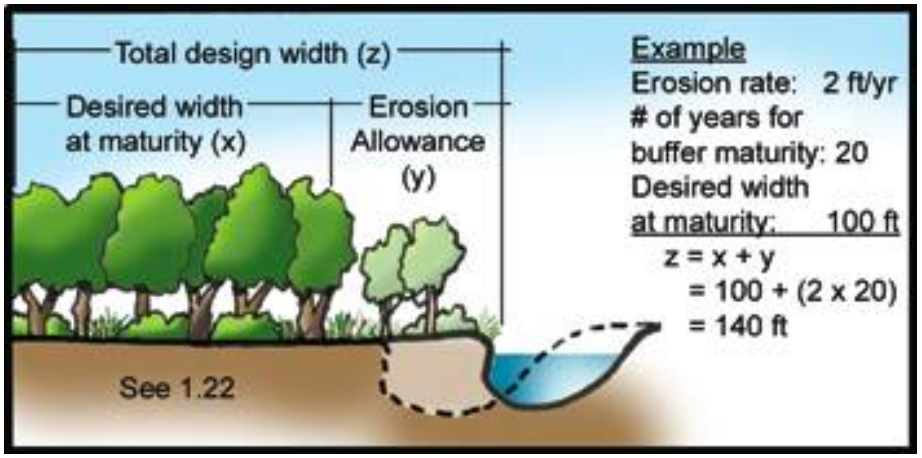
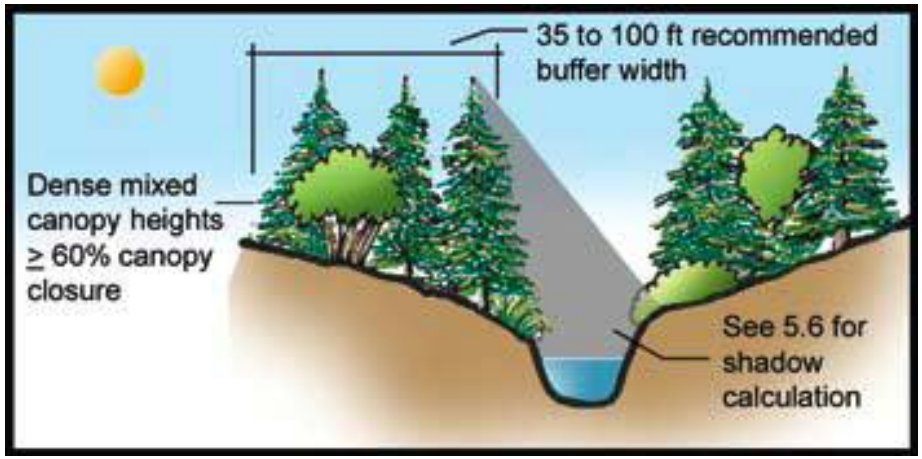
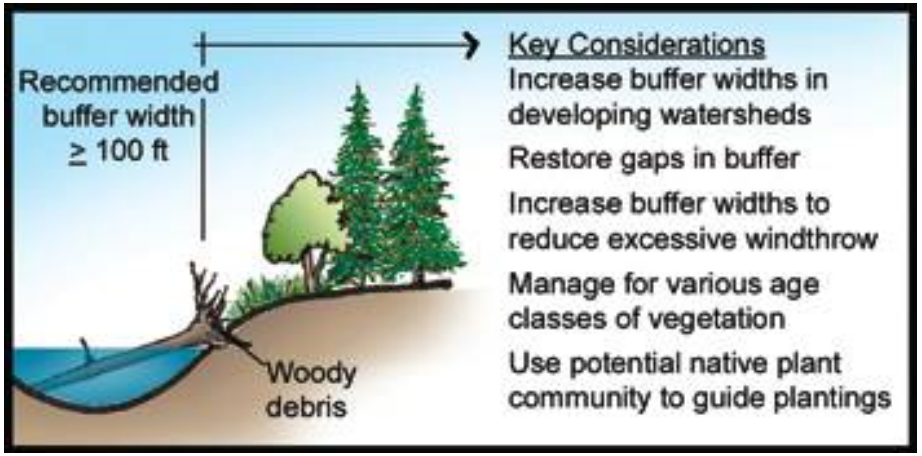
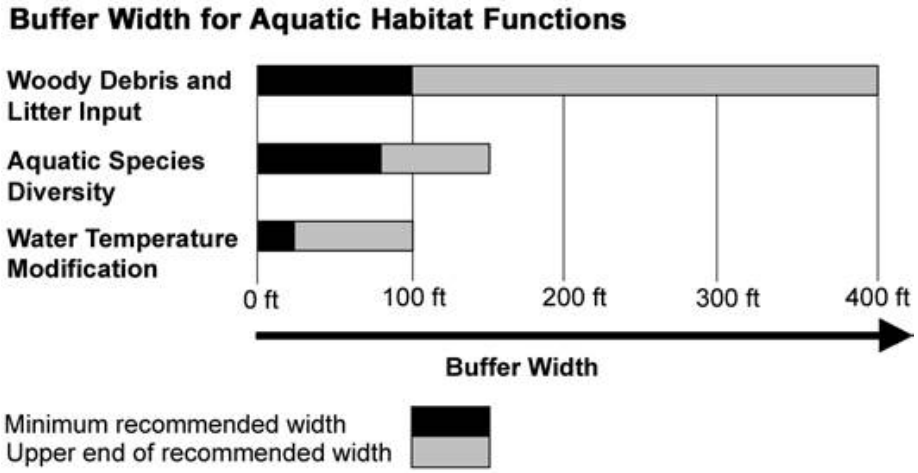
An excellent guide to designing conservation buffers of all types can be found at: http://www.unl.edu/nac/bufferguidelines/docs/conservation_buffers.pdf. The **illustrations below** from that guide suggest some of the issues related to designing your buffer. Clearly, the purpose and function of the buffer are among the most important considerations during design.









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Butterfly effect

The Butterfly Effect is a name given to what's more formally called "sensitive dependence on initial conditions." What this means is that in some systems, such as weather systems and watersheds, small differences in the conditions you start with (the initial conditions) can lead to big differences in the conditions you end up with. With respect to the weather, the saying goes that a butterfly flapping its wings in China can result in a tornado in the US.

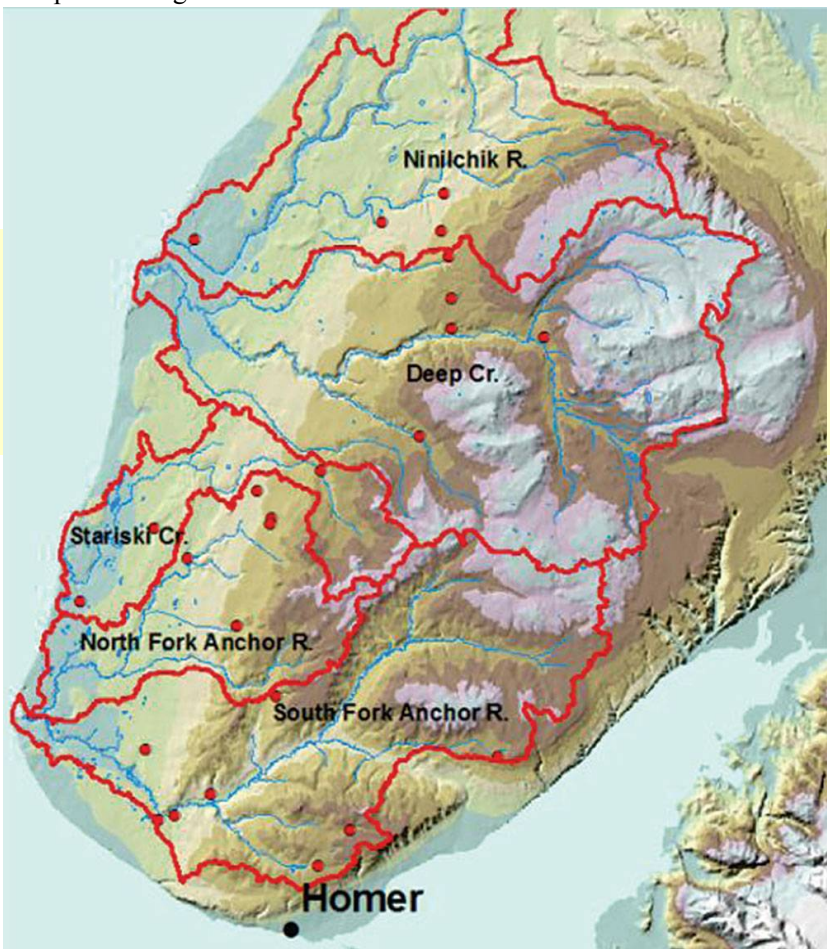
It's a strange-sounding concept, but not as strange as you might think: imagine a water droplet landing on the watershed divide between the Anchor River and Deep Creek—very small changes in initial conditions at the point where the droplet lands can lead to huge differences in where the droplet ends up, for example, into which watershed and valley and stream the droplet travels on its long journey to the sea (if it doesn't evaporate first). Watersheds are full of these kinds of relationships—a little too much sediment eroding over here may end up suffocating salmon eggs over there, a few acres logged here may raise stream temperatures there.

Because there are countless interactions like these in watersheds, landowners can help by recognizing that what they do on their lands represents a significant set of "initial conditions." Each landowner sets in motion many specific chains of events by creating or altering particular conditions on his or her property. Following salmon-friendly recommendations offered throughout this guide represent meaningful contributions every landowner can make to keep initial conditions in the watershed as suitable as possible for local salmon populations.

Caribou Hills geology

(see also Glacial history of the western Kenai Peninsula, Landforms)

The Caribou Hills are rolling hills located north of Homer and south of Clam Gulch and Tustumena Lake (see map to right). They reach an elevation of about 2860 at Ptarmigan Head, in the northwest corner of the Deep Creek watershed. These hills were shaped by repeated glaciations, the earliest of which covered them entirely. As glaciers melted back after each advance, they left behind exposed glacial landforms, such as moraines, plateaus, and terraces, as well as deposits known collectively as glacial till. The Caribou Hills are also characterized by earthquake faults. As described in *A Guide to the Late Quaternary History of Northern and Western Kenai Peninsula* (http://www.dggs.dnr.state.ak.us/pubs/id/15941): "A complex of near-vertical faults... in the Caribou Hills is delineated by linear drainage segments and topographic depressions, straight and abrupt changes in vegetation, aligned swamps and bedrock knobs, lines of springs, upslope-facing scarps, and offset bedrock ridges. The ages of these faults have not been evaluated, but some appear to be quite fresh."



The highest slopes of the Caribou Hills are indicated by late snow cover (source: http://www.guru.uaf.edu/kbay/2010%20KBAY%20Research%20Overviews.pdf)

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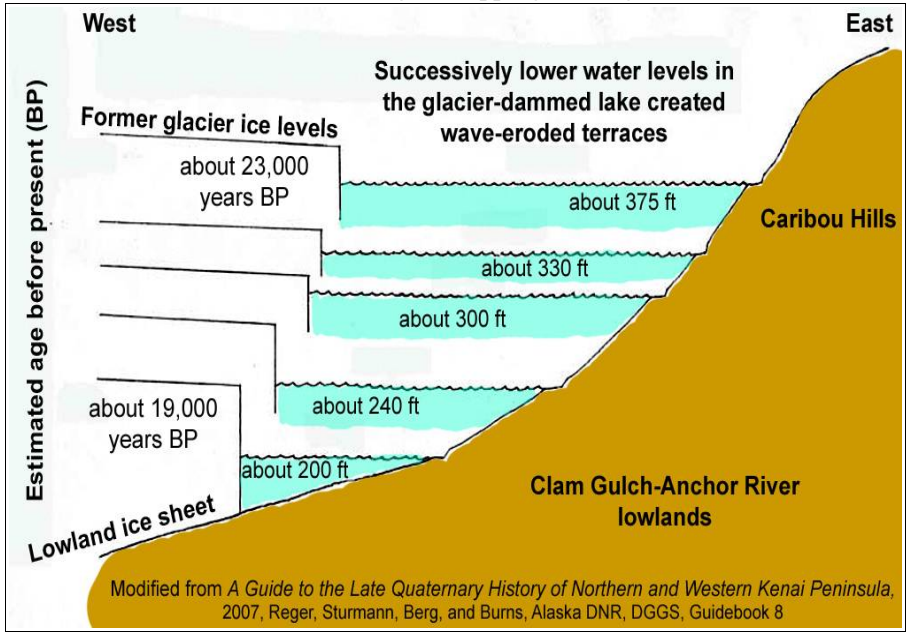
Geology

(The following is modified from http://www.kenaiwetlands.net/EcosystemDescriptions/ Intro.htm#Glaciation, see also http://www.dggs.dnr.state.ak.us/ pubs/id/15941. The story of Kenai Peninsula geology regularly changes with new information.) The Kenai Peninsula has been covered by glaciers repeatedly. Each successive glacial advance on the western peninsula was less extensive than the previous one. Only the oldest glaciations completely covered the Caribou Hills with ice. The oldest named regional glaciation is called the Caribou Hills glaciation. At lower elevations, evidence of this glaciation was destroyed by later glacial advances, so remnants of this advance are found only at the highest elevations in the Caribou Hills, above 1800 ft. The next glaciation, the Eklutna, carved high plateaus in the Caribou Hills at elevations between about 1500 and 1800 ft. Eklutna glaciation was followed by the Knik, probably some 35,000 years ago. Knik glaciation surfaces lie between about about 1000 and 1500 ft elevations in the Caribou Hills. Because Knik-carved landforms are steep-sided, glacial till has eroded away in many areas. Many headwaters of Anchor River, Deep Creek, Ninilchik River, and Stariski Creek arise here.

The most recent glaciation—the Naptowne—lasted from roughly 27,000 to 12,000 years ago. Four glacial advances occurred during the Naptowne; the first and most extensive was the Moosehorn, which peaked about 23,000 years ago. Ice from Moosehorn glaciers scoured the northeastern flank of the Caribou Hills up to an elevation of about 1,800 ft but did not enter the headwaters of the North Fork Deep Creek. No other Naptowne advances made significant inroads up the Caribou Hills (see **map at right**, from http://www.dggs.dnr.state.ak.us/pubs/id/15941). Instead, during Naptowne glacial advances, parts of the southern Kenai Peninsula lowland were inundated by a large meltwater lake impounded between the Caribou Hills and a massive compound ice sheet advancing eastward across Cook Inlet and northwestward out of Kachemak Bay (**purple area in map on right**). Pre-existing stream valleys were flooded by this meltwater lake. Lake levels began dropping as the glacial dam thinned after the peak of the Moosehorn advance, and incrementally lower lake levels eroded shoreline terraces in the Caribou Hills, as shown in the **figure at left**.



When the glacier-dammed lake finally drained away with the melting of its ice dam, braided and meandering streams coalesced in the Kenai lowlands, wandering back and forth across what was once the lake bottom, downcutting their streambeds in response to retreat of coastal bluffs and isostatic rebound (the rising of land compressed by the weight of glaciers as those glaciers melt and the land can rebound). Ninilchik River, Deep Creek, Stariski Creek, and Anchor River were all born this way, and each has cut down through lake deposits and glacial drift, which are fairly thick in some paleovalleys.

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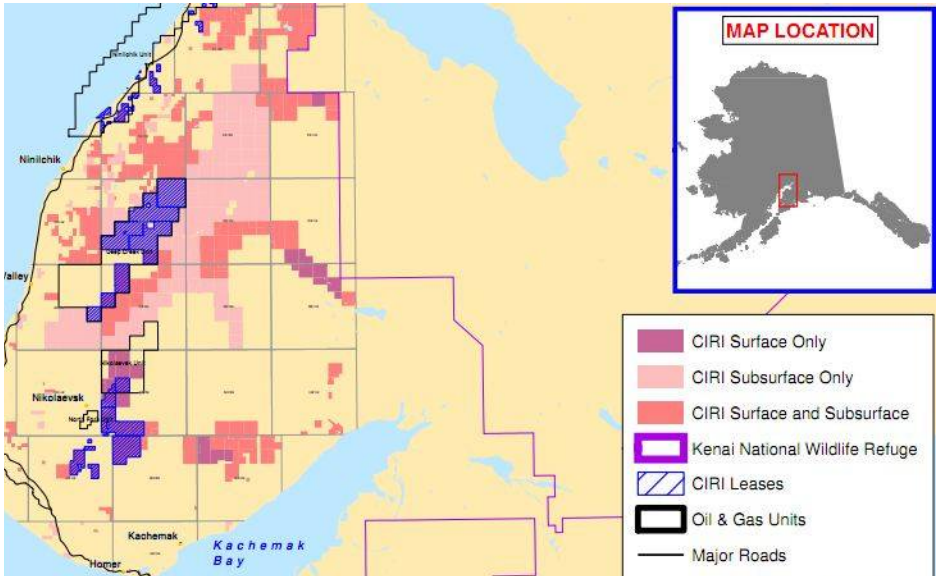
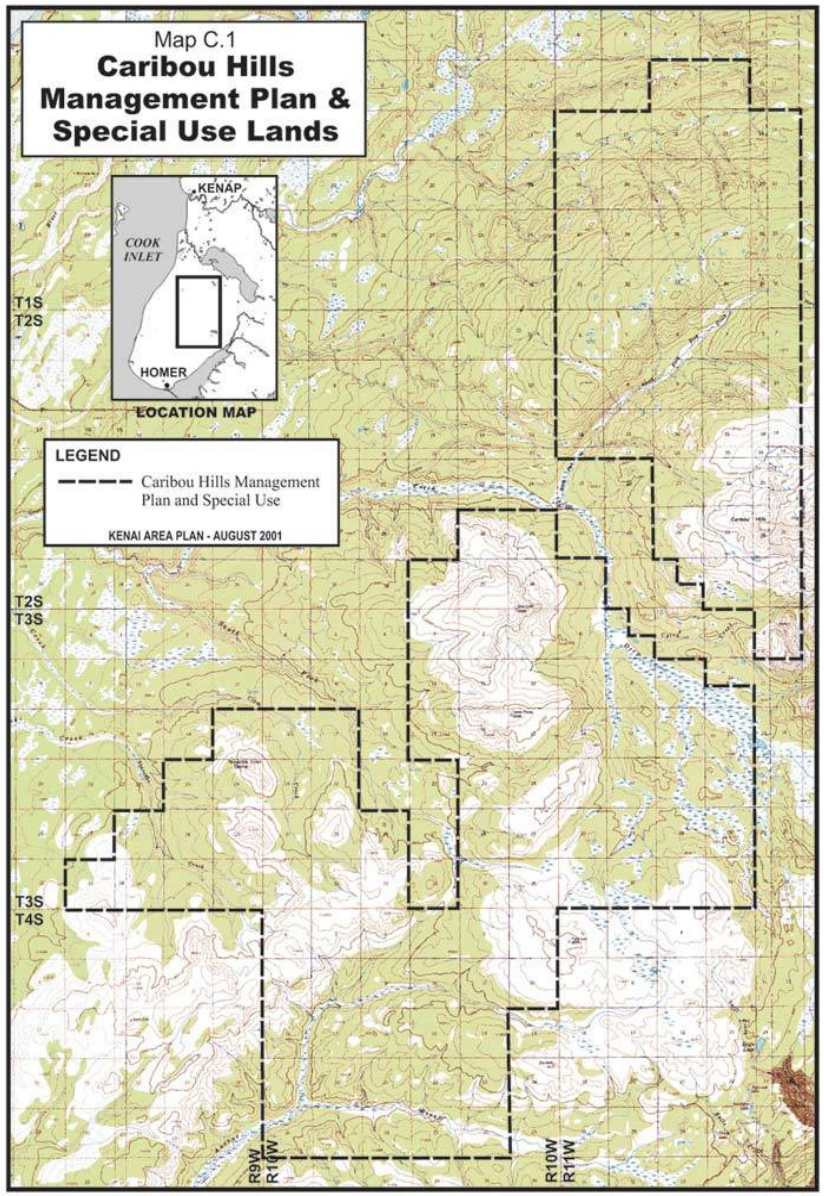
Caribou Hills Special Use Area and Management Plan
(see also ATVs and ORVs, Caribou Hills geology)

The Caribou Hills provide the only large block of easily accessible, state-owned, public-domain land on the Kenai Peninsula. The Caribou Hills Special Use Area (SUA) encompasses about 86,720 acres of state-owned land (see **map at right**). This includes all state lands within a number of units distinguished in the Kenai Area Plan (Units 45A, 45B, and 267, and portions of Units 260B and 266B). For more information, go to the watershedipedia entry for the Kenai Area Plan.

Primary uses the state has identified for its lands in the Caribou Hills SUA are snowmachining and fall hunting. Other identified uses include camping, hiking, mud-bog racing, Nordic skiing, dog mushing, forest management, fish and wildlife habitat, and oil and gas leasing. To download a pdf of *The Caribou Hills Management Plan and Special Use Land Designation*, go to http://dnr.alaska.gov/mlw/planning/areaplans/kenai/index.htm and scroll down to Appendix C.

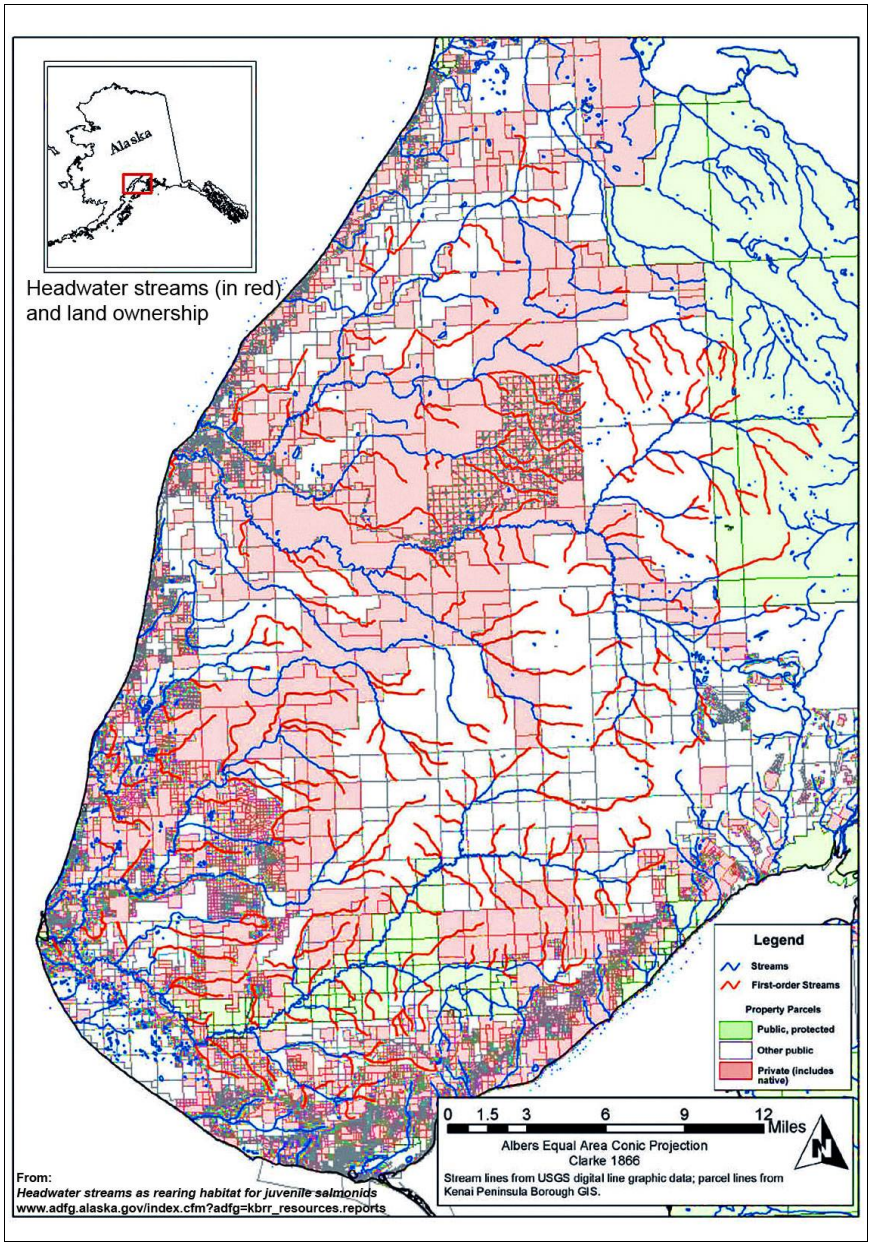
Federal, Native, and private lands surround state-owned lands in the Caribou Hills. For example, Cook Inlet Region, Inc. owns extensive acreage around state lands. Much of this is leased for oil and gas, as shown in the **map below** (from: www.ciri.com/content/company/documents/CIRIleases5-18-10.pdf).





e C-6 KENAI AREA PLAN - AUGUST 20

As the **map at right** shows, many tributaries of Anchor River, Deep Creek, Ninilchik River, and Stariski Creek have headwaters in the Caribou Hills. (Headwater streams are shown in red, white areas represent state-owned lands in the Caribou Hills Special Use Area, pink lands are privately owned—including Native ownership, see map above.) As recent research shows, headwater areas are critically important for health and rearing of local salmon stocks, especially coho (see *introductory article 1: Salmon species and life cycle*). Ensuring that land uses protect headwater streams will be essential for maintaining healthy salmon populations.



Caribou Hills trails
(see also ATVs and ORVs)

The Caribou Hills area is one of the most popular recreational areas on the southern Kenai Peninsula. Snowmachiners, users of ATVs and ORVs, hikers, skiers, skijorers, dog mushers, horseback riders, and others use the area. Some of these users have organizations that provide information about their activities and trails, including:

- Caribou Hills Cabin Hoppers, a nonprofit, volunteer snowmachine group (http://www.akchch.org/?page_id=2) (trail maps are available at the Cabin Hoppers website http://www.akchch.org/?page_id=45, the Cabin Hoppers also sponsor a Caribou Hills weather cam at http://www.akchch.org/?page_id=18);
- Kenai Peninsula Sled Dog and Racing Association, a volunteer organization promoting dog mushing and skijoring on the peninsula (http://www.psdra.org/);
- Homer Soil and Water Conservation District, which promotes sustainable trail use that protects natural resources such as wetlands, water quality, and salmon habitats.

Trail use in the Caribou Hills has a long history. The trail system that currently exists in the Caribou Hills was largely established on abandoned seismic lines created during oil exploration in the 1950s and 1960s. These cleared, straight-shot routes through the region lent themselves to quick travel from point A to B, but were not intended for use as year-round trails. Seismic lines were created without regard to terrain, soils, or land ownership, and as a result, many problems developed over the years as these lines became ad hoc trail routes. Other trails have been created using logging roads, power lines, and section lines, many of which have the same problems as trails on seismic lines.

To complicate matters further and as shown in maps above, the Caribou Hills encompass many different landowners and managers. These include the state; the Kenai Peninsula Borough; Ninilchik Native Association, Inc. (NNAI); Cook Inlet Region, Inc. (CIRI); the University of Alaska, and other private landowners, including holders of Native allotments.

Some preliminary attempts at trail and recreational planning in this area have been undertaken by the borough and the state (see Caribou Hills Special Use Area and Management Plan). In addition, occasional surveys have been conducted to assess trail impacts and needs. Two examples are available at http://dnr.alaska.gov/parks/misc/orv/appenda.pdf and http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/02_02_draft.pdf. The first link goes to *Deep Creek and Anchor River Off-Road-Vehicle Trails Assessment*, which was prepared by ADF&G in conjunction with ADNR in 2004. This report is part of a Deep Creek and Anchor River Off-Road-Vehicle Impact Assessment and Mitigation Strategy and includes topo maps of the trails assessed and many photos of trail conditions It also includes recommended trail prescriptions to help address identified problems. Excerpts from that report are provided below. The second link goes to a 2002 ADF&G report called *Lower Kenai Peninsula Summer Off-Road-Vehicle Trail Stream* Crossings (see ATVs and ORVs). The report provides a comprehensive identification and assessment of ORV-trail stream crossings throughout the Lower Kenai Peninsula, including trails in the Caribou Hills. Again, many photos are provided of trail conditions. Homer Soil and Water has also conducted a trail assessment of Caribou Hills trails. The reconnaissance survey, during summer 2007, reaffirmed that trail use exceeds sustainable levels in many areas. Homer Soil and Water installed geogrid on a section of the Water Hole Trail to determine how effective that treatment would be on a seriously degraded trail segment. For more information on problems associated with poorly designed and managed trail use near and through stream corridors, see ATVs and ORVs.

Trail assessments make clear that protecting salmon habitats in the vicinity of popular trail systems in the Caribou Hills will be an ongoing and long-term challenge—particularly where trails have developed to capitalize on corridors cleared for other purposes, such as seismic lines and utility corridors. Protecting salmon habitats in the Caribou Hills will require effective coordination among numerous landowners and an ongoing commitment from landowners and trail users to treat the lands and waters they affect in salmon friendly ways.

A trail in the Caribou Hills (from http://kb7q.blogspot.com/2010/07/hiking-caribou-hills.html).

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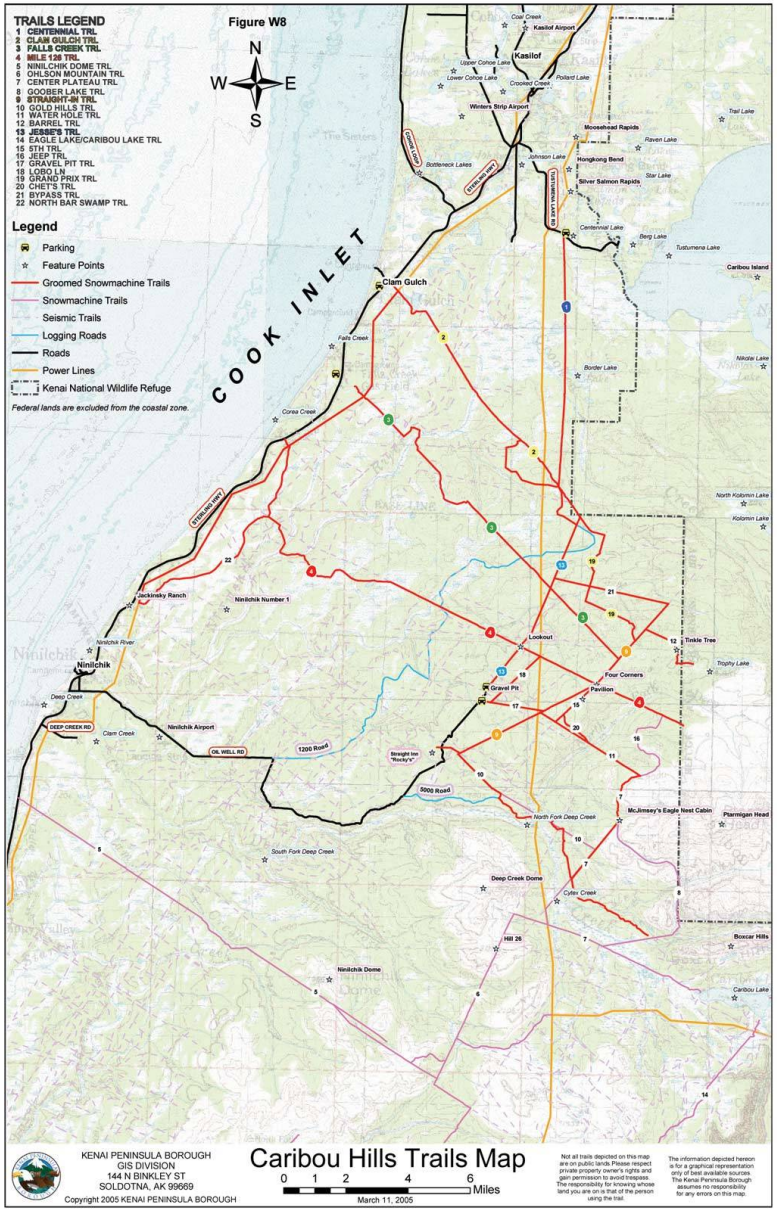
Excerpts (slightly modified) from trail assessments found in http://dnr.alaska.gov/parks/misc/orv/appenda.pdf.

The Ninilchik Dome Trail is approximately 18.25 miles long and crosses seven streams, four of which are cataloged as anadromous streams (see AWC). The trail begins on the east side of the Sterling Highway at MP 140. The current parking area is approximately .22 miles south of the beginning of the trail on the west side of the highway. It is a gravel pit leased/operated by the Department of Transportation and is not a designated trailhead or parking area. The first 4+ miles of the Ninilchik Dome Trail can be characterized as lowland muskeg, very wet and very flat. Along this section the trail intermittently intersects old logging roads for short distances on privately owned lands. After approximately 9 miles, the trail passes just south of the Ninilchik Dome and then crosses a large riparian area (2+ sq mi) that is the headwaters of Clam Creek.

The North Fork Trail is approximately 14.77 miles long and crosses five streams, one of which is cataloged as anadromous. The North Fork Trail trailhead is off North Fork Rd., just east of the community of Nikolaevsk, approximately 10 miles from the town of Anchor Point. This trail generally runs along ridgelines and high ground, although a redundant portion of the trail is situated in a wet area. Most of the trail crosses state or borough lands. There is some private land near the trail, but not directly crossed by it.

The map on the right shows trails in the northern Caribou Hills area. This map can be downloaded at http://www.homersnomads.org/images/media/north-caribou-hills.pdf. A similar map of trails in the southern Caribou Hills area can be downloaded at http://www.homersnomads.org/images/media/south-caribou-hills.pdf.



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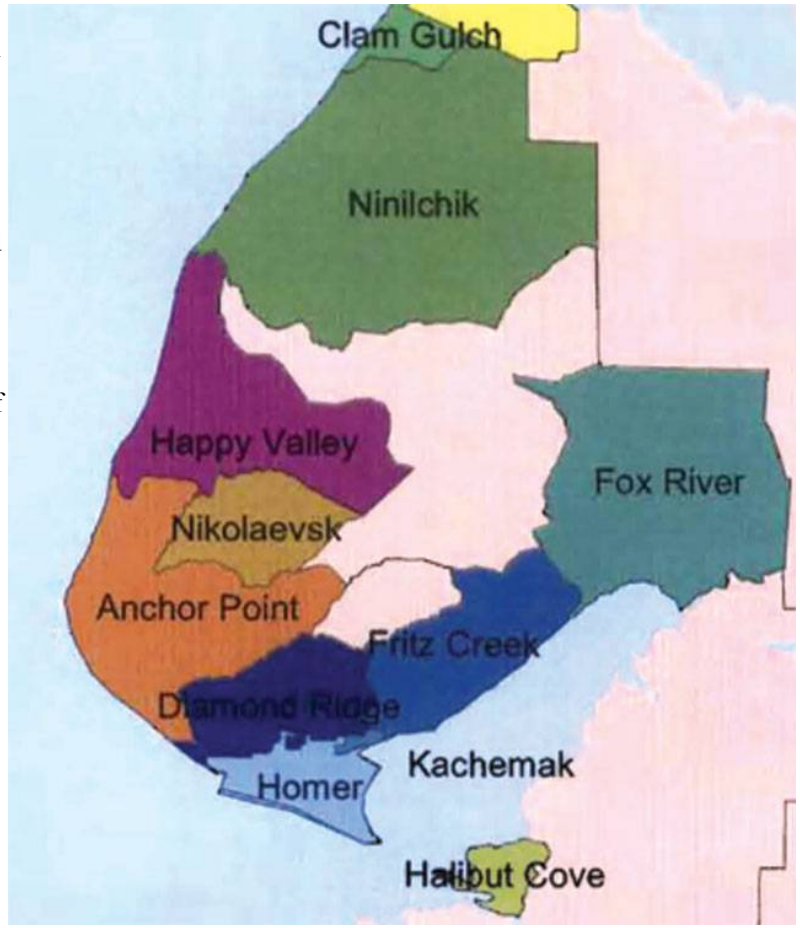
Catchment area or basin
(see Watershed)

Census Designated Places (CDPs)

People keep moving into and out of your watershed. Knowing how many people live in an area is an important way to track how much and how fast a watershed is likely to change, in addition to other uses for population data, for example, to outline voting districts or to allocate school funds.

Demographic information about your watershed is collected by many different entities. The US Census Bureau tracks local population statistics in terms of "Census Designated Places." The following link will take you to a list of the 51 CDPs distinguished in the Kenai Peninsula Borough http://alaska.hometownlocator.com/ak/kenai-peninsula/. Once at the list, click on a community or CDP of interest to find out more information.



As the map **at right** shows, southern peninsula watersheds overlap with some portion of five CDPs; Ninilchik, Happy Valley, Nikolaevsk, Anchor Point, and Diamond Ridge. (A small portion of the Anchor River watershed is also within Fritz Creek CDP, where Hutler Road crosses into the Beaver Creek subwatershed of the Anchor River watershed.) The Anchor River watershed encompasses almost all of the Diamond Ridge and Nikolaevsk CDPs, most of the Anchor Point CDP, and a small portion of the Happy Valley CDP. Stariski Creek watershed encompasses much of the rest of the Happy Valley CDP. Deep Creek and Ninilchik River watersheds encompass most of the Ninilchik CDP.

According to census data, total population within these five CDPs as of 2010 is just under 4,000 (3,997). Much of this is within the communities of Anchor Point and, to a lesser extent, Nikolaevsk, but many residents also live along North Fork, Diamond Ridge, and Ohlson Mountain Roads.

To find 2010 census data for Alaska, go to: http://www.cubitplanning.com/state/28-alaska-census-2010-population. A quick link to Alaska smaller cities is: http://www.city-data.com/city/Alaska2.html. "Quickfacts" about the Kenai Peninsula from the US Census Bureau can be found at: http://quickfacts.census.gov/qfd/states/02/02122.html.

Census Designated Places (source of data)	2000 population	2010 population	Percent change
Anchor Point (http://www.cubitplanning.com/city/17888-anchor-point-cdp-census-2010-population)	1,845	1,930	4.6% increase
Diamond Ridge* (www.borough.kenai.ak.us/Econ/2005/2Q/.../KPB%20Population.pdf)	404*	1,156*	186% increase*
Happy Valley (http://www.cubitplanning.com/city/17997-happy-valley-cdp-census-2010-population)	489	593	21.3% increase
Nikolaevsk (http://www.cubitplanning.com/city/18096-nikolaevsk-cdp-census-2010-population)	345	318	7.8% decrease
Total	3,083	3,997	29.6% increase
Ninilchik (http://www.cubitplanning.com/city/18099-ninilchik-cdp-census-2010-population)	772	883	12.6% increase

* In 2002, the City of Homer annexed much of the Diamond Ridge CDP (annexation was effective as of March 20, 2002). The population of Diamond Ridge CDP in 2001 was 1,812, in 2002—after the CDP was reduced by Home's annexation of much of its area—Diamond Ridge CDP's population was 404; in 2004, it was up to 761. As of 2010, the population was 1,156.

Channel shape
(see Stream channel "anatomy")

Chinook (king) salmon
(see introductory article 1: Salmon species and life cycle)

Cigarette butts
(see also Water quality)

Who would have thought that cigarette butts dumped on the ground could represent a threat to nearby salmon? As it turns out, nicotine is highly toxic to many fish and other aquatic organisms. The following is modified from a post by Jeffrey Kluger on April 27, 2011 (http://ecocentric.blogs.time.com/2011/04/27/a-new-victim-of-second-hand-smoking-fish/#ixzz1KqRHvLG5).

A New Victim of second-Hand Smoking: Fish

In the great river of litter human beings create each year, so tiny a thing as a cigarette butt hardly seems to amount to much. But with the world's smokers burning through a breathtaking 5.6 trillion cigarettes per year—4.5 trillion of which are simply tossed away outside after they're smoked— little things add up fast. That, as it turns out, can be especially dangerous for one type of nonhuman critter: fish.

About a third of all trash found on U.S. shorelines consists of cigarette butts. There's no such thing as good litter, but butts may be among the worst, since they're impregnated with concentrated quantities of the 4,000 chemicals—many of them highly toxic—that occur naturally in tobacco and are added in the cigarette-manufacturing process. In a paper published in *Tobacco Control*, researchers headed by Eli Slaughter of San Diego State University's Graduate School of Public Health sought to determine the kind of harm those poisons can do. Slaughter and his team broke cigarette waste down into three categories: smoked filters with some scraps of tobacco left; smoked filters with all of the tobacco burned or washed away; and unsmoked filters, which themselves contain a whole stew of chemicals. They immersed samples of each type of butt in separate 2-liter (0.5 gal) containers of water and allowed them to soak. In some of the vessels, 16 butts were added to the water, in some 8, in some 4, 2, 1 or just a half a butt. After 24 hours, the butts were removed and fish were added.

The two types of fish the researchers chose for their study were the topsmelt and fathead minnow, both common in U.S. waterways. All of the fish were 14 days old or younger. What Slaughter and his team were looking for was what's known as the LC50—the lethal concentration of cigarette butt leachate in water that would kill 50% of the sample.

Of the three types of cigarette butts used, they found, it was the filter with traces of tobacco still clinging to it that was the deadliest, with an LC50 of just one butt per liter. Smoked filters with no tobacco had an LC50 of 4.3. Unsmoked filters with no tobacco attached were not far behind, at 5.1. That figure surprised the researchers—but only a little. Even the most pristine cigarette filter is still made of 15,000 cellulose acetate fibers surrounded by paper or rayon and treated with glues, salts, and other chemicals to hold it all together and help the cigarette burn evenly... There's no telling what the deadliest chemicals in the smoked butts were, but high on the list have to be pesticides (sprayed on tobacco crops), acetone, formaldehyde, benzene, hydrogen cyanide, and argon.

There are obvious flaws in the study, not the least being that toxins from cigarettes dropped in or near the ocean get diluted a whole lot more than those dropped in a tiny 2-liter vessel. What's more, topsmelt and fathead minnows are hardly the only kinds of fish in the sea, and plenty of others may be affected by butt toxins differently. But Slaughter and his team did not intend their study to replicate what actually goes on in the real world; rather they simply wanted to establish toxicity thresholds that can be used as a baseline for further research. They acknowledge a 2002 study by the Royal Australian Society Chemical Institute concluding that littered cigarette butts pose a "low to moderate risk to aquatic organisms." Low to moderate risk, however, is still not good and that doesn't account for the "bioaccumulation" factor—the way long-term exposure to cigarette residue can cause toxins to collect in individual fish, and the way those poisons can get concentrated as big fish eat little fish and the chemicals move up the food chain.

Citizen's Environmental Monitoring Program (CEMP)

In 1996, Cook Inletkeeper (http://inletkeeper.org/) developed Alaska's first agency-approved volunteer water quality monitoring program: the Citizens Environmental Monitoring Program (CEMP). The program is designed to actively involve citizen volunteers in collecting and distributing important habitat and water quality data. Information collected by CEMP volunteers can help landowners and managers learn about and understand water quality in nearby streams sampled through the CEMP program.

CEMP objectives are to:

- inventory baseline water quality in the waters of Cook Inlet basin;
- detect and report significant changes and track water quality trends;
- raise public awareness of the importance of water quality through hands-on involvement.

Cook Inletkeeper trains CEMP volunteers to collect water quality data for selected parameters that will enhance understanding of overall environmental health and testing methods that have proven successful in citizen-based programs throughout the US. Water quality information collected by citizens is managed and analyzed in a relational database, and Inletkeeper produces annual water quality reports, which analyze all citizen-collected data in the Kachemak Bay and nearby watersheds.

For more information on how to join as a volunteer, contact Rachel Lord at 907.235.4068 ext. 29 or rachel@inletkeeper.org. Volunteer training is held twice a year, in the spring and fall.

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Clay

(see also Soil texture)

(From: http://soils.missouri.edu/tutorial/page8.asp.) Clay particles are the smallest of the particles found in soils and are less than 0.02 mm in diameter. A clay particle has a very large surface area and carries a negative charge. Because of these two characteristics, clay holds a tremendous amount of water and plant nutrients. Clay soils can be very hard when they are dry, and sticky and plastic (moldable, like ceramic clay) when wet. Unlike grains of sand or silt, clays tend to be shaped like tiny flakes or flat plates. There are numerous pores between clay particles, but they are so small that air and water move among them very slowly. There are different kinds of clay minerals, and these minerals give different properties to the soil. Shrinking and swelling, plasticity, water-holding capacity, and soil strength are all affected by the kind of clay mineral, as is the availability of plant nutrients.

Clean Water Act

(see also Army Corps of Engineers, Environmental Protection Agency, Nonpoint source pollution, Wetlands permits)

The Clean Water Act (CWA) is significant to landowners both because it helps protect water quality and because it relates to wetland permits (also known as 404 permits), which are needed to legally dredge or fill a wetland. (The following is slightly modified from http://www.epa.gov/lawsregs/laws/cwa.html.) The Clean Water Act (CWA, 33 U.S.C. §1251 et seq. (1972)) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972. "Clean Water Act" became the Act's common name with amendments in 1977.

(From http://www.epa.gov/oecaagct/lcwa.html#Summary .) Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports), and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States (including wetlands), unless the activity is exempt from Section 404 regulation. (Many normal farming and forestry practices are exempt from Section 404.)

(The following is modified from http://www.epa.gov/lawsregs/laws/cwa.html.) The CWA also made it unlawful to discharge any pollutant from a *point source* unless a permit was obtained (a National Pollutant Discharge Elimination System, or NPDES, permit). Point sources are discrete conveyances such as pipes or man-made ditches. Individual homes that are connected to a municipal system, use a septic system, or don't have a surface discharge don't need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. EPA's NPDES permit program in Alaska is now managed by the Alaska Department of Environmental Conservation) (see Nonpoint source pollution and NPDES permit). Under the CWA, EPA also developed regulations to reduce pollution from stormwater runoff, and this program is also being transferred to DEC (see Stormwater Pollution Prevention Plans).

Climate change

(see also Stream temperatures)

Potential climate change on the Kenai Peninsula has received considerable study. Climate change is significant for our salmon populations because stream temperatures correlate with air temperatures, so as air temperatures rise, so do stream temperatures. For a number of reasons, conditions for salmon deteriorate with increases in water temperatures above “threshold limits” safe for salmon (55.5 degrees F for spawning areas and egg and fry incubation; 59 degrees F for

fish migration routes). One of the main reasons for this is that warmer waters hold lower levels of dissolved oxygen. In addition, higher stream temperatures are correlated with the following impacts (from http://inletkeeper.org/resources/contents/changes-in-alaska-salmon-stream-habitat-due-to):

- reduced survival of salmon eggs and fry;
- reduced salmon growth rates due to increased rates of respiration and metabolism;
- premature smolting and shifts in emigration timing, which can reduce marine survival of salmon;
- greater vulnerability to pollution due to increased toxicity of some organic chemicals and metals, including mercury, in warmer waters; and
- greater risk of predation and disease.

Cook Inletkeeper has been measuring stream temperatures in peninsula salmon streams since 1998 to track change (see http://inletkeeper.org/resources/contents/changes-in-alaska-salmon-stream-habitat-due-to and http://inletkeeper.org/healthy-habitat/cold-water-refugia). In 2002, they expanded their research on the Anchor River. CIK's stream ecologist described their investigations at an April 30 public presentation in Anchor Point, from which the following is slightly modified.

> "When temperatures get warmer, salmon get more stressed; they become more vulnerable to pollution, predation, and disease, and it's more difficult for them to put on weight and to breathe. So in 2002, we went to look at what temperatures were in the Anchor River. We use temperature loggers that can collect stream temperatures year round every 15 minutes. What we've found is that for eggs in their redds, we have temperatures that are already warm for them, warmer than we would have expected for Alaska streams.
>
> "We're trying to understand how water temperature changes every year with air temperature because one of the good data sets that we DO have in the state is air temperatures. We have pretty good air temperature data sets that go back to about the 1930s from the airports. If we can understand how water temperature varies with air temperature, we can get a handle on whether the temperatures salmon are experiencing now is what they've always experienced or if temperatures are a warmer now than they were in the past. And, of course, with climate change, the expectation is that air temperatures will only get warmer. So we're really trying to understand where we are on that curve of stress for the salmon in the stream.
>
> "If we take the current water temperatures and air temperatures and backtrack to what historical water temperatures were, we can develop the relationships shown in the diagram on the right
>
> "In the past, based on the air past temperatures, streams have been below 55 degrees F most of July; 55 degrees is actually the temperature at which salmon eggs start to become stressed, so in the earlier part of the last century, we had cool temperatures that did not cause any stress for the eggs. In more recent time, we are above 55 degrees, and predictions based on air temperature models for the future are that those water temperatures are going to increase, so over the next 50-60 years, we're going to begin to get into stream temperatures over 60 degrees F for most of July.
>
> "This is important for us to understand for management of salmon populations and how motivated we are to make changes related to climate change and carbon emissions. But also, when we think about temperatures at the scale of the fish, it's not just air temperature that's driving water temperatures, there are other things that are important day-to-day and year-to-year on the Anchor River. In addition to air temperature patterns, stream temperatures are affected by how much water is in the stream—more water will warm up slower than less water. And also streamside vegetation can be very important for creating a shaded environment that might be a little bit cooler than the main part of the channel.

> "In an effort to understand smaller scale stream temperature patterns experienced by salmon, on June 30, 2010, 34 miles of the Anchor River were flown with a helicopter to collect thermal infrared imagery. The thermal imagery gives us a signature of surface water temperatures. That allows us to understand how well mixed the stream is where salmon are found, and whether they look for different temperatures in difference locations. What we found is that some places in the river have really good connections with groundwater, and these areas are providing cool patches of water that are going to become really important to salmon in the years ahead as overall river temperature continues to increase."

Kenai Watershed Forum has also studied possible effects of climate change on the peninsula, as well as the cumulative effects of other kinds of changes. The result was a report published in 2006 called Alaska Cumulative Effects (ALCES) Model at http://www.kenaiwatershed.org/alces.html.).

Finally, biologists at the US Forest Service and at the Kenai National Wildlife Refuge have also been studying climate change on the peninsula. The following list describes some of the changes documented in the Wildlife Refuge. The following write-up is slightly modified from http://alaska.fws.gov/nwr/kenai/science/ExternalReps/berg/clmt122.htm.

Rapid glacial retreat. Researchers developed a 2000-year chronology of glacial advance and retreat on the Kenai Peninsula. They found that glacier front positions on the western side of the Kenai Mountains are controlled primarily by summer temperatures, whereas glacier fronts on the Prince William Sound side are controlled by winter snowfall. They also showed that glacier fronts have generally been receding since the end of the Little Ice Age in the 1860's. Studies of aerial photographs of the Harding Icefield in the Kenai Mountains show a 5% loss of ice area between 1950 and 1985. A 1997 study reported a 70 ft reduction in thickness of the Harding Icefield from early 1950's to mid-1990's (see http://www2.gi.alaska.edu/ScienceForum/ASF13/1385.html).

Rising treeline. Sitka and white spruce on the flanks of the Kenai Mountains show a strong upslope gradient to younger trees. We have found that ring-widths of these trees generally do not show a strong correlation with temperature records of local meteorological stations. This indicates that the trees are not stressed for temperature and that they could grow at still higher elevation. Physiological tree line thus appears to be advancing so rapidly that the trees have not kept up with it. Local residents in Kachemak Bay say that treeline has visibly risen at least several hundred feet since the 1940's (Yule Kilcher, pers. Obs., 1997). Furthermore, this process appears to be unidirectional, because one does not see old dead trees at treeline that might suggest that treeline has temporarily receded at some point in the past. This unidirectional character of all climate-driven processes on the Kenai is quite striking, and suggests that this climate change is a long-term trend and not an oscillating process.

Wetland drying. This takes several forms on the Kenai Peninsula, including

a) *Disappearance of kettle ponds*. The hilly moraine areas of the KNWR have many kettle holes, left by foundered blocks of ice during retreat of glaciers about 13,000 years ago. The 1950 USGS quadrangle maps and 1950 aerial photos show these kettles as water-filled ponds, but today many are grassy pans with varying degrees of spruce and hardwood invasion. Horse packers who in the past depended on these ponds report increasing difficulty in finding water holes for their horses during fall moose hunts (Lou Albrant of Sterling, pers. Obs., 1998). Many small ephemeral ponds on the Refuge have either gone dry or their levels have dropped drastically between the first wood frog survey in 1991 and the most recent survey in 1998 (Ted Bailey, KNWR, pers. Obs., 1998). Spruce invasion of the Island soil series has been noted at least since the 1960's (Rieger et al. 1962). This soil series is usually found in small, open, bowl-shaped depressions in forest uplands. Prominent hummocks provide a thick insulating sod that keeps soil temperatures low and has effectively repelled trees in the past. Comparison of these depressions with the 1950 aerial photography, however, shows rapid forest encroachment (Scott Stewart, Mike Gracz, Homer NRCS, pers. Obs., 1998). Rieger et al. (1962) reported that in the Kenai-Soldotna area many of these depressions are completely forested. They still have the hummocky surface characteristic of the Island soils, but the soils have taken on

most of the properties of the surrounding Soldotna soil series, which are more acidic. We thus see a continuum from water-filled kettle ponds to grassy hummock depressions (with Island series soils) to forested depressions with forest-influenced soils of the Soldotna series. We expect that a careful look at tree ages and aerial photos will show that there is again a unidirectional process here, that the process initiated within the last 100-150 years and that it has greatly accelerated since the 1950's.

b) *Spruce invasion of wetlands and muskegs*. The Kenai lowlands have tens of thousands of acres of shallow lakes and marshes. Many of the marsh edges show invasion of stunted black spruce trees that appear to be living at the limit of their tolerance to water-logged soils. We sampled black spruce at two marsh edges and found that trees 1 ft to 2 ft tall were as much as 30-40 years old, with fairly even recruitment beginning in the 1950's. Like treeline, we observed no visible mortality (dead stems) in the stunted trees, which would have indicated a temporary rise of water level above what the trees could tolerate (EB, KNWR, pers. obs, 1996). This recruitment also acts like a unidirectional process. Similarly, there are extensive glacial lake beds of Naptowne age (~16,000 years before present) south of the Kenai River toward Kasilof and in the Anchor Point area (Reger and Pinney 1997). These are very flat with only an occasional channel for drainage. They are dominated by sedges, *Sphagnum* moss, ericaceous shrubs, and cloudberry (*Rubus chamaemorus*) on the wet end and grade into grass (*Calamagrostis canadensis*) on the dry end. We see every stage of spruce invasion on these lake beds, from open treeless areas, to scattered stunted black spruce, to closed canopy black spruce thickets. We expect that most of this recruitment has taken place within the last 100-150 years as water levels have slowly declined. Again, one does not see stands of dead trees on these lake beds, and we infer that the water table decline is unidirectional.

c) *Falling lake levels*. On the Kenai lowland there are many examples of lakes whose water levels have fallen several feet in recent years. Residential boat docks can be seen that no longer reach the water (e.g., Bernice Lake, EB, KNWR, pers. obs, 1998). In some cases we see willow, cottonwood, or alder recruitment on the newly exposed shores, but in other cases we see only herbaceous weeds that favor exposed mineral soil. These patterns suggest that lake levels have fallen within the last 5 years or so. It is worth remarking that various long-term hydrological changes occurred on the western Kenai Peninsula as a result of the March 27, 1964 earthquake. These should not be confused with climate change effects.

Strongly increasing temperatures at the Kenai and Homer meteorological stations. Kenai records a 2.9 degree F/50 year increase in mean annual temperature since the mid-1940's, and Homer records a 3.9 degree F/50 year increase in the same period. Much of this increase occurs in warmer Decembers, but summer temperatures are up as well. These are extremely strong gradients. (Data are from monthly NOAA Climatological Data Reports.). Annual precipitation varies considerably on the Kenai Peninsula, with Kenai annual precipitation ranging from 11 to 27 inches. In spite of great year-to-year variation at both stations, there is no apparent long-term trend toward lower or higher precipitation values, such as we see in air temperatures. If precipitation is more-or-less constant and temperatures are rising, this suggests that increased evapotranspiration is the source of the declining water tables described above.

Treeline chronologies. The instrumental meteorological record on the western Kenai Peninsula begins in 1932 in Homer and 1944 in Kenai. It is possible to reconstruct pre-instrumental temperatures from treeline tree rings. At tree line the trees should be stressed for temperature (and not precipitation), so a warm year should produce a wide ring and a cold year should produce a narrow ring. Such temperature-sensitive trees are good recording thermometers, and their ring-widths can be used to estimate past temperatures. KNWR Grad student Andy DeVolder prepared a 290-year chronology from hemlock trees growing on a north-facing slope at treeline on the Skyline Trail. He found that the hemlock ring-widths correlated best with growing season temperatures (May-July), and that growing season temperatures at this site have increased from a low in the 1810's to the present. Like the stock market, this chronology has many local ups and downs, but the long-term trend at this treeline site is clearly upward.

Drought stressed trees and spruce bark beetles. Many of the larger white/Lutz/Sitka spruce trees in mature stands show substantial narrowing of the annual rings in recent decades. Slow growing spruce trees are especially vulnerable to bark beetle attack (Hard 1985, 1987). Part of this narrowing is due to increased

canopy competition as stands have matured. Part of it, however, may be due to drought stress, which is a potentially greater problem for large trees than small trees. Spruce bark beetle outbreaks have followed two recent periods of multi-year warm weather drought stress (the central Peninsula in 1968-69 and the southern Peninsula in 1989-1997). We have substantial tree-ring evidence of regional beetle outbreaks in the 1820's and especially in the 1880's (Berg, 1998; Fastie et al., in preparation). Andy DeVolder's temperature chronology (see above) shows a major cool period in the 1810's and a very dramatic cooling in 1876-78, presumably caused by three high latitude volcanic eruptions in 1875 and 1876. In these two cases the beetle outbreaks occur after a cool period, rather than during a warm period such as 1968-69 or 1989-1997. Probably, the key variable here is drought rather than temperature. Warm summers can certainly create drought stressed trees, but low annual precipitation can also create drought stress.

Here are links to some other sources of information on climate on the Kenai Peninsula:
http://inletkeeper.org/issues/climate-change
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_038171.pdf
http://www.lter.uaf.edu/dev2009/pdf/1055_Riordan_Verbyla.pdf
http://www.inletkeeper.org/salmon/71009lkp.pdf

Coho (silver) salmon

(see introductory article 1: Salmon species and life cycle)

As you can see by looking at salmon distribution maps under Anadromous Waters Catalog, coho (silver) salmon are the gypsies of our watersheds, traveling far and wide in a search for rearing and overwintering habitats. They have been found rearing in tiny headwater streams—almost too small to map—and they may also travel through "pipestreams" buried in peat-dominated wetlands.

Connectivity

(see also Fragmentation)

Stream systems, wetlands, moose migration corridors, and many other ecological systems can only function well—and provide us with benefits like healthy salmon populations and clean water—when critical connections are protected. Connections between parts of these systems allow many essential processes to occur, including maintenance of water quantity and quality in streams and rivers, transport of essential nutrients and chemicals, and movement of organisms between habitats needed during different stages of their lives. Breaking these kinds of links, as when a road or subdivision is developed in ways that block or change physical or biological connections, can disrupt processes essential for affected ecosystems, leading to lower environmental quality, habitat loss, and the decline of fish and wildlife populations. Obviously, this kind of issue is critical to salmon populations, which are very dependent on these kinds of connections because of their highly migratory life cycle (see *introductory article 1: Salmon species and life cycle*). Issues of ecological connectivity and resilience are best addressed watershed-wide and as far in advance as possible before development fragments connections that become extremely difficult to re-establish.

As the Earth's climate changes, many species will have to move across human-dominated landscapes searching for suitable habitats in their changing ecosystems. Expanding and connecting networks of different natural environments is one way to provide species with as many potentially suitable habitats as possible. Landowners can play a central role in maintaining habitat connections by implementing recommendations found throughout this watershedipedia (e.g., see Best Management Practices).

The following two articles provide more information on this topic:
Landscape connectivity promotes plant biodiversity spillover into non-target habitats http://www.pnas.org/content/106/23/9328.full

and Beyond Reserves and Corridors: Policy Solutions to Facilitate the Movement of Plants and Animals in a Changing Climate; John Kostyack, Joshua J. Lawler, Dale D. Goble, Julian D. Olden and J. Michael Scott; *BioScience,* Vol. 61, No. 9 (September 2011), pp. 713-719 (article consists of 7 pages) Published by: University of California Press on behalf of the American Institute of Biological Sciences; abstract found at: http://www.jstor.org/pss/10.1525/bio.2011.61.9.10 Abstract

Conservation easement

A conservation easement is a voluntary agreement that allows a landowner to permanently limit the type and amount of development on his or her property while the property remains in private ownership. On the Kenai Peninsula, the Kachemak Heritage Land Trust (KHLT, at http://kachemaklandtrust.org/) helps landowners establish conservation easements on their property. The Land Trust Alliance website (http://www.landtrustalliance.org/) also provides useful information about conservation easements and land trusts.

Working with KHLT, a landowner identifies specific permitted uses of the property. These normally include agriculture, forestry, recreation, or other open space uses. The easement limits or prohibits certain activities, including industrial, commercial, and/or residential development. The easement is signed by the landowner(s) (the easement donor), and KHLT or other appropriate entity (the party receiving the easement). The easement is then recorded with the state's recording office and becomes a restriction that runs with the title of the land. Easements are flexible and easily tailored to meet a landowner's needs, for example, an easement may cover portions of a property or an entire parcel. Easements are legally binding on all future owners, and are monitored and enforced by the land trust (or local government) receiving the easement.

Cook Inletkeeper (CIK)

(From http://inletkeeper.org/.) Cook Inletkeeper is a community-based nonprofit organization that combines advocacy, education and science toward its mission to protect Alaska's Cook Inlet watershed and the life it sustains. Inletkeeper's monitoring and science work builds credibility with scientists and resource managers, its education and advocacy efforts enhance stewardship and citizen participation, and together, these efforts translate into Inletkeeper's ability to effectively ensure a vibrant and healthy Cook Inlet watershed.

CIK goals are to
1. Grow support for clean water and strong local economies;
2. Promote the shift from fossil fuels to renewable energy;
3. Protect healthy habitats in a changing climate; and
4. Build an effective organization with the capacity to achieve its vision.

One CIK program of potential interest to landowners is the Citizens' Environmental Monitoring Program (CEMP). This program trains volunteers to collect stream data in scientifically valid ways so that current conditions and long-term trends can be tracked; for more information, see Citizens' Environmental Monitoring Program at http://inletkeeper.org/clean-water/citizen-monitoring/cemp-partnership.

Another program of interest to landowners began in 1998. In partnership with Homer Soil and Water Conservation District, Inletkeeper began an in-depth water quality study to better understand the ecological effects of land-use activities and climate change on the area's economically, socially, and culturally valuable salmon streams: Ninilchik River, Deep Creek, Stariski Creek, and Anchor River. Using EPA-approved or Standard Methods, Inletkeeper's Stream Ecologist monitors 12 sites in local streams for discharge, temperature, dissolved oxygen, pH, conductivity, nitrate-nitrogen, ammonia-nitrogen,

orthophosphate, total phosphorus, apparent color, turbidity, settleable solids, total suspended solids and bacteria. Monitoring goals are to
1) inventory baseline water quality in lower Kenai Peninsula salmon streams,
2) compare data with state water quality standards, and
3) inform citizens and natural resource managers about concerns related to salmon stream protection.

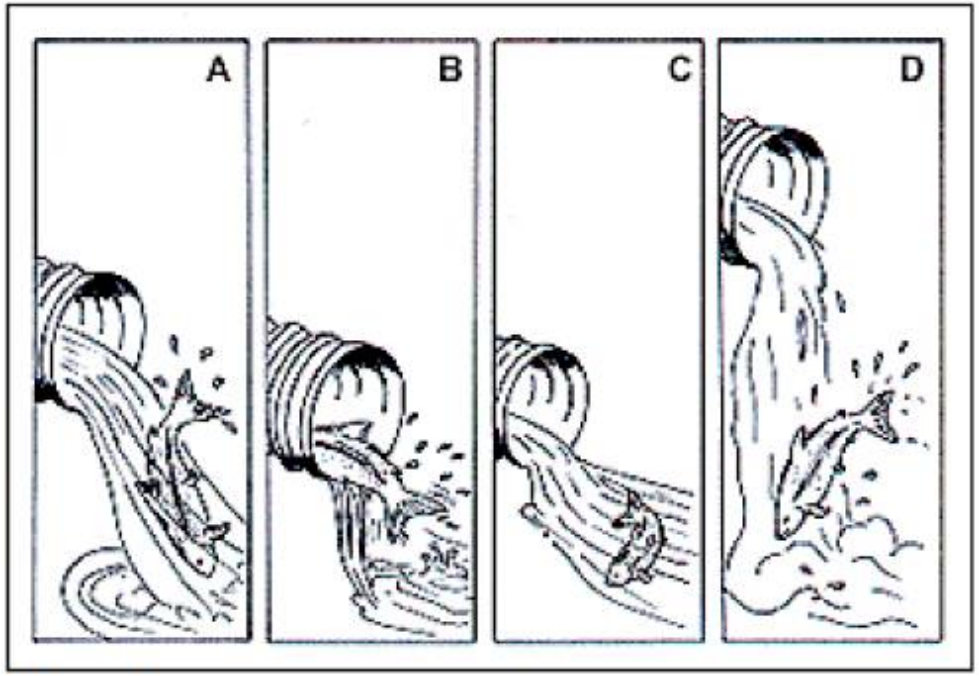
The Salmon Stream Monitoring Program was developed under the direction of a Technical Advisory Committee (TAC) of scientists from federal and state agencies. The TAC chose sampling sites, determined the sampling frequency, and reviewed the chosen methods to best address concerns related to salmon stream health. Sampling and analysis methods were chosen so that data could be compared with data from other professional-level studies both in Alaska and around the United States. All quality assurance methods are described in the Project's Quality Assurance Project Plan.

Data collected during this time have shown increasing temperature trends, where summer stream temperatures consistently exceed Alaska's water quality standards for fish protection, and warmer temperatures are occurring earlier and for more days each year. In addition to a disturbing warming trend, Inletkeeper's data suggests increasing amounts of sediment entering stream channels (see Turbidity), high phosphorus levels, and sharp declines in macroinvertebrate communities. For more information on CIK's stream temperature monitoring, see http://inletkeeper.org/healthy-habitat/stream-temperature-monitoring-network.

Culverts
(see also Fish passage)

Improperly designed or installed culverts prevent fish from swimming through them, thus blocking fish passage and access to potential habitats upstream or downstream of the culvert. A single culvert may block fish passage to large areas of a watershed. Culverts block fish passage in a number of ways. Four are illustrated in the **drawing at right** (from http://www.fws.gov/midwest/fisheries/streamcrossings/images/PDF/culvert-bmps-english.pdf).

A: Velocity of water flow through culvert is too fast for fish to swim against.
B: Water depth in culvert is too shallow for fish to swim in.
C: No resting pool exists at the outlet of the culvert.
D: Culvert is perched above stream level too high for fish to jump.



Small juvenile salmon may have as much (or more difficulty) passing through problem culverts as larger adults. This can prevent juvenile salmon from accessing rearing or overwintering areas, or from traveling downstream as smolts.

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Below left: The culvert is perched, preventing fish passage. Below right: the culvert has been replaced and is at the proper depth for streamflow and fish passage (from HSWCD).

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Culvert in center photograph was blocking fish passage up Beaver Creek (a tributary of the Anchor River). Larger photos show replaced culvert (from HSWCD).

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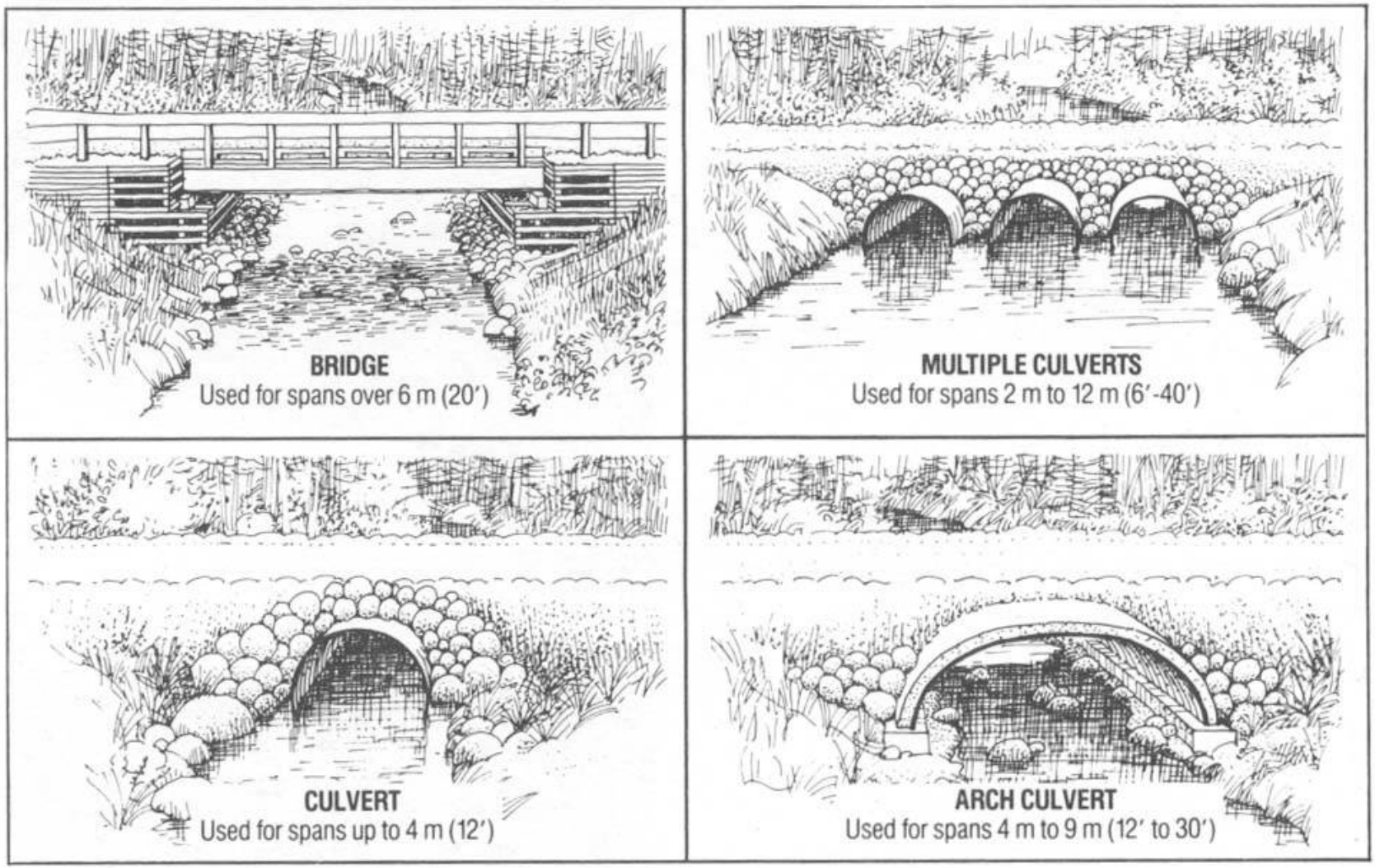
Because of the importance of culverts in how salmon move throughout our watersheds, culverts have been surveyed to identify problem sites. Many problem sites are identified in the Kenai Watershed Forum atlas at http://www.kenaiwatershed.org/atlas.html. (See *introductory article 3: Exploring your watershed with online tools* for more details.) Instructions for installing culverts in salmon friendly ways are available from many websites. Illustrations below are from an example, a report called Culvert Installation in Salmon Streams, http://www.fws.gov/midwest/fisheries/streamcrossings/images/PDF/culvert-bmps-english.pdf.



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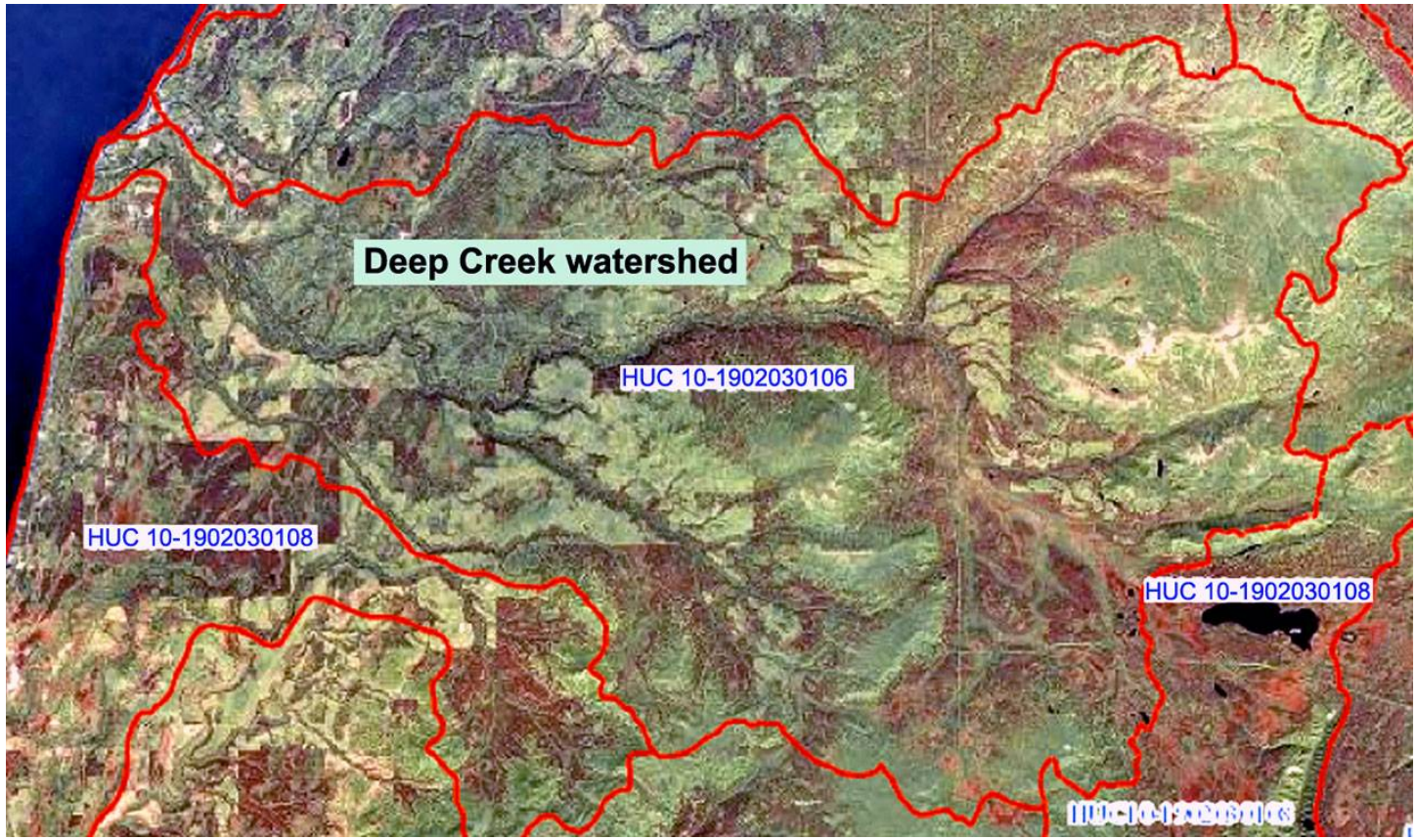
Deep Creek and its watershed

Deep Creek and its watershed lie between the Ninilchik River watershed to the north and Anchor River and Stariski Creek watersheds to the south (as well as watersheds not covered in this guide). The mouth of Deep Creek is about 4.0 mi. south of the mouth of Ninilchik River. The watershed covers roughly 218 sq mi (just over 139,500 acres) and headwaters in the Caribou Hills, which reach an elevation of about 2860 ft at Ptarmigan Head. The mainstem channel is about 40 miles long when measured "as the boat floats."

Deep Creek follows channels carved by much larger flows that drained melting glaciers (see Caribou Hills). As noted in the Quaternary Guidebook discussed under Glacial history of western Kenai Peninsula, deeply incised, straight reaches of Deep Creek trend generally northwest and are sharply separated by shorter straight reaches that generally trend east–west. Evidence in the Caribou Hills indicates that the straight northwest-trending reaches follow a system of parallel bedrock faults. The deep valley of lower Deep Creek is wider than the lower valley of the Ninilchik River and is deeply cut into Tertiary bedrock (which are much older sediments). Stream terraces on opposite sides of Deep Creek do not match in elevation and have cross sloping treads, indicating, along with the relatively wide valley, that Deep Creek meandered back and forth across its valley during incision (channel downcutting). Distribution of moraines, ice-marginal meltwater channels, and outwash terraces indicate that ice from the Kenai Mountains entered the upper Deep Creek drainage during middle and late stades of the early Wisconsin glaciation. Ice of the Naptowne glaciation scoured the northeastern flank of the Caribou Hills up to an elevation of about1,800 ft but did not enter the headwaters of the North Fork of Deep Creek.



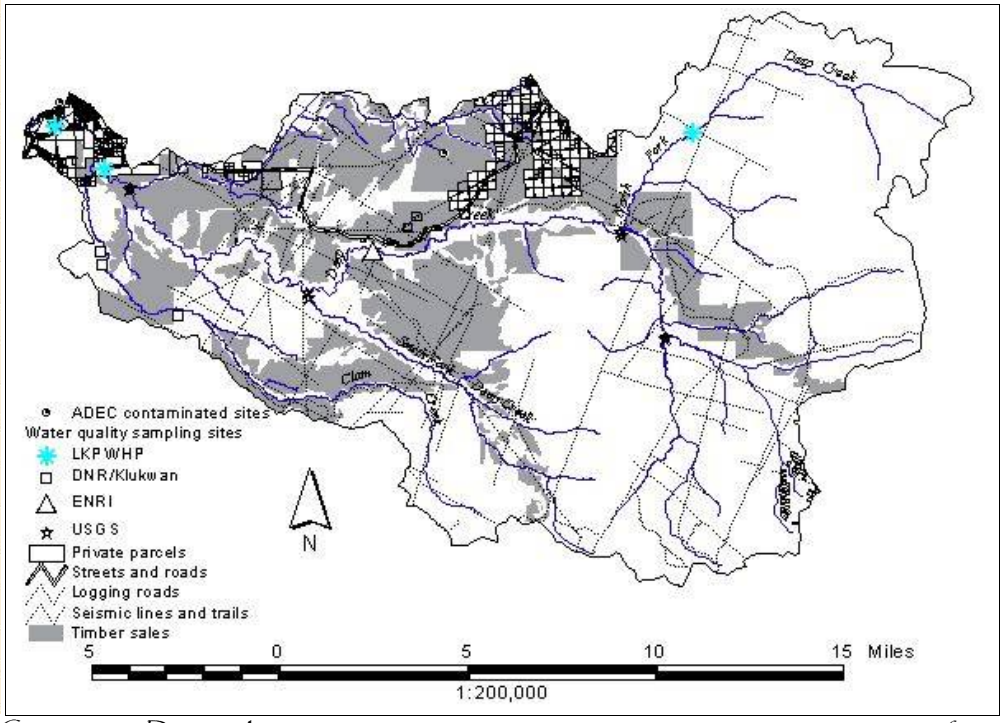
The Kenai Watershed Forum atlas divides Deep Creek watershed into five subwatersheds: North Fork, South Fork, Gamma, Cytex, and Clam Creeks (see **map after following page**). The combined

length of subwatershed streams and mapped tributaries is about 270 rive miles (for comparisons with neighboring watersheds, see Anchor River or Stariski Creek entries). Like neighboring watersheds covered in this guide, Deep Creek supports chinook, coho, and pink salmon, as well as Dolly Varden and steelhead (see *introductory article 1: Salmon species and life cycle*).

Some streamflow data are available for Deep Creek from the US Geological Survey and National Weather Service. The table below shows discharge and stream temperatures on the North Fork of Deep Creek. Compare these flows with data reported for October 24, 2002, when Deep Creek discharge reached 22,000 cubic ft per second (cfs) and a stage height of 23.3 ft at the Deep Creek bridge gage.

Sample Datetime	Time datum	Time datum reliability code	Sample Medium Code	Temperature, water, deg C (00010)	Instantaneous discharge, ft3/s (00061)	Specific conductance, wat unf uS/cm @ 25 degC (00095)	Discharge, instantaneous m3/s (30209)
1978-07-12 18:20	AKDT	T	WS	14.5	131	75	3.7
1978-08-17 08:25	AKDT	T	WS	10.0	115	90	3.3
1978-09-14 09:00	AKDT	T	WS	8.0	225	70	6.4
1978-10-09 14:17	AKDT	T	WS	5.0	311	65	8.8
1978-10-12 12:30	AKDT	T	WS	4.0	237	80	6.7
1978-11-09	AKST	T	WS		129		3.7
1979-01-11 10:10	AKST	T	WS	0.0	106		3.0
1979-03-13	AKST	T	WS	0.0	99		2.8
1979-04-18 18:05	AKST	T	WS		142		4.0
1979-05-02 11:45	AKDT	T	WS	1.0	E 930	50	E 26
1979-05-16 18:45	AKDT	T	WS	5.5	E 560	40	E 16
1979-05-31 11:10	AKDT	T	WS	9.0	334	40	9.5
1979-06-14 17:20	AKDT	T	WS	16.0	134	65	3.8
1979-07-19 16:15	AKDT	T	WS	15.5	140	75	4.0
1979-08-15 16:30	AKDT	T	WS	12.5	122	85	3.5
1980-03-04 10:15	AKST	T	WS	0.0	173	75	4.9
1980-07-24 12:10	AKDT	T	WS	12.5	196	60	5.6
1980-09-03 10:10	AKDT	T	WS	5.0	157	75	4.4

The map below shows some basic data for the Deep Creek watershed. This map was developed in 2005 by Cook Inletkeeper as part of a project to monitor lower Kenai Peninsula watershed health. You can see that large portions of the Deep Creek watershed were included in timber sales after the spruce bark beetle outbreak in the 1990s (see Forests and spruce bark beetles). A wealth of recent data such as is shown below is available in the Kenai Watershed Forum atlas mentioned above.



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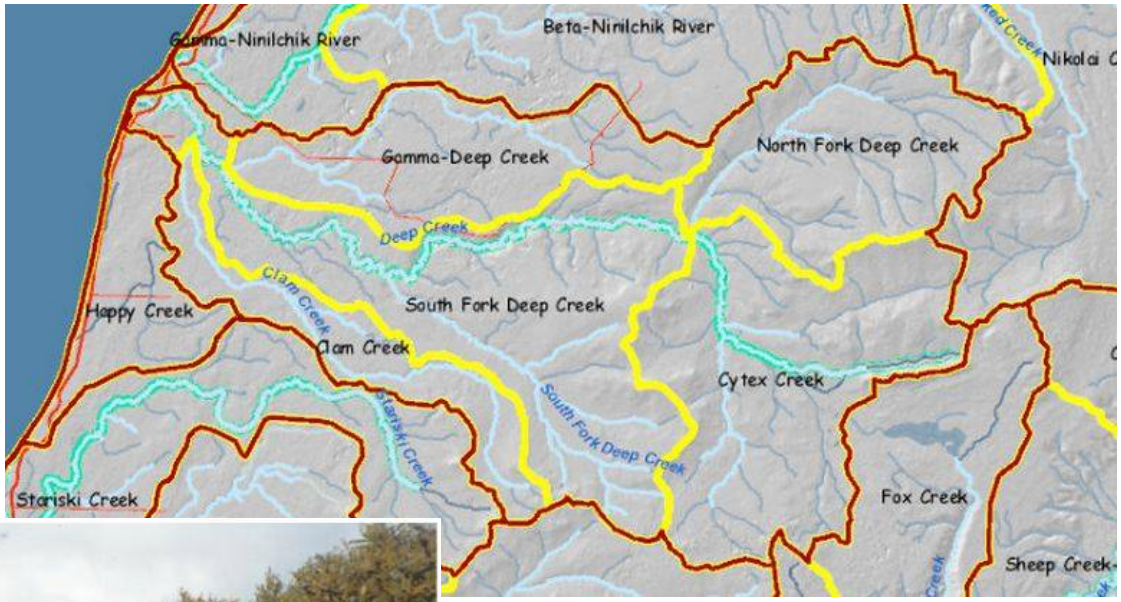
Map at right shows Deep Creek watershed as divided into five subwatersheds in the Kenai Watershed Forum atlas: Gamma, North Fork, Cytex Creek, South Fork, and Clam Creek. Specific information about each of these subwatersheds can be found in the KWF atlas (http://www.kenaiwatershed.org/ Atlas/index.html#). For instructions on using the atlas, see *introductory article article 3: Exploring your watershed with online tools*.

The **photo below** shows Upper Deep Creek (taken by Cook Inletkeeper biologists monitoring Lower Kenai Peninsula Watershed Health).



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Depression wetland ecosystem

(see also Glacial history of the western Kenai Peninsula)

Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands. Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia listing wetland functions and values.

(Slightly modified from http://www.kenaiwetlands.net/EcosystemDescriptions/Depression.htm.) Depression wetland ecosystems are surrounded by upland, there is no wetland connection to a navigable waterbody. However, large Depression wetlands could be navigable-in-fact lakes. They are uncommon and diverse on the lowlands. Depressions occur on younger glacial surfaces such as the large 'Moosehorn' recessional moraine east of Sterling or the pitted till between Nikiski and Moose River. These younger surfaces have yet to become subdued by erosion. Although Depression wetlands are not connected by other wetlands to a navigable waterbody, and thus may not be jurisdictional under recent interpretations of Section 404 of the Clean Water Act, they do meet hydrological, plant, and soils criteria as wetlands and perform typical wetland functions, such as duck nesting habitat and groundwater recharge. Larger navigable-in-fact isolated lakes are jurisdictional wetlands subject to wetland permits.

A forested depression near Deep Creek, 10 miles east of Ninilchik.

Depression wetland ecosystems can be difficult to discern from Kettles. Depressions are hydrologically isolated at or near the surface, but connections can be difficult to detect without careful scrutiny of aerial photography or a thorough ground search. Some connections between kettles and other wetlands were too small to map at a scale of 1:25,000. If a connection was discernible using stereo-paired aerial photographs, or was discovered on the ground, the wetland was mapped as a Kettle even if the connection was not mapped. If no connection was found, it was mapped as a Depression. Depressions are most common north of Clam Gulch.

Both Kettles and Depressions were formed by similar processes, namely deposition at the margins of ablating glaciers. Depression wetlands are of two types, neither connected by other wetlands to a navigable waterway. One type is a small steep-sided feature created as late-Wisconsin glaciers melted. After the glaciers melted, they left behind terminal moraines with material in closely spaced parallel ridges. The material was either pushed into ridges by re-activated retreating ice or deposited in crevasses at the glacier margin. The depressions between the closely spaced and steep-sided ridges almost always cover less than 5 acres, and are separated by intervening upland material. The second type of Depression wetland is a large depression, often a lake, on the reworked till between Nikiski and Sterling.

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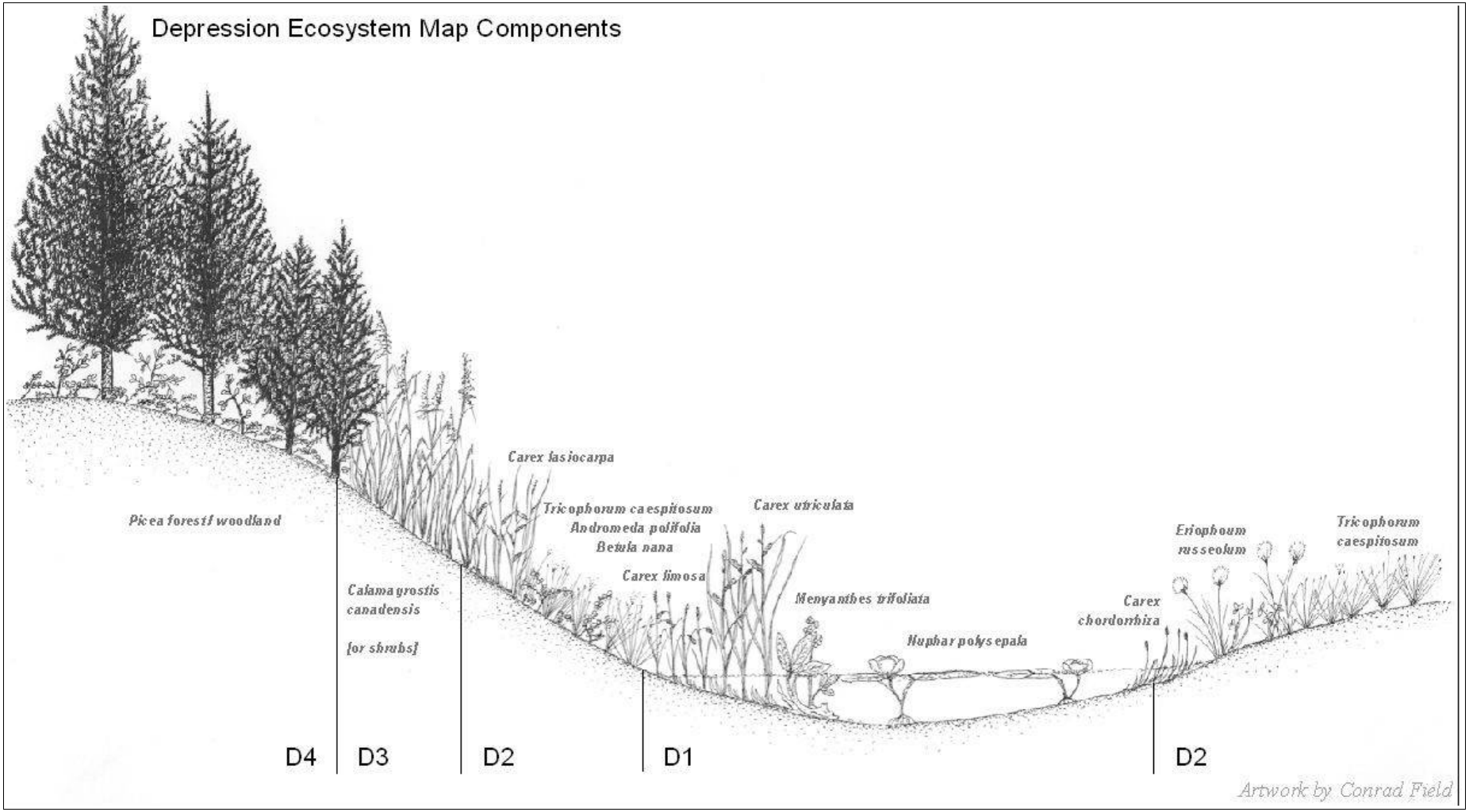

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Discharge
(see Stream discharge)

Discharge area (slope)
An area where groundwater discharges (flows or seeps) out onto the land's surface, usually into a wetland or a stream, and often at a change in slope.

Discharge slope wetland ecosystem
Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands. Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia entry wetland functions and values.

(Slightly modified from http://www.kenaiwetlands.net/EcosystemDescriptions/DischargeSlope.htm.) These wetland ecosystems occur over a mineral soil at the wetland to upland transition. Peat is typically thin or absent and mineral soils dominate. Discharge Slope Wetland Ecosystems are found at the edges of all wetland ecosystems and at slope breaks on terraces. They commonly occupy foot- and toe-slope landscape positions at the edge of peatlands or stream valleys where groundwater discharges or where dense till perches a water table close to the surface. Discharge slope wetlands are fed either by upslope groundwater storage capacity or a perched water table atop dense glacial till. Many are forested. All wetlands that border uplands contain a Discharge Slope component, though sometimes this component is narrowly restricted and not mappable at 1:25,000.

Lutz spruce with a rusty menziesia/field horsetail understory on a terrace riser footslope above the large fen east of Anchor Point.

Because they occur at the wetland/upland edge, Discharge Slope wetlands encompass plant communities that may also occupy drier sites. Even after field visits, many discharge slope wetlands are difficult to map because they are wet in some spots, dry at others. Forested Discharge Slopes are the most difficult wetlands to discern on aerial photography. Although 15% of the Lutz spruce discharge slopes we visited were re-classified as upland, Lutz spruce discharge slope wetlands are very common, and many were missed on the National Wetland Inventory mapping done during the late 1970's.

Discharge slopes are important sites of groundwater nutrient supply to peatlands. Peatlands classified as fens have higher available nutrient concentrations than bogs. One nutrient source is the cations in groundwater percolating through nearby mineral soil. Nutrients from other sources, such as tephra, ocean-derived aerosols deposited by precipitation, or deeper groundwater discharge within the peatland may also support fens.

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Discharge Slopes are the second most extensive wetland ecosystem type mapped in the project area, even though they are frequently too narrow to map at 1:25,000, especially north of Clam Gulch. Although they are nearly ubiquitous at upland-wetland fringes by definition, they often cover less than 10% in any wetland (at 1:25,000) and so are frequently not named as a mapped component. All wetlands bordering uplands contain a Discharge Slope Ecosystem component whether or not it is named. Discharge Slopes are more extensive on dense, poorly sorted till, especially south of Clam Gulch.

On the southern Lowlands, Discharge Slopes usually occupy a broader foot- or toe-slope. Discharge Slope wetlands extend upslope to back-slope positions above some peatlands along the west margin of the Caribou Hills and along the northern shore of Kachemak Bay.

Lutz spruce with Barclay's willow and field horsetail at the margin of a small fen in the Caribou Hills.

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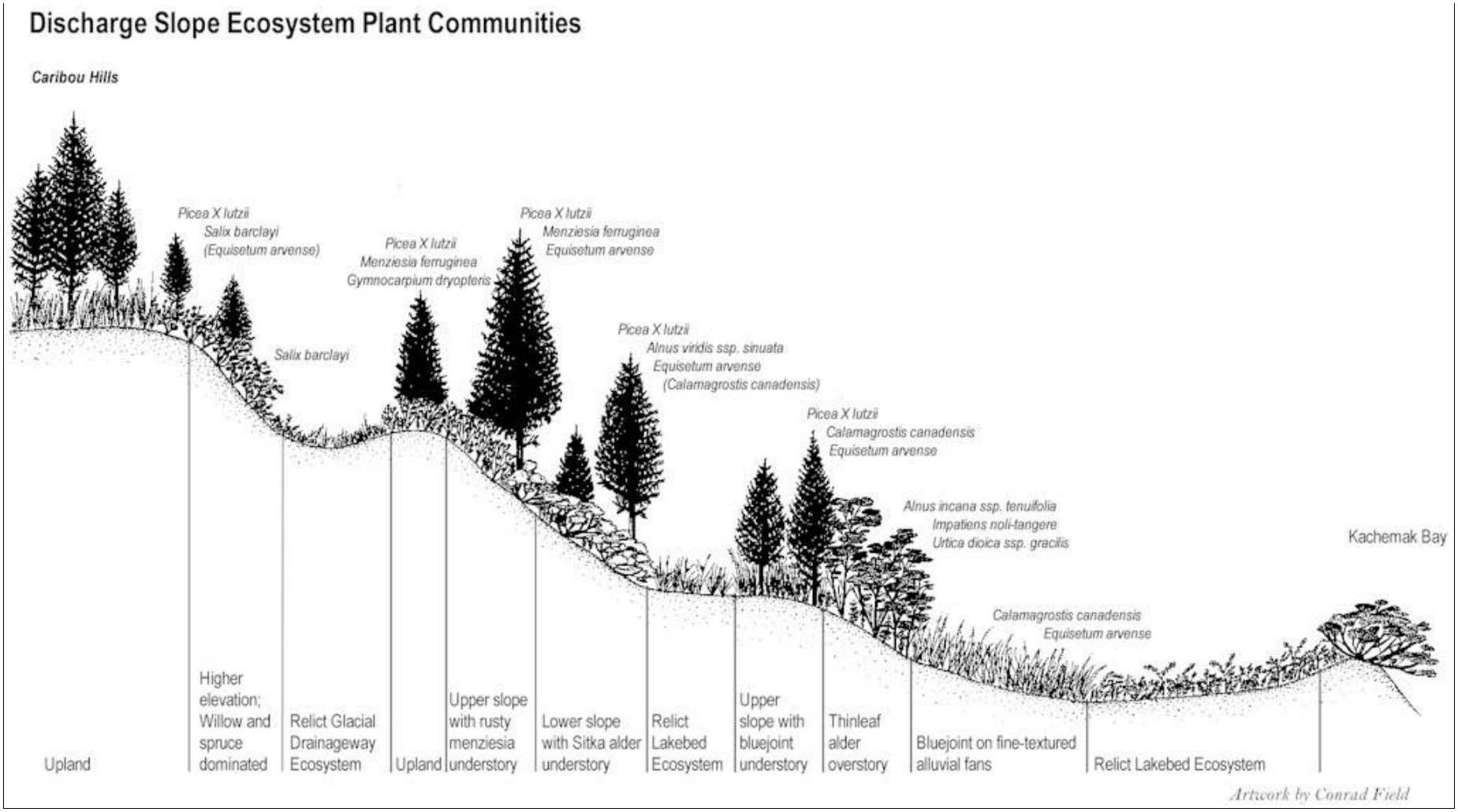
Idealized representation of Discharge Slope Ecosystem plant relationships along a hypothetical gradient from the Caribou Hills to Kachemak Bay.



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Dolly Varden

(See introductory article 1: Salmon species and life cycle)

Drainageway wetland ecosystem (relict glacial drainageways)

(see also Glacial history of the western Kenai Peninsula)

Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands. Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia listing wetland functions and values.

(Slightly modified from http://www.kenaiwetlands.net/EcosystemDescriptions/Drainageway.htm.) All Relict Glacial Drainageway wetland ecosystems contain significant shallow groundwater flow, but segregate into a diverse array of five major types. These types all basically function as spring fens, areas where groundwater discharge supports a rich peatland. The five types are: (1) abandoned features, which can be either wide (1) or narrow (2); (3) stream fringes, which are features adjacent to modern streams; (4) spring fens, which are areas of relatively strong groundwater discharge; or (5) surface water fens, where a stream originating on the slopes above empties onto a peatland terrace. With the exception of most spring and surface water fens, Relict Glacial Drainageway wetlands occupy broad linear features that transported meltwater from ancient glaciers.

Most drainageways function as spring fens, although other characters define them. In this classification, map components typically stratify along a depth-to-water-table gradient. However, the water table is near the surface in many Relict Drainageway wetlands, regardless of whether sedge, shrub, or spruce plant communities are dominant. At spring fens, groundwater composition probably determines the type of vegetation. Dissolved oxygen, mineral content, and flow rate are probably all important.

Abandoned Drainageways segregate into the first two types of drainageways: wide and narrow features. They vary in gradient (both perpendicular and parallel to flow) and wetness. Wider abandoned drainageways tend to be occupied by perennial surface flow, while narrower abandoned drainageways tend to support shallow, subsurface flow, or seasonal flow, or may be drying due to a wide combination of factors from climatic warming to drainage or groundwater depletion.

Some wide abandoned drainageways gradually grade in and out of Relict Glacial Lakebed wetland ecosystems characterized by strang-flark features, creating a confusing combination of ecosystem elements. Some narrow Relict Drainageways occur as short run connections between Kettle wetland ecosystems, especially where kettles are larger.

Stream fringe Relict Glacial Drainageway Ecosystems lie along the margins of modern underfit streams. Underfit stream valleys formerly carried large volumes of meltwater from glaciers. These modern streams are too small to have carved the valley they now occupy; they flow across deposits laid down by larger, glaciofluvial processes. A few poorly integrated drainageways, associated with the interlobate moraine, between the Moose River and Cook Inlet, may be the result of catastrophic flooding when Glacial Lake Cook emptied around the end of Eklutna time (see Glacial history of the western Kenai Peninsula).

At stream fringe drainageways. stream flow and probably groundwater discharge seem to support a high water table in an underfit valley. The fringes are different from the well-developed floodplains of larger streams. Underfit stream valleys were carved by larger, ancient glacial meltwater, and the modern

underfit stream only floods its oversized valley because the slope is nearly flat. Point bars and cut banks are absent.

Not all Relict Glacial Drainageway wetlands are linear features. A striking example of the fourth type of Relict Glacial Drainageway, the spring fen, lies between two moraines northwest of Tustumena Lake. A wet wooded peatland is supported by a broad area of groundwater discharge from beneath the moraine closer to Tustumena Lake. The peatland forms a headwater divide between Slikok Creek, which flows northward to the Kenai River, and Coal Creek, which flows west into the Kasilof River. So, water originating in Tustumena lake makes its way outside the Kasilof River watershed into the Kenai River.

At some spring fens groundwater discharges to the surface of the peat. A few of these fens are found in the same landscape position as the headwater divide, described above, but further south, east of Clam Gulch.

At surface water fens, modern streams spread across the surface of a peatland from the slopes above. A very wet sedge fen grows where the stream enters the peatland. Most spread out widely. At a few locales the streams re-form, eroding through the peat down to the till. At one locale east of Anchor Point the stream forms a small waterfall over a peatland headwall.

An ericaceous shrub/sphagnum mat DW5 unit in the upper Anchor River watershed

A water sedge-dominated stream fringe Relict Glacial Drainageway along the wide valley margin of the upper Anchor River.

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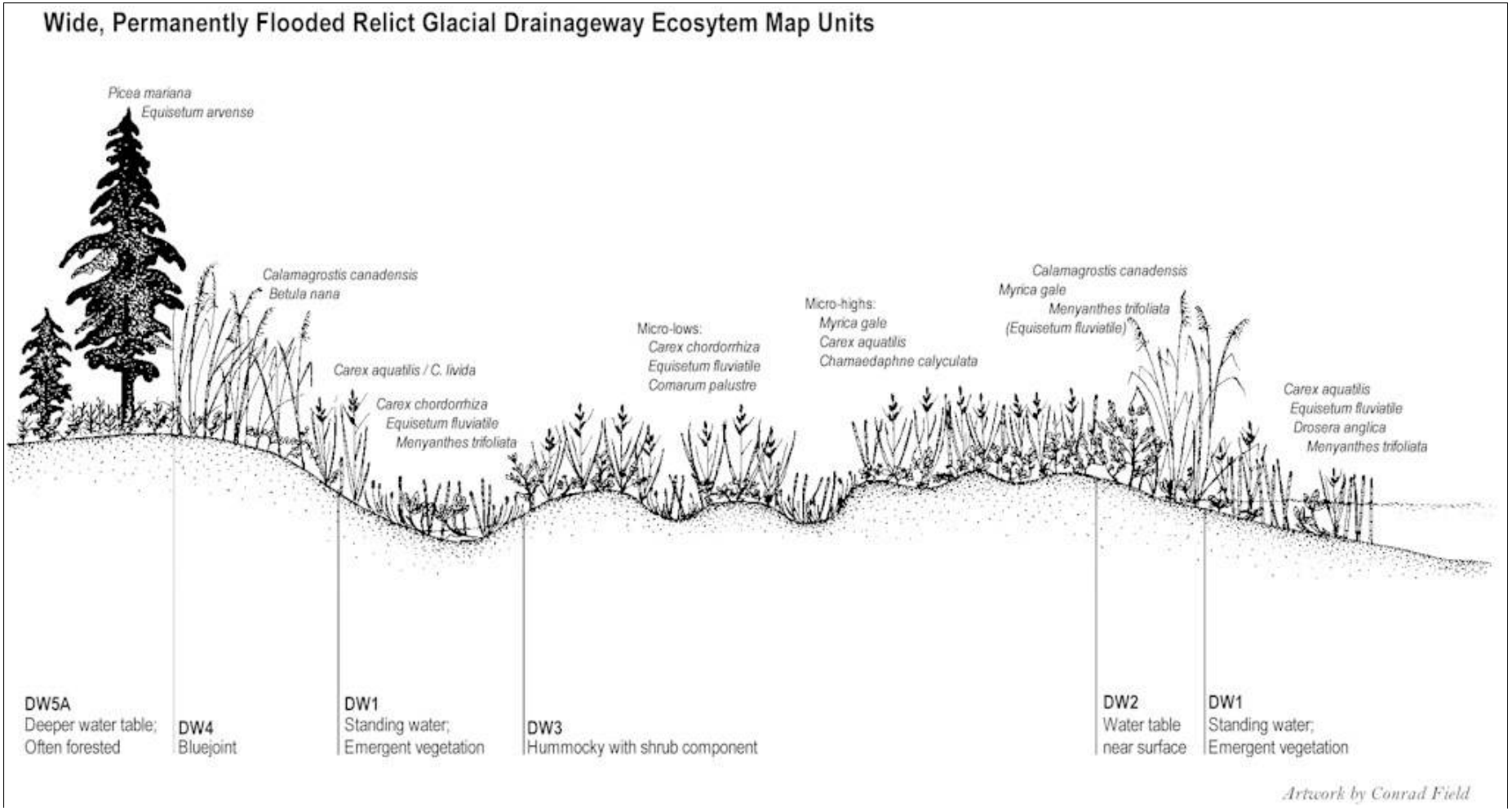

Plant relationships along a wide, permanently-flooded Relict Glacial Drainageway Ecosystem above Suneva Lake, northern Soldotna Creek watershed.

Dredge and fill

With respect to wetlands, dredging means digging up and removing material found in the wetland (or in other surface waters); digging ditches in a wetland is a kind of dredging. Filling means depositing any material in or on a wetland, including material dredged up or earth material excavated from elsewhere or piled up during land grading activities. Building a road across a wetland almost always involves filling (unless the road is built on pilings; driving pilings into a wetland is not considered dredge or fill).

Both dredge and fill activities change how water flows within and through a wetland, and also disturbs wetland plant communities. Because wetlands play such important and complex roles in an area's hydrology—and thus affect nearby streams and other waterbodies—it is not in society's best interests (or in the best interests of local salmon stocks) to alter wetland conditions or functions without careful consideration of possible impacts, including cumulative impacts caused by many projects scattered throughout a watershed. That's why wetland permits are required for dredge and fill activities in wetlands

Earthquakes

Landowners throughout Alaska have to deal with the possibilities of earthquakes, from minor shaking to extremely powerful and extensive earth movements. The 9.2 magnitude earthquake that shook Southcentral Alaska in 1964 is the second largest earthquake worldwide since 1900. (Only the 9.5 earthquake in Chile in 1960 was larger. The Japanese earthquake of March 11, 2011—which led to such massive and horrifyingly destructive tsunamis—had a magnitude of 9.0; see http://earthquake.usgs.gov/earthquakes/world/10_largest_world.php for more information.)

As explained throughout this landowner's guide, your actions can affect many of the more routine processes that shape your watershed and affect salmon habitats—processes like storm runoff, bankfull discharges, and baseflows; as well as infiltration and interception. These are the processes we encourage landowners to be aware of so that they can help keep their lands and water salmon friendly. With processes like earthquakes, tsunamis, flooding, and fires, the best action landowners can take is to prepare for these emergencies in advance to reduce risks to life and property. (Although, as explained under flooding, landowners can help minimize flood heights and how quickly floodwaters move downstream, and they can avoid causing localized flooding associated with flow obstructions such as undersized culverts or poorly designed roads.)

To help landowners prepare for natural events like earthquakes, the Kenai Peninsula Borough Office of Emergency Management has compiled a lot of useful information on its website: http://www2.borough.kenai.ak.us/emergency/. The following links take you directly to more information about earthquake preparedness: http://www2.borough.kenai.ak.us/emergency/prepared/emergency.htm and http://www2.borough.kenai.ak.us/emergency/prepared/earthquake.htm. The second link suggests how to take a number of useful actions to prepare your home and property for earthquakes. Two of these actions that CAN benefit salmon are:

- Anchor and Brace Propane Tanks and Gas Cylinders—this will minimize possible fuel spills that could pollute local groundwater and nearby water bodies (http://www2.borough.kenai.ak.us/emergency/EQ/how2009_anchor_tanks_cylinders.pdf) and
- Use Flexible Connection on Gas and Water Lines—this will also help minimize fuel spills and polluted runoff (http://www2.borough.kenai.ak.us/emergency/EQ/how2014_flex_connections.pdf).

Ecological footprint
(see also Sustainability)

This term was introduced by William Rees in 1992 and elaborated on in his book, *Our Ecological Footprint: Reducing Human Impact on the Earth*

(coauthored with Mathis Wackernagel, New Society Publishers, 1996). Our ecological footprint can be defined as:

> A measure of how much land and water is needed, on the one hand, to produce the resources we consume and, on the other hand, to dispose of the wastes we produce.

Each of us constantly leaves a bigger or smaller ecological footprint with every choice we make day to day. The smaller we make our cumulative ecological footprint, the more we increase the chances of keeping our watersheds salmon friendly. Below are listed some general recommendations to keep our ecological footprint as small and salmon friendly as possible. The "it" referred to in the list is whatever thing (resource) we're thinking of acquiring or using. These recommendations are modified from: http://inquiringsystems.org/index.php?option=com_content&view=article&id=62:sustainability&catid=36:articles&Itemid=65

- Be aware of misrepresenting *needs* for *desires*—do we really need it?
- If it's already available and accessible, do we need to go back into an ecosystem to get more of it, or can we produce it sustainably ourselves in areas already modified by human activities?
- If we really do need to get more of it, get it carefully—extraction infrastructure and processes will likely disrupt many relationships in the ecosystems from which we get more of it.
- If we already have it—take care of it, use it wisely and well to reduce the need to go back and get more of it (e.g., reduce, reuse, recycle).
- Respect what we have; many living things were destroyed and the health of ecosystems were put at risk in the process of getting it.
- Act responsibly when negatively impacting plants, animals, and other forms of life when obtaining it (e.g., resources for food, shelter, and well-being). Each form of life in natural ecosystems plays important roles in sustaining the health of those ecosystems; we (and salmon) depend on healthy ecosystems for survival and well-being.
- Encourage neighbors, communities, organizations, businesses, and governments to minimize their ecological footprints and move along the path toward sustainability.
- Don't let those whose values and ethics we don't respect determine how to live our lives.

Ecological (or ecosystem) services/green infrastructure

The concept of ecological services, or green infrastructure, helps us understand and describe benefits that the environment provides us that we've traditionally viewed as free, but that we would have to supply and pay for ourselves if our surroundings no longer furnished them. Examples include stormwater storage and the filtration of pollutants carried in overland runoff. Not all environments provide all services or provide services in the same ways or to the same degrees.

Homer Soil and Water explored this concept for the city of Homer by developing maps of "green infrastructure" that could be used to identify lands that provided one or more key ecological services. Development interests and regulations are built primarily around parcel boundaries, and are therefore not guided by larger landscape patterns that support ecological services. Landscape systems cross parcel boundaries, and as a result, beneficial natural functions (and values) are often sacrificed without regard to larger systems when individual parcels are developed. This project provided tools, training, and incentives needed by property owners and public entities to include landscape systems in development planning. Maps from the project are at http://www.suitabilitymap.org/.

(Modified from the EPA link http://cfpub.epa.gov/npdes/home.cfm?program_id=298.) Green infrastructure approaches and technologies maintain or restore natural hydrologies and other landscape processes, such as habitat connectivity for wildlife. By protecting ecologically significant landscape features (such as

forests, wetlands, riparian corridors), along with their functions and interconnections, communities can derive valuable services such as improved water quantity and quality, productive plant communities and fish and wildlife habitats, and opportunities for outdoor recreation and education.

How Does Green Infrastructure Benefit the Environment? (Slightly modified from http://cfpub.epa.gov/npdes/home.cfm?program_id=298#benefit.)
The benefits of green infrastructure are particularly accentuated in urban and suburban areas where green space is limited and environmental damage is more extensive. Green infrastructure benefits include:

- Reduced and Delayed Stormwater Runoff Volumes - Green infrastructure reduces stormwater runoff volumes and reduces peak flows by utilizing the natural retention and absorption capabilities of vegetation and soils. By increasing the amount of pervious ground cover, green infrastructure techniques increase stormwater infiltration rates, thereby reducing the volume of runoff entering combined or separate septic systems, and ultimately lakes, rivers, and streams.
- Enhanced Groundwater Recharge - The natural infiltration capabilities of green infrastructure technologies can improve the rate at which groundwater aquifers are recharged or replenished. This is significant because groundwater provides about 40% of the water needed to maintain normal base flow rates in our rivers and streams (and base flows are critical to salmon). Enhanced groundwater recharge can also boost the supply of drinking water for private and public uses.
- Stormwater Pollutant Reductions - Green Infrastructure techniques infiltrate runoff close to its source and help prevent pollutants from being transported to nearby surface waters. Once runoff is infiltrated into soils, plants and microbes can naturally filter and break down many common pollutants found in stormwater.
- Reduced Sewer Overflow Events - Utilizing the natural retention and infiltration capabilities of plants and soils, green infrastructure limits the frequency of sewer overflow events by reducing runoff volumes and by delaying stormwater discharges.
- Increased Carbon Sequestration - The plants and soils that are part of the green infrastructure approach serve as sources of carbon sequestration, where carbon dioxide is captured and removed from the atmosphere via photosynthesis and other natural processes.
- Urban Heat Island Mitigation and Reduced Energy Demands - Urban heat islands form as cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. The displacement of trees and vegetation minimizes their natural cooling effects. By providing increased amounts of urban green space and vegetation, green infrastructure can help mitigate the effects of urban heat islands and reduce energy demands. Natural (and enhanced) windbreaks can also lower the demand for heating, thereby decreasing use of fossil fuels and emissions from power plants.
- Improved Air Quality - Green infrastructure facilitates the incorporation of trees and vegetation in urban landscapes, which can contribute to improved air quality. Trees and vegetation absorb certain pollutants from the air through leaf uptake and contact removal.
- Additional Wildlife Habitat and Recreational Space - Greenways, parks, urban forests, wetlands, and vegetated swales are all forms of green infrastructure that provide increased access to recreational space and wildlife habitat.
- Improved Human Health – Many studies suggest that vegetation and green space - two key components of green infrastructure - can have a positive impact on human health. Recent research has linked the presence of trees, plants, and green space to reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performance, and even reductions in the symptoms associated with attention deficit and hyperactivity disorders. F or more information on other studies, visit: http://www.lhhl.uiuc.edu/all.sci entific.articles.htm.
- Increased Land Values - A number of case studies suggest that green infrastructure can increase surrounding property values.

Another way of looking at ecological services or the benefits of green infrastructure is in terms of *categories* of services that natural environments can provide

when they function well. Examples include:

1. *direct services*, which include:
    - soil (for growing plants, filtering water, supporting critical micro-organisms, etc.)
    - water (for drinking, growing food, maintaining fish and wildlife, supporting commercial and industrial uses, etc.)
    - air
    - plants (including plants that provide food or fiber)
    - animals (including livestock)
    - minerals
    - energy sources
2. *regulating services*, which include:
    - water filtration, purification
    - waste decomposition and detoxification
    - climate mitigation
    - carbon sequestration
    - crop pollination
    - pest and disease control
3. *support services*, which include:
    - nutrient dispersal and cycling
    - seed dissemination
4. s*ocial and cultural benefits*, which include:
    - recreation
    - intellectual, cultural, and spiritual inspiration
    - scientific discovery
    - ecotourism

Elevated, light-penetrating walkways and decks

(Photos: ADF&G. Contact the Gilman River Center for more information.)
These walkways (also called "gratewalks") allow light to penetrate to the ground, enabling plants to grow on soils beneath the walkways. Streamside plants stabilize streambanks and improve adjacent fish habitat.
Design requirements include:

- Decking must provide at least 60 percent light penetration.
- Length of gratewalk can be no more than 1/3 the length of the parcel's river frontage.
- Width of gratewalk must be 8 feet or less.
- Gratewalks must be elevated at least 4 inches above the ground (everything except pipe support).
- No pipe supports below ordinary high water.
- No pipe supports driven permanently into ground.
- Lightweight construction and seasonally removed

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Environmental Protection Agency (EPA)

EPA conducts a variety of programs to protect the health of citizens and the quality of environments throughout the country. A wealth of information about watershed processes and values, and how to keep watersheds healthy, is available at EPA's website (http://www.epa.gov/). For example, EPA's Science and Technology homepage (http://www.epa.gov/gateway/science/), which is accessed from EPA's main website, links to information about climate change, ecosystems, sustainable practices, and water, to list a few examples. Clicking on each of these topics links to much more information. A variety of EPA links are provided where appropriate throughout this watershedipedia.

One of the EPA's key focuses within Kenai Peninsula watersheds is assisting the Army Corps of Engineers in reviewing and commenting on wetlands permits. Under the Clean Water Act, Section 404, EPA shares responsibility with the Corps for regulating discharges to wetlands; develops and interprets wetlands policy, guidance, and criteria for evaluating permit applications; and reviews and comments on permit applications. EPA also supports state, tribal, and other entities in developing and improving wetlands and related programs. For example, EPA provided funding for the mapping and classifying of Kenai Peninsula wetlands (see http://www.kenaiwetlands.net/) and is now funding a project to assess the functions and values of these wetlands (see http://www.homerswcd.org/projects/wetlands.php and the watershedipedia entry: Wetland functions and values). EPA funding also supported development of the Kenai Watershed Forum atlas discussed in *introductory article 3: Exploring your watershed with online tools*. The local office of the EPA is located in the Gilman River Center in Soldotna, where EPA works closely with personnel from the borough, state, and other partners.

EPA

(see Environmental Protection Agency)

Erosion

(see also Stormwater runoff, Turbidity, Sedimentation)

Erosion is the removal of solids (sediment, soil, rock and other particles) in the natural environment. These earth particles are carried away by gravity (sometimes called slope creep), wind, water, or ice; or by living organisms, such as burrowing animals. Regardless of how they're moved, when soil particles are detached and transported away, erosion has occurred.

Streams are prime agents of erosion. Streams erode because they have the ability to pick up rock fragments and transport them to new locations. The size of the fragments they can move depends on the velocity of the stream and whether the flow is laminar or turbulent. Turbulent flows can keep fragments in suspension longer than laminar flow (see stream load). Streams can also erode by undercutting their banks and causing mass-wasting processes like slumps or slides. Streams can cut deeper into their channels if the region is uplifted (by an earthquake, for example) or if base level is lowered. Streams that are actively downcutting towards their base level, like those flowing down steep bluffs, often erode headward. As streams cut deeper into their channels. they remove material from the channel bottom and sides. Streams can erode their channels sideways (like a meander bend), laterally and downward at the same time, or just downward (downcutting).

Erosion is a natural process that shapes landscapes. Stream systems that support salmon have developed in balance with natural rates of erosion. This means that streams are receiving enough sediment so as not to downcut their channels but not too much sediment so as to fill in parts of their channels. When streams reach this kind of dynamic equilibrium, the location of particular stream features like meander bends, point bars, gravel beds, or pools and riffles may change, but the availability of these features—their frequency in the stream—will remain relatively stable. This is beneficial to species like salmon that need these kinds of instream habitats.

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After a major disturbance—such as flooding in 2002—streams will work to re-establish a dynamic balance between discharge, channel shape, and sediment load (see stream channel processes). As streams do this, habitats that were destroyed or damaged are re-established.

But when natural rates of erosion increase because of human activities, a number of changes can occur that can be harmful to salmon.

- Spawning gravels can become covered by sediments, suffocating eggs and alevins (hatched salmon) that are developing within the gravel beds.
- The increased turbidity clouds the water, making it more difficult for feeding salmon to see and find food.

[add suitable illustration]

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Erosion and erosion control
(see also Erosion, Soil bioengineering)

Erosion is the general name for processes that break down rocks (weathering) and that carry away the breakdown products. Weathered particles, including soils, are transported by water, gravity, wind, and ice (e.g., glaciers). Currently, the most active agent of erosion on the peninsula is no doubt water; and as discussed under topics like Surface runoff, the unmanaged transport of sediments by storm runoff and snowmelt can harm salmon. For example, sediments carried into streams by erosion can silt in gravel beds used for spawning, suffocate salmon eggs and alevins incubating in streambeds, irritate salmon gills and make them more susceptible to infections, increase stream turbidity so that salmon have difficulty finding food (salmon feed by sight), and smother aquatic plants needed by the insects and other invertebrates on which young salmon feed. The **photo below** shows a stream corridor well protected from erosion.

Many Kenai Peninsula soils formed in volcanic ash, which is particularly susceptible to erosion. When we put in driveways or excavate for a building or till up a garden bed or do any activity that disturbs the ground surface, we remove the organic mat of plants and plant litter and thus expose volcanic ash to wind and rain. When this happens, soils start to move downhill. As explained by a local soil scientist at an April 30, 2010, workshop in Anchor Point:

> "It [erosion of local soils] doesn't need much slope, either; the wind'll pick it up, and particularly this time of year, with the ground frozen, it doesn't take much. If we get a lot of runoff out of snowmelt, I've seen little rivulets of soils coming off my property. And they're going to make it to the headwater streams, even the little tiny streams at the bottom of the valley, they're gonna get carried down there over the frozen ground. When you remove that organic surface, you open [the soils] up to erosion. Erosion material goes from the top of the hill or the top of the slope and wants to do downhill; it accumulates at the low point. The Anchor River is the lowest point around here. What happens when [eroded material] makes it to the Anchor River? Well, [spawning gravels] in gravel bars get buried, pollutants can get concentrated. Soils out of place in the water column contribute to turbidity. Pretty simple message really. Careless upland action can fill the stream with sediment." (Source: Mike Mungoven, former NRCS soil scientist in Homer.)

Erosion is a natural and often beneficial process; it only becomes a problem for salmon when disturbances—like those caused by some human land uses and activities—increase the amount of material getting washed or blown away. Simple things landowners can do to minimize erosion include:

- Maintain existing plant communities. Plants are a landowner's most important ally in preventing erosion. Photos to the right and below show two examples of plants that are preventing erosion. **To the right** is a photo of a naturally vegetated streambank and riparian area that is preventing any erosion into the stream (from Beaver Creek, a tributary to

the Anchor River, source: HSWCD); the second **photo shows** a soil bioengineering practice called brush layering being installed to prevent streambank erosion. Cut willow stems are dormant in the photo, but they will leaf out during the growing season (source: ADF&G).

- Cover dirt piles or any other areas where soils have been cleared of vegetation or been exposed.
- Replant cleared areas with native plants (see, for example, Best Management Practices and Soil bioengineering).
- Keep organic cover (plants and plant materials, like mulch) on your soils.
- Minimize impervious surfaces and reduce surface runoff.

During larger projects, landowners can incorporate erosion control measures like the following (see also Best Management Practices):

- Develop an erosion control plan (such as a Stormwater Pollution Prevention Plan) and set aside adequate funds to install recommended measures.
- Identify critical areas (for example, areas with steep slopes or nearest waterbodies or sensitive wetlands) and protect these from disturbance.
- Identify appropriate access and staging areas that will be stable and non-erosive.
- Locate access near access roads or routes but away from sensitive areas.
- Avoid stream crossings or areas near streambanks.
- Use fencing or other barriers to protect identified areas and to mark areas being used for access, staging, etc.
- Schedule work so as to avoid exposing soils during periods of high seasonal rainfall or during snowmelt.
- Minimize surface runoff onto and off your project site using Best Management Practices, such as silt fences and sediment retention ponds.
- Minimize the cleared "footprint" of your project and impervious surfaces.
- Protect existing vegetation as much as humanly possible.
- Minimize the length of time that soil is exposed.
- Monitor installed or established erosion control measures, particularly during rain events.

Escapement

Escapement is the portion of an anadromous fish population that escapes commercial and recreational fisheries and reaches freshwater spawning grounds. A more formal definition of escapement (from an ADF&G primer at http://housemajority.org/coms/jcis/pdfs/adf&g_salmon_escapement_20080522.pdf.) is: "*...annual estimated size of the spawning salmon stock*; quality of the escapement may be determined not only by numbers of spawners, but also by factors such as sex ratio, age composition, temporal entry into the system, and spatial distribution within the salmon spawning habitat."

The Alaska Department of Fish and Game (ADF&G) works with the Board of Fisheries to set escapement goals for particular salmon species and stocks (e.g., chinook salmon in the Anchor River). ADF&G uses weirs, sonar, counting towers, mark-recapture, aerial surveys, and other means to count how many fish

swim upstream each season on managed rivers. The goal is to achieve escapement levels that sustain salmon populations at healthy levels long term and that maintain normal ecosystem functioning. The Sustainable Escapement Goal for Anchor River chinook salmon is 3,800 to 10,000 spawning fish (see http://www.alaskafisheriessonar.org/anchor_fish.html).

Spawning chum salmon (from http://carlsafina.org/2007/09/09/baked-alaska/).

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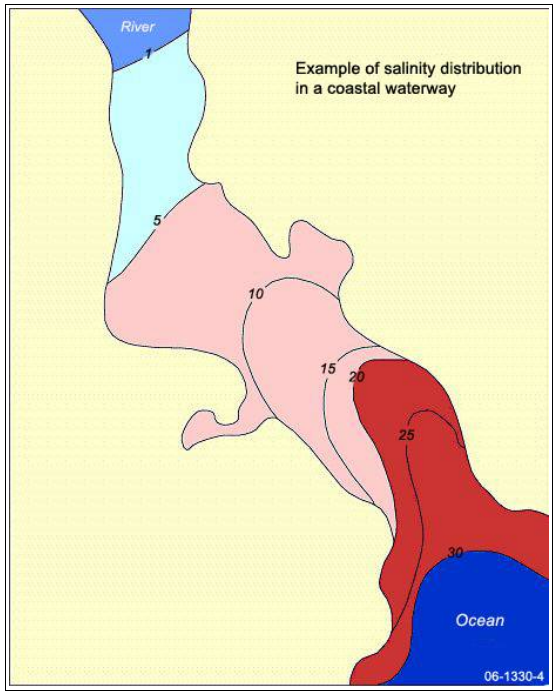
Estuary

(Modified from http://water.epa.gov/type/oceb/nep/about.cfm.)
An estuary is a body of water formed where freshwater from rivers and streams flows into the ocean, mixing with seawater. Estuaries are places of transition from land to sea, and from freshwater to saltwater. That means that salinities (salt concentrations in the water) range from almost zero where freshwater flows into the estuary to ocean levels at the seaward edge of the estuary. As the tide comes in and goes out, the location of different salinity concentrations will move upstream and down. The map on the right shows how salinity levels change in a hypothetical estuary.



Aerial view of salinity distribution in a hypothetical estuary, salinity is lowest near the freshwater source (from www.ozcoasts.org.au/indicators/salinity.jsp)

Estuaries come in all shapes and sizes and have many names—e.g., bays, lagoons, harbors, inlets, sounds. Although influenced by the tides, estuaries are often protected from the full force of ocean waves, winds, and storms by fingers of land, mud, or sand that surround them. The photos on the following pages show this for all four of our estuaries.

Estuarine environments are among the most productive on earth, creating more organic matter each year than comparably sized areas of forest, grassland, or agricultural land. The tidal, sheltered waters of estuaries also support unique communities of plants and animals especially adapted for life at the margin of the sea. Many different habitat types are found in and around estuaries, including shallow open waters, freshwater and salt marshes, swamps, sandy beaches, mud and sand flats, rocky shores, oyster reefs, river deltas, tidal pools, and seagrasses.

The photo below shows part of the Anchor River estuary (source: http://s3.amazonaws.com/loa.images/inv/634269/634269-0911111357087165-s.jpg.)

Thousands of species of birds, mammals, fish, insects, crustaceans, plants, algae, and other forms of life depend on estuarine habitats. Estuaries, for example, are critical to salmon, both to salmon smolts—who use estuaries to undergo physical and behavioral changes that prepare them for life at sea—and to returning adults—who congregate in estuaries waiting for incoming tides to help them head upstream to spawning areas. Because so many species rely on the sheltered waters of estuaries to feed, reproduce, and grow, estuaries are often called the "nurseries of the sea."

Because of the importance of estuaries, the National Estuarine Research Reserve System (NERRS) was established to protect and study estuaries across the US (learn more at: http://www.nerrs.noaa.gov/). NERRS currently includes 28 estuarine areas, representing different biogeographic regions. Established by the Coastal Zone Management Act of 1972, as amended, NERRS is a partnership between the National Oceanic and Atmospheric Administration (NOAA) and various coastal states. NOAA

provides funding, national guidance, and technical assistance, but each reserve is managed by a lead state agency or university, with input from local partners. The Kachemak Bay Research Reserve (KBRR) is the largest of the nation's NERRS, encompassing over 370,000 acres of estuarine and upland habitats, including the mouth of the Anchor River. KBRR is the only NERR in Alaska and is jointly administered by NOAA and the Alaska Department of Fish and Game. To find out more about the Kachemak Bay Research Reserve, go to: http://www.adfg.alaska.gov/index.cfm?adfg=kbrr.home.

Photos below from the Kenai Peninsula Borough interactive parcel viewer, photo on left: Deep Creek estuary; photo on right, Ninilchik River estuary.

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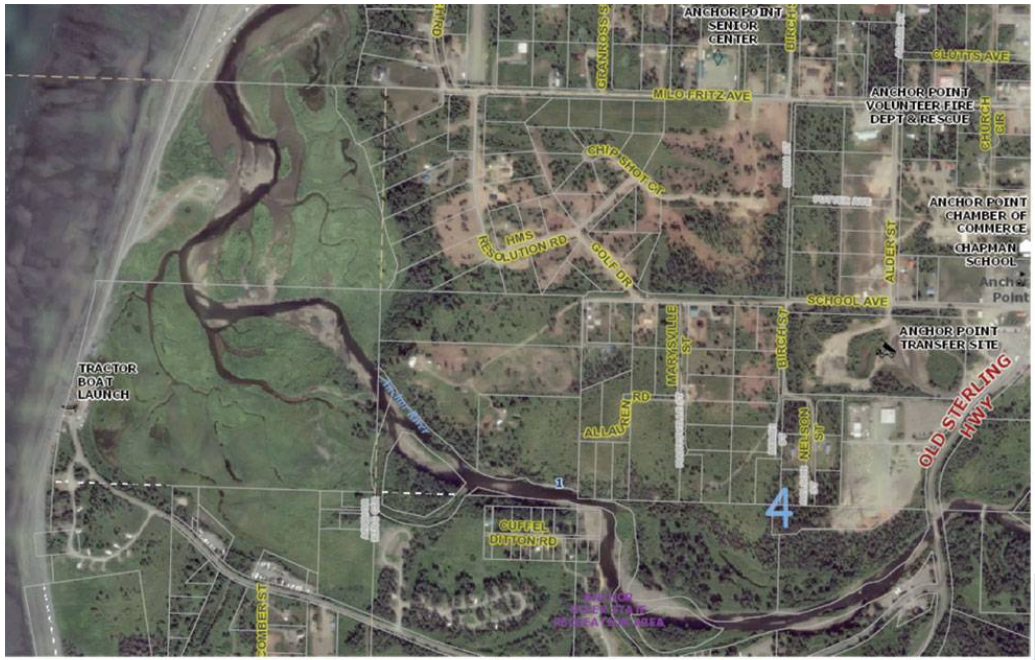

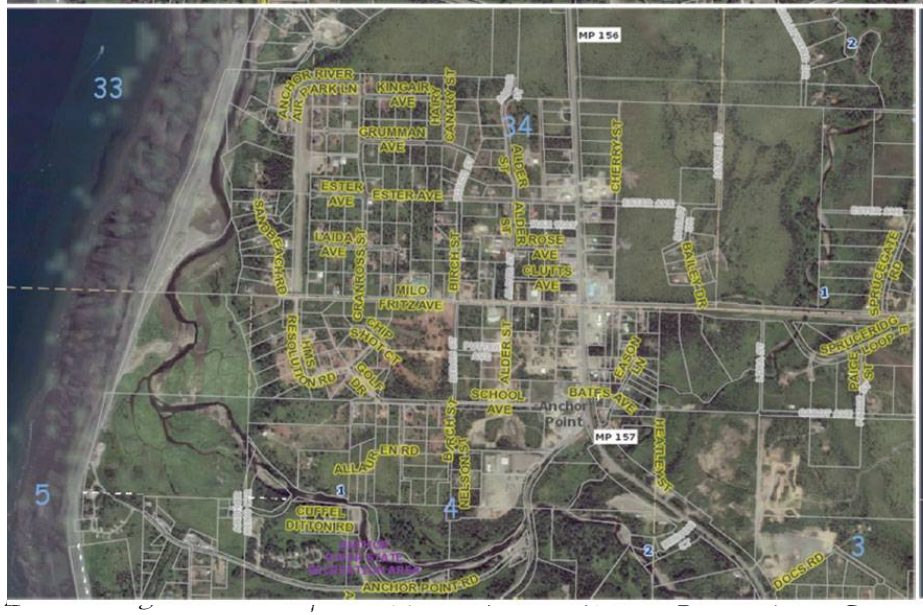

The two photos to the far left are of the Anchor River estuary; the top photo is twice as enlarged as the bottom photo. The photos above and just to the left are of the Stariski Creek estuary.

The aerial photos are from the Kenai Peninsula Borough's GIS website; you can see even closer aerial images on that site (see *introductory article 3: Exploring your watershed with online tools*).

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Fens (Headwater Fens wetland ecosystems)

(see also Stream Order, Wetlands)

(Modified from http://water.epa.gov/type/wetlands/fen.cfm.) Fens, are peat-forming wetlands that receive nutrients from sources other than just precipitation: usually from upslope sources through drainage from surrounding mineral soils and from groundwater movement. Fens differ from bogs because they are less acidic and have higher nutrient levels. They are therefore able to support a more diverse plant and animal community. These systems are often covered by grasses, sedges, rushes, and wildflowers. Over time, peat may build up to such a depth that plants on the surface of the fen are separated from any groundwater supply. When this happens, the fen receives fewer nutrients and may become a bog.

On the southern Kenai Peninsula, fens and related wetlands were identified and mapped as part of mapping and classification of wetlands on the Kenai Lowlands (see: http://www.kenaiwetlands.net/). The following description of *headwater fens* is from http://www.kenaiwetlands.net/EcosystemDescriptions/Headwater.htm. Related kinds of wetlands are discussed under Kettles, Depressions, Relict Glacial Drainageways, Relict Glacial Lakebeds, and Late Snow Plateaus.

Headwater Fen wetland ecosystems are restricted to elevations above about 300 meters in the Kenai Lowlands. These are smaller fens located in headwater basins surrounded by Tertiary bedrock, or thin, discontinuous till. Other higher elevation fens, including Kettles and Depressions, do not occupy headwater basins. Kettles occupy landscape dominated by glacial till; Depressions are surrounded by uplands. Linear features which straddle high divides, and drain to a first-order stream on both sides of the divide, are also considered Headwater Fens, although they sometimes resemble and function similar to Relict Glacial Drainageways.

Carbon export in a fen at the headwaters of the Anchor River. This stream re-emerges from a tunnel under the peat. The headwall and sides of the tunnel have abundant evidence of slumping into the stream. The carbon from the peatland is an important energy source for the stream ecosystem, including developing anadromous fish.

Headwater fens are found in the Caribou Hills occupying first-order stream basins at elevations above about 300 m. Below 300 meters, streams originate either outside the project area, or in large Relict Glacial Lakebed or kettle-and-kame complexes. On older glacial and tertiary surfaces of the Caribou Hills, small peatlands often head short-run streams, particularly the streams that flow southeast into Kachemak Bay, and Anchor River and Deep and Stariski Creeks.

Headwater fens have most likely formed as small post-glacial tarns filled with peat. These tarns are almost exclusively found on early or pre-Wisconsin 'Knik' and 'Eklutna' surfaces. On older, higher elevation 'Eklutna' surfaces, thin, discontinuous till overlies relatively flat Late Snow Plateaus, which surround many Headwater Fens. On younger 'Knik' surfaces, slopes are steeper, till is thin or absent and Headwater Fens are bordered by steep-sided upland slopes; their only connection to other wetlands is by stream outflow.

Headwater Fens and upper stream reaches: a first order stream will frequently flow beneath the surface of the peat. Where it emerges, steep headwalls form, which deteriorate into large chunks of peat which fall into the stream. The carbon in

the peat is important to organisms at the core of the stream's food web. Insects obtain part of their food from carbon processed by micro-organisms. Larger organisms feed on the insects, and the initial carbon source eventually supports larger organisms, such as anadromous fish.

Fingerling

(see also introductory article 1: Salmon species and life cycle)

A fingerling is a young (juvenile) fish, usually a salmon or trout. The term fingerling is used when young salmon reach about the size of a finger, as in the photo below. They will continue to grow in freshwater until they head downstream and turn into smolts. Fingerling salmon have dark vertical "parr" marks on their sides to help camouflage them, so they're also called parr. They eat voraciously, hunting by sight and eating mostly aquatic insects and insects that have fallen (or been washed) into the stream. The chinook (king) fingerling below went for an angler's fly.

This hungry chinook fingerling was caught on the Jim River in Alaska (source: http://www.troutnut.com/trout-fly-fishing-stream/107/Jim-River-Alaska-pictures).

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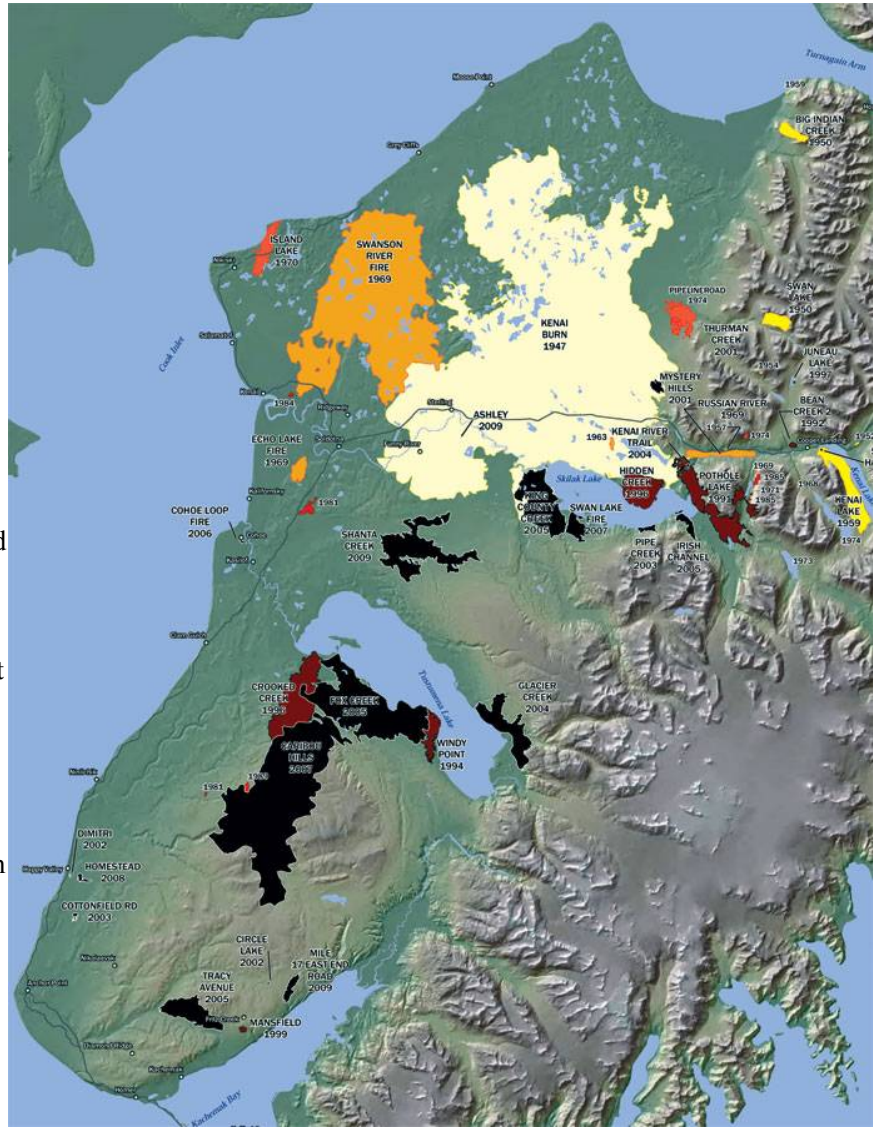
Fires and Firewise

(see also Forests and spruce bark beetles)

Wildfires play a significant ecological role in Alaska's wildland environments. They shape plant communities and wildlife habitats, creating herbaceous and shrubby communities on soils exposed to solar warming where once large forests shaded soils. They return to the soils many nutrients otherwise tied up in large trees. Fire intervals increase and decrease over time as climates warm and cool or become drier or wetter. The **map at right** of historical fires is from the Kenai Peninsula office of emergency management.



Wildfires affect the distribution and quality of salmon habitats in a number of ways. In particular, wildfires influence watershed patterns of *surface runoff*, *sediment erosion and transport*, and *availability of large woody debris*, but the effects of these processes on salmon habitats are difficult to generalize because disturbances that degrade habitats in the short-term may help create productive habitats in the long-term. Surface runoff increases when trees are killed—which otherwise provide significant amounts of interception of rainfall and snowfall—and when plant cover is burned off and is no longer present to slow runoff and promote its infiltration into soils. Incineration of plant cover also increases soil susceptibility to erosion—both because of the increased runoff mentioned above and because of the decreased binding together of soils and slopes provided by live plant roots. Similarly, fire-related tree mortality reduces tree root reinforcement of soils and slopes, as well as the slope "buttressing" effect of large, live trees. This can increase the frequency of shallow landslides (mass wasting) and further increase erosion. As a result, wildfires increase the amount of sediment carried into streams. Excessive sediment supply can pose serious problems to salmon, for example, by clogging spawning gravels, suffocating eggs and fry, aggrading stream reaches so that they become warmer and drier during summer low flows, and reducing the feeding success of all stages of juvenile salmon, which find their food by sight and struggle to do so as water turbidity increases with rising sediment loads. On the other hand, fire-killed trees that topple, slide, or roll into streams are a significant source of large woody debris, which provide a critical component of salmon habitat. Clearly, the roles of fire in shaping watershed processes and stream conditions are complex and difficult to predict.

Within a watershed, the availability of suitable salmon habitats depends on **balanced** patterns of natural disturbance and recovery at the landscape scale. Fire has historically been a defining source of watershed disturbance, playing keys role in initiating other changes, particularly in plant communities. Understanding **natural** patterns of disturbance and recovery, and allowing them to operate throughout the watershed, is most likely to protect salmon productivity long term.

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Firewise

Firefighting agencies call places where human development meets or mixes with natural vegetation the wildland/urban interface. Wildland fires that occur in or near these areas, whether caused by lightning or by careless human behavior, can pose significant threats to homes and other structures. Being firewise means being aware of the things you can do to minimize your vulnerability to wildfire. An excellent guide on how to be "firewise" and protect your property from wildfires can be downloaded at: http://www2.borough.kenai.ak.us/SBB/documents/02firewise.pdf. The guide contains the following topics:

- Wildland Fires: Necessity and Threat
- Step I: Evaluation
- Step II: Six elements of a firewise community
  - Element 1: Landscaping
  - Element 2: Firewise construction
  - Element 3: Emergency water supply
  - Element 4: Access and signs
  - Element 5: Home planning
  - Element 6: When wildfire threatens
- Resource List
- Appendix: Fire-Resistant Vegetation and Landscaping

To give you an idea of what you'll find in the Firewise guide mentioned above, below we've excerpted a few comments and illustrations from that material.

From ***Step I: Evaluation***: ...The first step toward developing a Firewise plan for defense against wildland fire is to look at your surroundings and evaluate them for susceptibility to fire. When you are doing your evaluation, imagine the worst wildland fire scenario: winds greater than 20 mph; hot, dry conditions; and dry vegetation. All wildland fire disasters have these conditions in common. Fires under these conditions are very difficult to control, even for professional firefighters... Work through the Home Hazard Assessment rating form provided in the Firewise handouts to determine the hazard level for your home and property. If you need help with the worksheet, you can contact your nearest fire response agency.

From ***Element 1: Landscaping:*** Remove or transplant more flammable vegetation within 30 feet of your home and replace it with low growing, fire-resistant plants.

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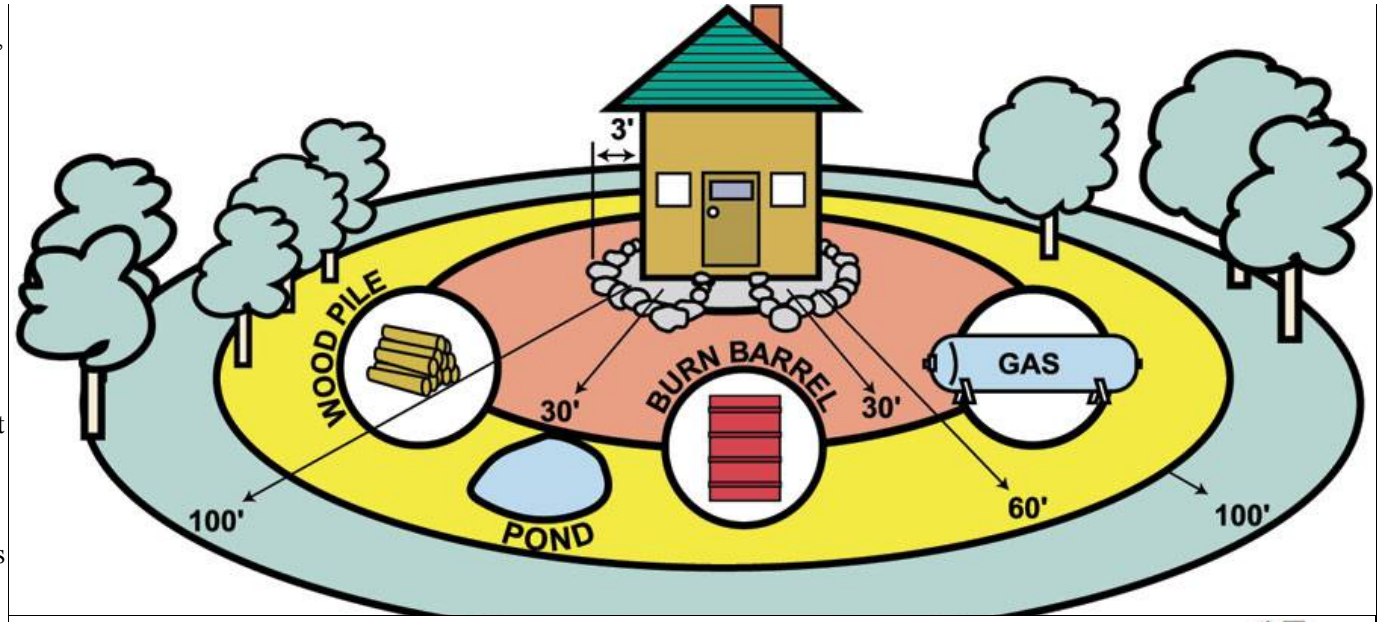
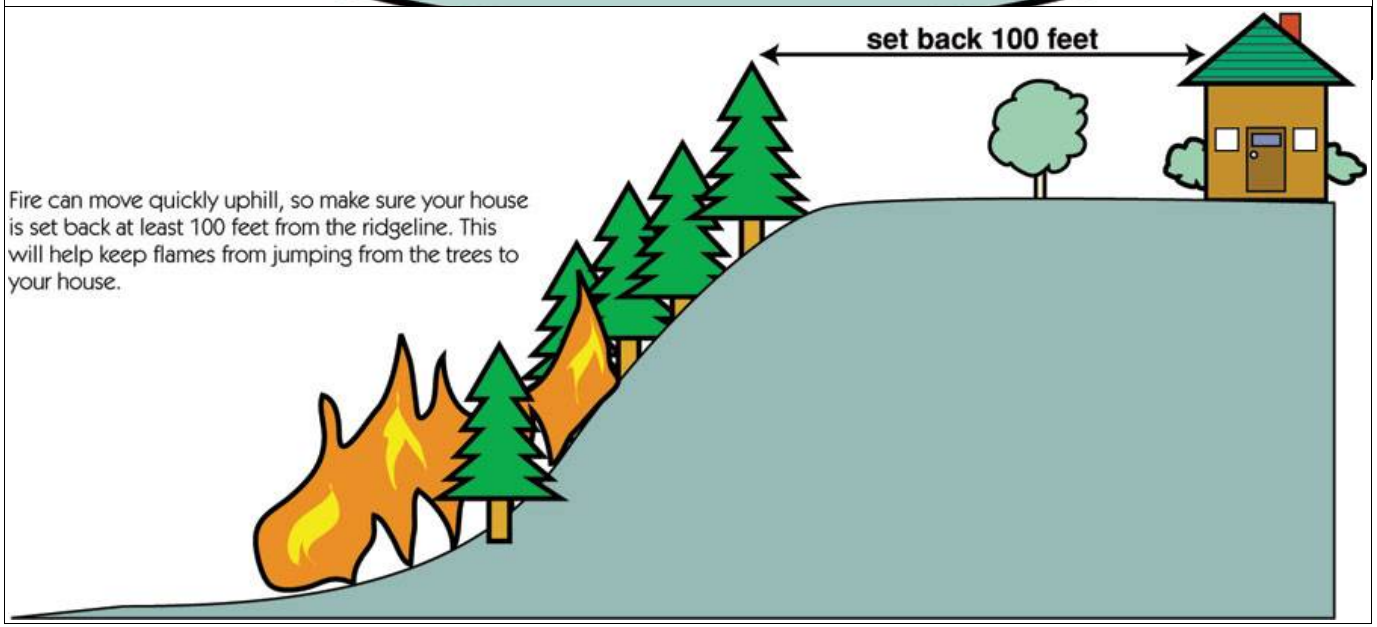
From ***Element 2: Firewise construction***: Don't build on ridge tops, in canyons, and between high points on a ridge. These are extremely hazardous locations because they become natural chimneys. A fire moves rapidly upslope, preheating the fuels in front of the fire and increasing its intensity. You should set the home back from the top edge of the slope to avoid direct impact by flames burning up the slope.

Your roof is the most vulnerable part of your house because it can easily catch fire from windblown sparks. The single most important step you can take to create a Firewise house is to build or reroof with a fire-resistant or noncombustible material.





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Fish and Wildlife Service (FWS, USFWS)

(see also Agencies with responsibilities for watershed resources)

(Based on information at http://alaska.fws.gov/fisheries/fieldoffice/kenai/outreach.htm.) The USFWS, Fisheries and Ecological Services, maintains a field office in Soldotna. The Kenai Field Office promotes conservation in Kenai Peninsula communities through technical assistance and educational programs. The goal is to enhance understanding, appreciation, and stewardship of Alaska's fish and wildlife resources. Staff participate in numerous outreach programs. Below you'll find a brief overview of Kenai Fish and Wildlife Field Office Office activities and programs. If you're looking at this watershedipedia online, the name of each program is a link to more information. Landowners interested in protecting or rehabilitating banks along anadromous streams may be able to get assistance from the FWS through the Habitat Restoration program, or call the FWS Soldotna office at (907) 262-9863.

- ***Fisheries Program*** (http://alaska.fws.gov/fisheries/fieldoffice/kenai/field/program_overview.htm Research on fish populations and habitats in Southcentral Alaska watersheds provides information used to help conserve these valuable fishery resources.
- ***Subsistence Program*** (http://alaska.fws.gov/fisheries/fieldoffice/kenai/subsistence.htm) Field investigations help to monitor fish populations harvested by subsistence users.
- ***Habitat Restoration*** (http://alaska.fws.gov/fisheries/fieldoffice/kenai/habitat_restoration.htm) Government agencies and private landowners partner to restore and protect streambanks and riparian habitat in the Kenai, Kasilof, and Anchor River watersheds.
- ***Conservation Planning Assistance*** (http://alaska.fws.gov/fisheries/fieldoffice/kenai/environmental.htm) Biologists work with project developers to help minimize the impacts on fish and wildlife resources.
- ***Outreach and Education*** (http://alaska.fws.gov/fisheries/fieldoffice/kenai/outreach.htm) Community festivals and the Adopt-A-Stream program in local schools promote conservation through education.

Fish Habitat Partnership

(see Kenai Peninsula Fish Habitat Partnership)

Fish passage

(see also Culverts, Fish Passage Program, and introductory article 1: Salmon species and life cycle)

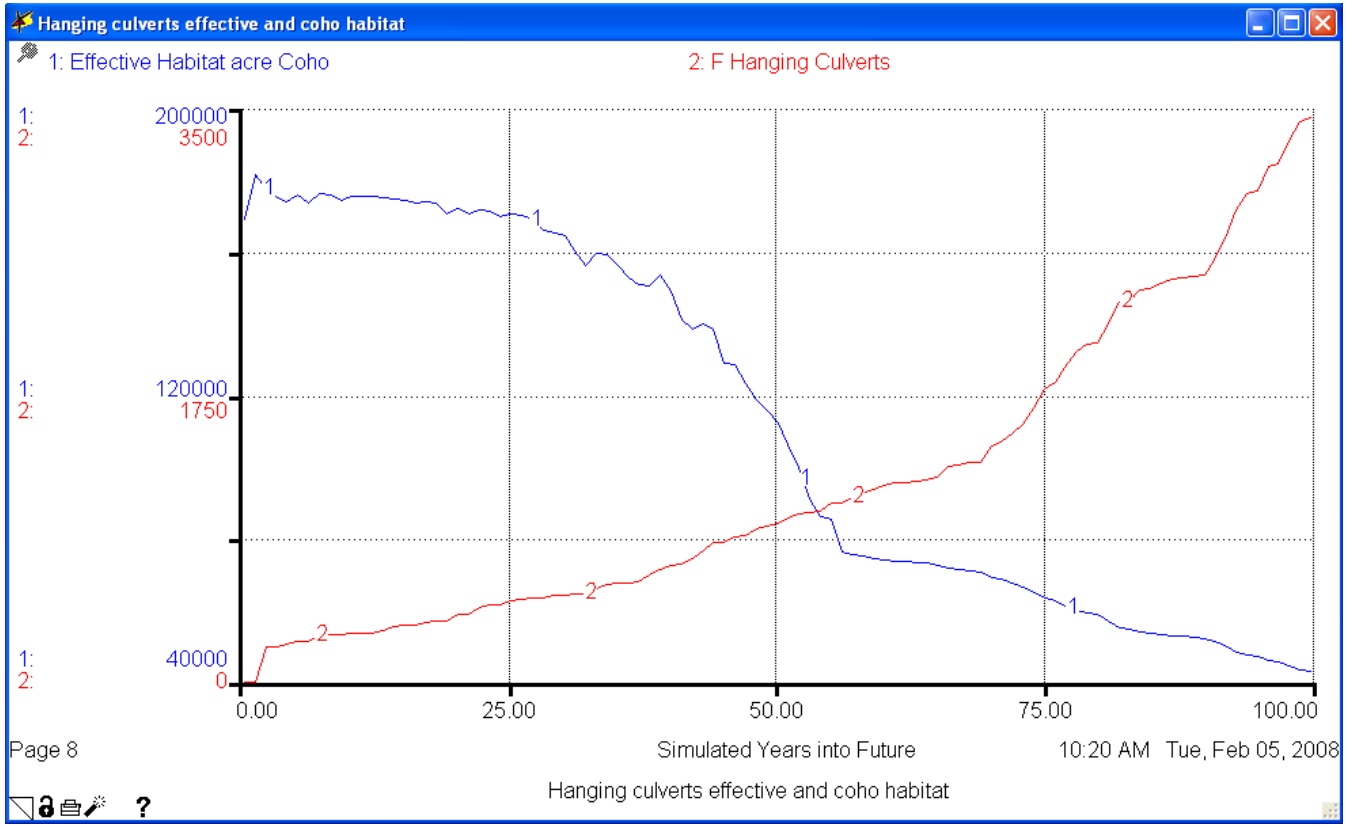
A fish passage is any accommodation (design, structure, etc.) that enables fish to swim upstream or downstream around or through an obstacle or obstruction. When designing and installing fish passages for salmon, all life stages should be considered, from the smallest juvenile to the largest adult.

Obstructing fish passage is a serious threat to salmon populations. One perched culvert can block off thousands of acres of salmon habitat. This problem is particularly acute for juvenile salmon—especially wide-ranging coho that rear in tiny headwater streams—because they are too small to navigate even minor blockages, like culverts perched by only inches or in which water velocities are too strong for them to swim against.

An alarming indication of how serious a problem fish passage can become was reported by the US Forest Survey after they surveyed fish passage at stream crossings on **50,000 miles** of Forest Development roads in Montana, northern Idaho, and eastern North and South Dakota. USFS assessed whether road crossings allowed passage of adult and juvenile cutthroat trout. Findings indicated that about **80%** of surveyed culverts impeded passage of cutthroat at some life stage or during certain stream flows. Of those barriers, 576 culverts impeded **all** fish passage and represented total barriers (see http://www.fs.fed.us/r1/projects/engineering/fish_passage_web.pdf). The Kenai Watershed Forum has conducted a similar assessment of fish passage through culverts on peninsula

roads and has found numerous blockages. An evaluation of the likely cumulative effects of development on selected peninsula resources reported that: "*An increase in roads with poorly constructed culverts results in declining coho habitat as these culverts create barriers to juvenile salmon migration.* ***The blue line*** [in the graph below] *represents declining coho habitat while* ***the red line*** *represents the increasing number of barriers or hanging culverts.*" (For more information on this study, see Alaska Landscape Cumulative Effects (ALCES) Model at http://www.kenaiwatershed.org/alces.html.)

Landowners can help maintain salmon populations by alerting ADF&G or KWF of any culverts that appear to obstruct fish passage; ADF&G and KWF have offices at the Gilman River Center in Soldotna (http://www.kenairivercenter.org/index.htm, (907) 260-5992).

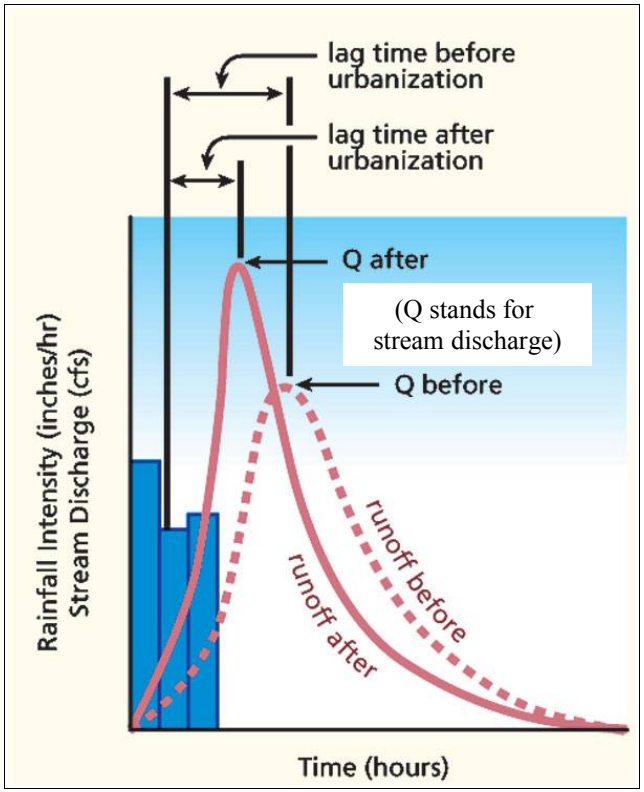


Fish Passage Program
(see Culverts, Partners for Fish and Wildlife Program)

Flood frequency
(see also Bankfull, Flooding, and Stream discharge)

(Slightly modified from http://seagrant.oregonstate.edu/sgpubs/onlinepubs/ t01003.pdf.)
Flood frequency is based on historic streamflow records from stream gaging stations (see Stream stage). Flood frequency is measure of likelihood, or *probability*—what is the probability that a flood of a particular magnitude will occur in a particular year? In other words, every year there is a 1-in-100 probability that a 100-year flood event will occur. It is entirely possible to have more than one "100-year flood" in a year, but the probability of that magnitude flood is 1-in-100 for any particular year. On the Kenai Peninsula, two 100-year floods occurred in 2002, one in October and the other in November. (For more information on these floods, go to Flooding.)

The height of the 100-year flood is not an exact number, and there are several sources of error that can influence the accuracy of the calculation. One source of error is the length of record at a gaging station. The shorter the record, the greater the error in calculating the height of the 100-year flood. Many stream gage records in Alaska cover fewer than 30 years; therefore, the 100-year flood height has to be projected from a set of data that might not ever have recorded a 100-year event. For a gage record that is 25 years long, the confidence level might be 85 percent. In other words, the calculated height of the 100-year flood could be off by 15 percent. Also, climate cycles of relatively wet and dry years occur;. if the years of record are predominantly in dry years, flood heights can be significantly underestimated. Another possible source of error is changing conditions in a watershed over time. For instance, if urbanized areas have increased in size, the amount of land covered by impervious surfaces will also have increased. As the diagram to the right shows, urbanization leads to faster, higher, and more frequent flood flows during rain events.



Flooding
(see also Hydrograph—which explains the diagram on right)

Floods are natural processes that can turn into disasters when people and property are affected. Landowners who build homes and businesses in flood prone areas put themselves at risk. Floodplain maps prepared as part of the federal Flood Insurance Program (FIP) can help landowners determine where flooding is most likely. For more information about these maps, contact the Gilman River Center in Soldotna.

In addition to flooding that affects entire river systems, localized flooding can occur where bridges and culverts are too small to carry streamflow even during moderate rainstorms or snowmelt, causing water to back up behind these blockages and flood upstream areas. Undersized bridges and culverts can also cause sediment deposition upstream of their locations because backed-up water slows down,

causing sediments to settle out. Undersized bridges and culverts are also more prone to plugging up with debris during flood flows, which can compound upstream flooding problems.

Landowners living near rivers or streams should be aware of the possibility of flooding. Because flows are monitored on so few rivers in Alaska, it's important to know the location of the river nearest your home that IS monitored, since records from these nearby rivers can tell you something about flood frequencies and flood flows that might occur in your area. Stream gages are in place on both the Ninilchik and Anchor Rivers, and what's happening on those rivers can be used to suggest what may happen on tributaries or other streams nearby. The National Weather Service monitors both Ninilchik and Anchor Rivers and forecasts conditions, including possible flooding. Terminology used by the National Weather Service (NWS) related to high water levels and flooding on streams and lakes in Alaska is explained below.

(From http://aprfc.arh.noaa.gov/resources/docs/floodterms.php). Gages are devices that allow for the manual or automated monitoring of water level in streams, rivers, and lakes. The term used for the water level of a stream or lake at a gage is *stage* (see Stream stage). The gage datum is a horizontal surface used as a zero point for measuring water level. Only a very small fraction of rivers in Alaska have gages that monitor their water levels.

High water terms used by the National Weather Service include *bankfull* stage, *action* stage, and *flood* stage (defined below). In Alaska, the sparse gage network requires that these terms be defined with a broader definition that reflects characteristics of the gaged waterbody, as well as nearby waterbodies. Thus the definitions consider both the specific impacts that can be documented in the vicinity of the gage and the expected impacts that could result on any waterbody in the general area during an event of that magnitude. The assignment of these stages thus includes the combined assessment of specific impacts and the frequency of occurrence of the event. The concept of using the frequency of occurrence of high water events to supplement the assessment of flood stages is based on the assumption that frequently occurring water levels, such as the 2-year flood (50% chance of occurring in any year), will have few impacts in comparison to the significant impacts expected during an infrequent event, such as a 100-year flood (1% chance of occurring in any year). When high water stages are determined from a flood frequency analysis, the impacts listed for the applicable stages will be the recurrence interval associated with that level and a qualifier to assess the quality of the recurrence interval estimate.

Bankfull Stage - an established gage height at a given location along a river or stream, above which a rise in water surface will cause the river or stream to overflow the lowest natural stream bank somewhere in the corresponding reach. The term lowest bank is, however, not intended to apply to an unusually low place or a break in the natural bank through which the water inundates a small area. Bankfull stages on streams with natural or manmade high banks can be defined by the predominant vegetation line on the banks. The bankfull stage on many streams is associated with the 2-year recurrence interval flood. Bankfull stage is not necessarily the same as flood stage.

Action Stage - the stage which, when reached by a rising stream, represents the level where the NWS or a partner/user needs to take some type of mitigation action in preparation for possible significant hydrologic activity. The type of action taken varies for each gage location. Gage data should be closely monitored by any affected people if the stage is above action stage.

Flood Stage - an established gage height for a given location above which a rise in water surface level begins to create a hazard to lives, property, or commerce. The issuance of flood advisories or warnings is linked to flood stage. Flood stage is not necessarily the same as bankfull stage.

Flood categories are terms defined for each gage location that describe or categorize the observed or expected severity of flood impacts in the corresponding

stream segment or nearby stream. The severity of flooding at a given stage is not necessarily the same at all locations along a stream due to varying channel/bank characteristics on portions of the stream. Therefore, the stage for a given flood category is usually associated with lowest water level corresponding to the most significant flood impacts somewhere in the reach. The flood categories used in the NWS are *minor*, *moderate*, and *major* flooding, but all three of the flood categories do not necessarily exist for each gage location. Most commonly, gages in remote areas may not have a major flood stage assigned. Record flooding is flooding that equals or exceeds the highest stage or discharge at a given site during the period of record keeping.

Minor Flooding is defined to have minimal or no property damage, but possibly some public threat. A Flood Advisory product is issued to advise the public of flood events that are expected not to exceed the minor flood category. Examples of conditions that would be considered minor flooding include:

- water over banks and in yards
- no building flooded, but some water may be under buildings built on stilts (elevated)
- personal property in low lying areas needs to be moved or it will get wet
- water overtopping roads, but not very deep or fast flowing
- water in campgrounds or on bike paths
- inconvenience or nuisance flooding
- small part of the airstrip flooded, and aircraft can still land
- one or two homes in the lowest parts of town may be cut off or get a little water in the crawl spaces or homes themselves if they are not elevated

In remote areas with few specific impacts, floods with 5-10 year recurrence intervals would be assumed to be causing minor flooding on streams in the area.

Moderate Flooding is defined to have some inundation of structures and roads near the stream. Some evacuations of people and/or transfer of property to higher elevations may be necessary. A Flood Warning is issued if moderate flooding is expected during the event. Examples of conditions that would be considered moderate flooding include:

- several buildings flooded with minor or moderate damage
- various types of infrastructure rendered temporarily useless (i.e. fuel tanks cannot be reached due to high water, roads flooded that have no alternates, generator station flooded)
- elders and those living in the lowest parts of the village are evacuated to higher ground
- access to the airstrip is cut off or requires a boat
- water over the road is deep enough to make driving unsafe
- gravel roads likely eroded due to current moving over them
- widespread flooding, but not deep enough to float ice chunks through town
- water deep enough to make life difficult, normal life is disrupted and some hardship is endured
- airstrip closed
- travel is most likely restricted to boats

In remote areas with few specific impacts, floods with 15-40 year recurrence intervals would be assumed to be causing moderate flooding on streams in the area.

Major Flooding is defined to have extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher

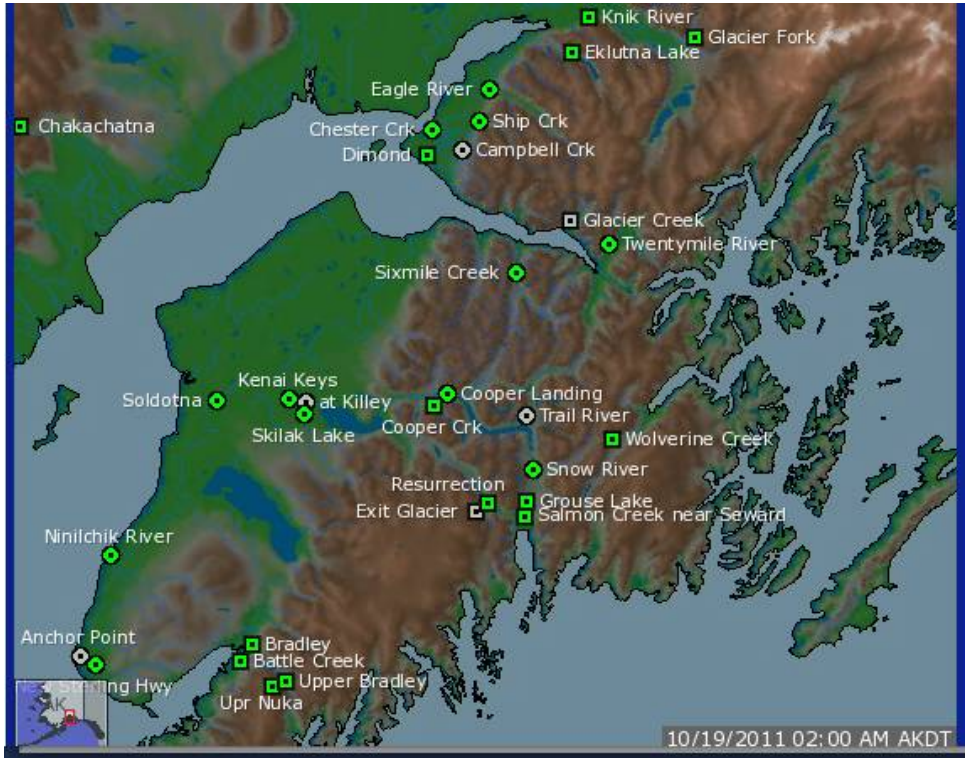
elevations are necessary. A Flood Warning is issued if major flooding is expected during the event. Examples of conditions that would be considered major flooding include:

- many buildings flooded, some with substantial damage or destruction
- infrastructure destroyed or rendered useless for an extended period of time
- multiple homes are flooded or moved off foundations
- everyone in threatened area is asked to evacuate
- National Guard units assist in evacuation efforts
- erosion problems are extreme
- the airstrip, fuel tanks, and the generator station are likely flooded
- loss of transportation access, communication, power and/or fuel spills are likely
- fuel tanks may float and spill and possibly float downstream
- ice chunks floating though town that could cause structural damage
- high damage estimates and high degree of danger to residents

In remote areas with few specific impacts, floods with 50-100 year recurrence intervals would be assumed to be causing major flooding on streams in the area.

Realtime flood forecasting for Southcentral Alaska can be found at this link to the National Weather Service Advanced Hydrologic Prediction Service: http://water.weather.gov/ahps2/index.php?wfo=pafc. A map like the one on the right will appear. You can click a site on the map to see data for that site. Below the map, you will find a list of Southcentral rivers, including the Anchor River and Ninilchik Rivers. Click on a river's name to see data for that river. The Anchor River has two gaging sites, one at Anchor Point and the other at the New Sterling Highway.

Flooding that occurred in 2002 on the southern peninsula was the worst flooding so far recorded at the gaging stations. An account and photos of the 2002 flooding can be downloaded at: http://www2.borough.kenai.ak.us/emergency/prepared/flood.htm



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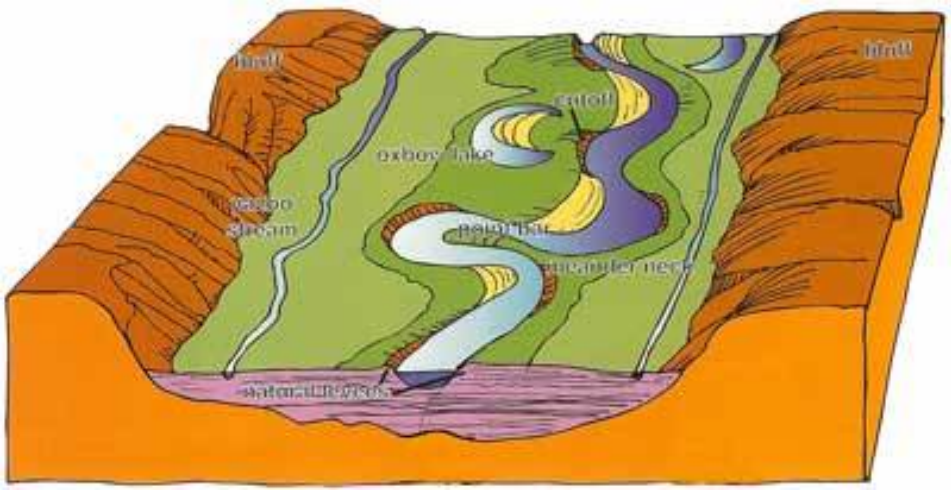
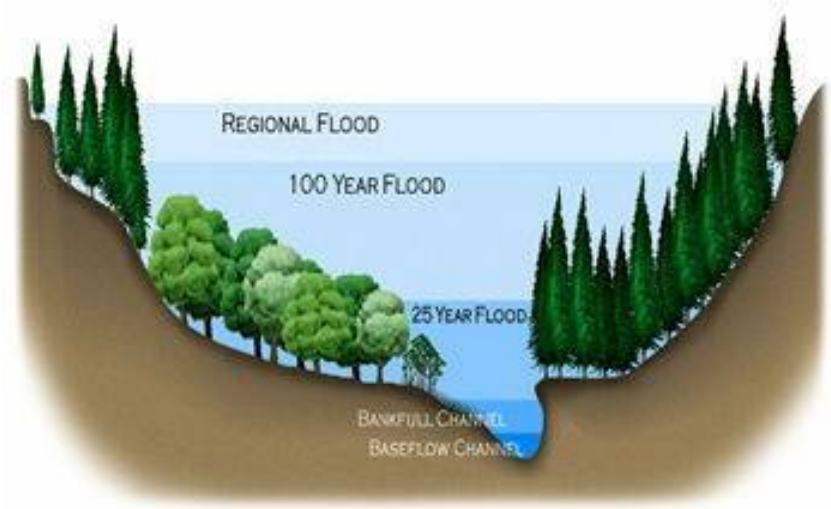
Floodplains

(see also Flooding, Hyporheic flow and zone, Stream channel processes)



(Modified from http://www.brownsguides.com/blog/how-georgia-rivers-work/.) A floodplain is a relatively flat area adjacent to a stream or river and that is frequently covered by water during flooding. A flooded stream has the capacity to carry more and larger sediments in its channel due to higher volumes and velocities of flood flows. In addition, rivers and streams that are flooding may add to their stream load by eroding their own banks and bed. If a stream flows within a floodplain, however, as it overflows its banks, the velocity of the overflow water decreases rapidly, and some of the stream's load is deposited in the floodplain. (This process is called overbank deposition.) This limits the water levels of flood flows and helps reduce the volume of water flowing downstream in the channel. Of sediments suspended, bounced, and rolled down a stream channel during flooding, the finest (silts and clay) are carried by overbank flow farthest out into the floodplain; coarsest (heaviest) sediments drop out first, closest to the river channel, and these may build up an embankment or natural levee. Floodplains are a natural feature of many rivers, but where channels are entrenched, overbank flows cannot occur and floodplains are unable to develop.

(Modified from http://www.cees.iupui.edu/education/Information_Resources/floodplains.htm.) Floodplains in their natural form are beneficial for a number of reasons. For example, floodplains: a) reduce the number and severity of floods by giving flood flows a place to spread out and slow down, b) minimize pollution and sedimentation downstream by allowing sediments and other pollutants to settle out on the floodplain, c) provide many kinds of habitat for plants and animals, and e) provide aesthetically attractive areas and places for outdoor recreation. Also, by moderating flood severity, floodplains help keep the conditions that typically occur within salmon streams within less extreme ranges, reducing damage and destruction of salmon habitats. After flooding, salmon habitats can benefit again when water absorbed by the floodplain percolates back into the channel, increasing flows during times of low water.



As suggested above, floodplains are home to many types of plants and animals and may also have forests and wetlands on or adjacent to them. These river edges provide habitat for insects and other invertebrates, many birds, and mammals. On an ongoing basis, floodplain vegetation helps filter contaminants out of water flowing downslope and into the river, including stormwater runoff. Additionally, vegetated floodplains can provide shade for adjacent rivers and streams, lowering stream temperatures and increasing dissolved oxygen levels and consequently improving habitat for aquatic plants and animals.

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The following information about the borough's floodplain ordinance and participation in the National Flood Insurance Program (FIP) is from a website maintained by the Gilman River Center. (Slightly modified from http://www.kenairivercenter.org/Agencies/Floodplain/Floodplain.htm.) The Kenai Peninsula Borough manages a Floodplain Ordinance (http://www.kenairivercenter.org/Agencies/Floodplain/FloodplainOrdinance.htm) that addresses proper development to reduce flood risks and economic losses caused by flood events. The ordinance provides building standards for construction projects within the floodplain to ensure the availability of flood insurance through the National Flood Insurance Program (http://www.fema.gov/about/programs/nfip/index.shtm. (NFIP is an insurance program available through the federal government for people with property in floodplains and flood prone areas—homeowner's insurance rarely covers flood damage). These building requirements also are intended to minimize or prevent damage when flood events occur. The ordinance requires floodplain development permits (http://www.kenairivercenter.org/Permits/Permits.html) for all projects in floodplains.

The KPB Floodplain Administrator works with landowners and developers whose property is in a mapped floodplain or other flood prone area. The Floodplain Administrator can help make the determination as to where in the floodplain the property is located and what restrictions may apply to buildings and other developments on the property. The Floodplain Administrator is also able to provide information about proper building techniques to reduce flood damage. This link identifies which borough streams have mapped floodplains: http://www.kenairivercenter.org/Agencies/Floodplain/MappedFloodplain.htm.

The photos below are from the borough's floodplain website introduced above. More photos of local flooding are available at that site.

Ninilchik River bridge under water – 2002 flooding

Debris and sediment deposited by 2002 flooding on the Kenai Peninsula

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Forests and spruce bark beetle
(see also Spruce bark beetle)

In general, the forests in our watersheds consist of Lutz spruce (a hybrid between Sitka and white spruce) and black spruce. Lutz spruce is generally found on on better drained sites, and black spruce on poorly drained sites. Stands of birch, cottonwood, and aspen are common, with cottonwood particularly common along river channels where floods or other disturbances create exposed mineral soils. What happens to forests matters to salmon for many reasons, including the effects of forests on interception and surface runoff patterns, as well as the importance of mature trees in contributing large woody debris to salmon streams.

Lutz spruce forests have changed dramatically in the last decade as a result of an outbreak of spruce bark beetle, which killed off extensive areas of mature trees (see maps under Spruce bark beetle). The following article by Ed Berg, formerly with the Kenai National Wildlife Refuge, provides an interesting ecological perspective for better understanding the beetle outbreak and the processes that are likely to shape forests in coming decades.

(The following is slightly modified from two articles in the Homer Tribune: http://homertribune.com/2011/11/reading-andrew-nikiforuk%E2%80%99s-empire-of-the-beetle/ and http://homertribune.com/2011/11/lessons-to-be-learned-from-the-spruce-bark-beetle/).
To learn about past outbreak history, biologists at the Kenai National Wildlife Refuge borrowed a tree-ring methodology from Colorado, based on the idea of looking for growth pulses (releases) in suppressed small trees which survived beetle outbreaks that killed their larger neighbors. Examining thousands of tree-ring samples showed us growth releases in the 1810s, 1870s, 1910s, and 1970s, up and down the peninsula and across Cook Inlet, indicating that the beetles have long been major players in our forests.

The most important consequences of the spruce bark beetle outbreak were logging, new roads, and land subdivision. When the trees died, most private landowners on the Kenai logged their forests, seeking to capture what little value remained before the trees rotted. The logging usually required new roads. Once the land was logged, the land was greatly improved for building, especially if the new view was attractive, so subdivision and sales inevitably followed. Dense roadless forests that wouldn't have been subdivided for decades were suddenly logged and ready for home sites, complete with road access. The birch and other hardwoods were of no interest to the loggers, so most of the cutover land was not completely barren of trees and actually looked quite nice, at least when the grass and fireweed covered the stumps.

One lesson learned as a result of the beetle epidemic is that unselective logging can intensify and prolong a beetle outbreak, by leaving slash, which breeds more beetles. Trees on clearcut perimeters typically are blown down and provide the best possible beetle nurseries. Slash and bucked up logs left along the Bradley Lake powerline construction in the late 1980s probably helped spread the spruce bark beetle outbreak at the head of Kachemak Bay.

Another lesson is that massive fires have not followed beetle kill. Beetle-kill spruce does indeed burn, especially in the first-year red-needle stage, but drought-stressed live trees with dry needles burn even better. The rate of spread of most fires on the Kenai is determined by ground fuel moisture, be that of litter or grass, and not by whether tree crowns are dead or alive. Dry weather, especially in the spring, is the chief fire danger.

We've also learned that diverse forest structure is the best guarantee of healthy forests in the future. The southern Kenai forests were quite homogeneous, with a long fire cycle of 400-600 years, and hitherto protected by cool and moist climate. The fairly even size structure was due to the fact that our forests had regrown from a massive beetle-thinning in the 1880s. The forest was a loaded gun, waiting for a trigger to be pulled. On the Kenai; it was runs of warm summers that pulled the trigger. An unprecedented 11-year run of warm summers from 1987 to 1997 allowed the beetle populations to increase exponentially every summer until the beetles simply ate themselves out of house and home.

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What should we do with the land that has been logged, if anything? This is a major conundrum. It is certainly a question in the minds of landowners on the Kenai, such as the various Native groups that own thousands acres of cutover grasslands, as well as owners of smaller tracts and homeowners with the now-emerged views. Many will not agree with this, but in my opinion the best response at this point in time is to do nothing. There is no point in planting white, Sitka or Lutz spruce because these species will all be susceptible to beetle kill with increasingly warmer summers. Planted spruce could probably be harvested for pulp in 40-50 years, but I would expect the beetles to hammer these trees when they get to be more than 6-8 inches in diameter. Some landowners have planted lodgepole pine and it is generally growing well, but it is only a matter of time before the mountain pine beetle gets blown up here from northern British Columbia. Monoculture stands of lodgepole pine provide poor wildlife habitat and to reproduce they require fire to open their pitch-sealed (serotinus) cones. Siberian larch can also grow on the Kenai, but it is susceptible to browsing by moose and hares, and to larch sawfly mortality, and it is expected to do poorly with warmer summers. Hardwoods like birch and aspen are nice in the yard but they require fences or wire mesh to keep the moose off. In short at present there appears to be no tree species worth planting on the Kenai on a large scale, from either an economic or ecological point of view.

In time the Kenai cutover grasslands will burn, as some have already done. If they burn late in the season, which we expect with warmer and drier summers, these fires will expose mineral soil and provide a good seedbed for both spruce and hardwood germination. In the beetle-killed forests that have not been logged, the trees are falling down and beginning to rot. The stilted roots of this deceased generation of trees show that they germinated "up in the air" on nurse logs and stumps, and now they themselves will become the nurse wood for the next generation of trees.

The Canadian experience, as chronicled by Andrew Nikiforuk in his book *Empire of the Beetle*, makes a strong case that the best defense against massive insect outbreaks and large forest fires is to have a diverse landscape with a heterogeneous variety of stand ages and tree composition. The central and northern Kenai forests have this diversity because of the short fire cycle of 130 years in upland mixed white spruce and hardwoods, and 80 years in lowland black spruce. The southern Kenai could well achieve similar diversity, because the new forests will be recruited very unevenly if we wait for fire and nurse wood to do their natural work at their own pace.

To simply replant monoculture crops of the pine and spruce will create a mosaic of even-aged stands that will provide the ultimate beetle fodder in a warmer climate. At best, these kinds of tree farms could be cut for pulp on a short rotation before the trees reach beetle-killable diameter. North America has an ever increasing demand for wood pulp for paper products, and I would prefer to see pulp harvested near where it is utilized rather than cut from virgin tropical rainforests in third-world countries. A safer approach, if harvest is the goal, would be to develop a kind of forestry that plants a variety of species, both softwoods and hardwood, on the same plots so as to mimic a natural forest. With this kind of poly-cropping a forest pest like a bark beetle, defoliator or blight can take out one tree species but not the whole stand. Foresters are developing poly-crop methods in the tropics and these methods certainly deserve study in our northern forests.

Final note: The remarkable scale of the logging in British Columbia can be seen on a virtual computer tour with GoogleEarth. A tour can start in the south at Kamloops BC and wander northwest toward Prince George and Vanderhoof, and then up toward Chetwynd. The splay of irregular logged patches looks like huge insect bites out of the forest quilt. For comparison, on the western Kenai a tour can start at Anchor Point, then head northeast to Ninilchik and then eastward toward the Caribou Hills. Only private land was logged on the western Kenai; no logging was done on the 2-million acre Kenai National Wildlife Refuge, which covers about 1/4 of the Kenai Peninsula. Only a small amount of logging was done in the Kenai Mountains on the Chugach National Forest, which can be seen, for example, northwest of Cooper Landing.

404 permits
(see also Clean Water Act, Wetland permits)
(Modified slightly from: http://water.epa.gov/type/oceb/habitat/cwa404.cfm.) Section 404 of the Clean Water Act establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands. Responsibility for administering and enforcing Section 404 is shared by the U.S. Army Corps of Engineers (USACE) and EPA. The Corps administers the day-to-day program, including individual permit decisions and jurisdictional determinations; develops policy and guidance; and enforces Section 404 provisions. EPA develops and interprets environmental criteria used in evaluating permit applications, identifies activities that are exempt from permitting, reviews/comments on individual permit applications, enforces Section 404 provisions, and has authority to veto USACE permit decisions. (An excellent EPA factsheet about 404 permitting is available at: www.epa.gov/owow/wetlands/pdf/reg_authority.pdf. For additional information about the USACE Regulatory Program in Alaska and guidance on obtaining 404 permits, see http://www.poa.usace.army.mil/reg/.)

Fry
(see Salmon fry; see also introductory article 1: Salmon species and life cycle)

FWS
(*see Fish and Wildlife Service*)

Geographic information system
(see GIS, introductory article 3: Exploring your watershed with online tools)

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Geotextile

Geotextile fabrics are used in various civil and bioengineering applications to control soil conditions that would otherwise prohibit or impede construction and to stabilize soils prone to erosion. In contrast to a geomembrane, which is an impervious barrier designed to restrict the movement of moisture between surfaces, geotextiles generally have some degree of permeability. Classified as either woven, non-woven, or knitted, each type provides a varying degree of soil control based on its composition. Geotextiles aid in drainage of soils, separation of soil layers, filtration and capture of soil particles, and reinforcement of unstable soils.

Modern geotextile fabrics are often made with synthetic polymers such as polypropylene, which provide increased strength for applications like road building, railroad-track construction, and foundation reinforcements. Synthetic geotextiles provide long-lasting strength for soil structural improvement. Traditional geotextiles are produced using bio-fiber materials, usually made of coir (coconut fiber), jute, cotton, and wood. While not as strong or durable as synthetics, these plant-based fibers are biodegradable, and do not create pollution in their manufacture or installation. They are particularly useful for erosion control and drainage applications, and are most often used in environmental conservation and restoration projects due to their enhanced ability to promote revegetation.

For more information about geotextiles, take a look at the U.S. Army and Air Force publication at http://armypubs.army.mil/eng/DR_pubs/DR_a/pdf/tm5_818_8.pdf, or check out the NRCS engineering guidebook at http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17538.wba.

Road underlayment with synthetic geotextile (photo from fema.gov_5812_geotextile).

Slope stabilization with high-density coir fabric (photo from dot.ca.gov_cslp09).

Erosion control and revegetation (photo from (HSWCD 07-14-2011).

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Gilman River Center

The Gilman River Center, or just River Center, is located in Soldotna, at 514 Funny River Road (http://www.kenairivercenter.org/index.htm). The River Center is a multi-agency office that allows landowners to have a "one-stop-shop" for getting help with EPA, ADF&G, and borough permits and for obtaining many kinds of guidance on land uses affecting peninsula streams and rivers. For example, the center can help landowners figure out what soil bionengineering practices they might want to consider, or can provide instructions for installing elevated light penetrating boardwalks.

Four agencies maintain offices at the center: the Alaska Department of Fish and Game, Division of Habitat; Alaska Division of Parks and Outdoor Recreation; Environmental Protection Agency; and the Kenai Peninsula Borough. The Kenai Watershed Forum also maintains an office at the center and coordinates with the other agencies on outreach and education programs.

GIS (geographic information system)

(From www.esri.com.) Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

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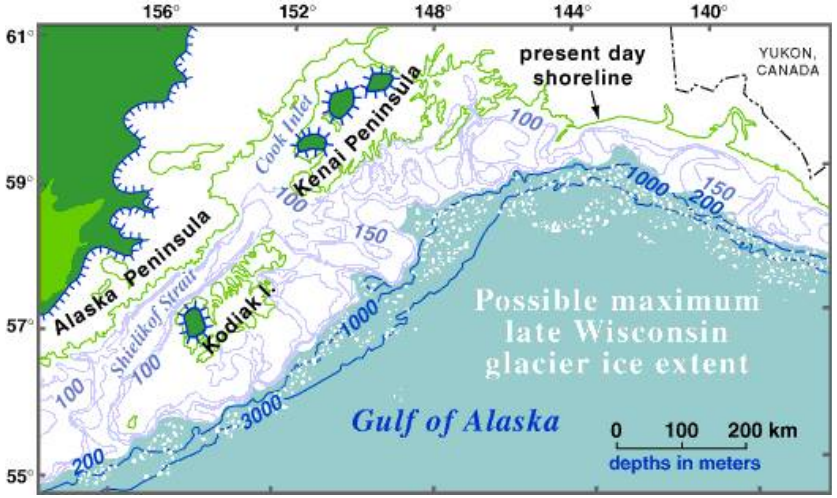
Glacial history of the western Kenai Peninsula
(see also Landforms)

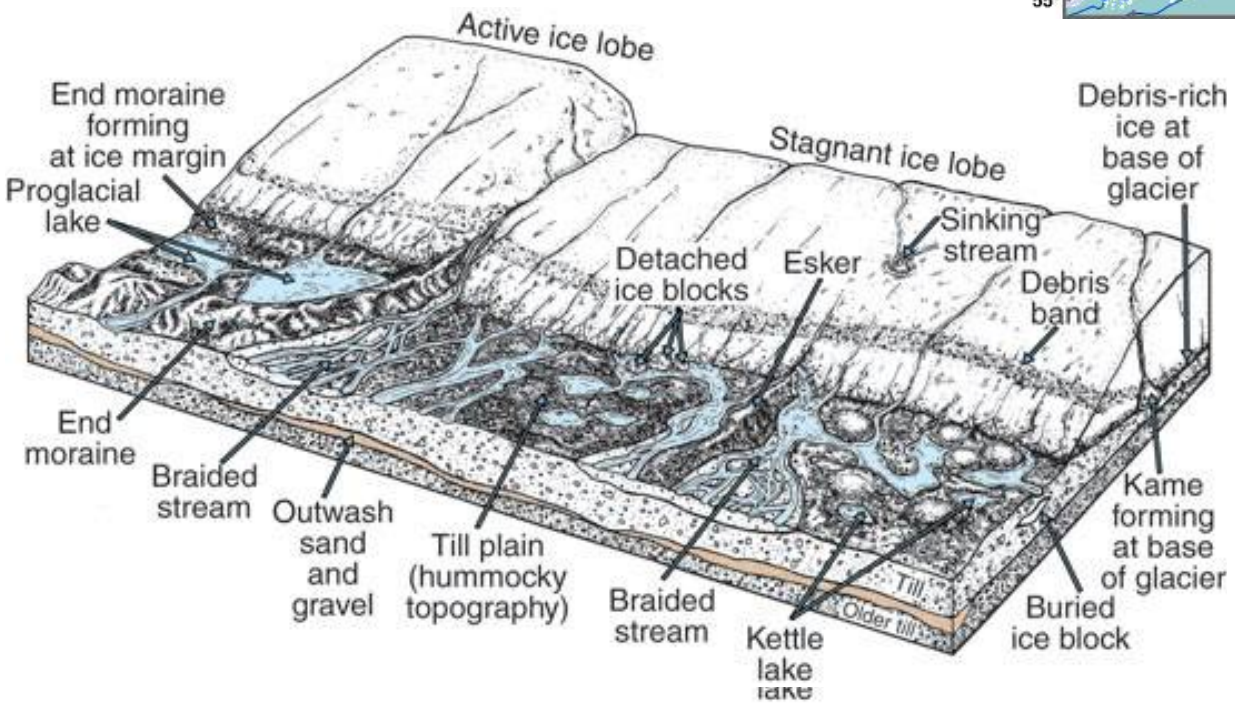
The advance and retreat of glaciers profoundly shaped the Kenai Peninsula landscapes we see today. Topography and landforms reflect glacial processes, as do stream channel "anatomy," soils, wetlands, and most other features of our watersheds. In fact, learning about local glacial history may be one of the best ways that landowners can gain a better understanding of their watershed's features and the nature of its streams.

A user friendly introduction to the glacial history of the Kenai Peninsula is *A Guide to the Late Quaternary History of Northern and Western Kenai Peninsula* (2007, Reger, Sturmann, Berg, and Burns, Guidebook 8, Alaska Division of Geological and Geophysical Surveys). That guide describes much of the the peninsula's Quaternary glacial history (the Quaternary period began about 2 million years ago and is divided into the Pleistocene——also called the Ice Age—which ended about 12,000 years ago—and the Holocene—which is the epoch we're in now.) Perhaps of most interest to landowners, the guide provides a milepost-by-milepost explanation of glacial land-

Maximum glacial ice extent about 23,000 years ago. (The late Wisconsin overlaps the Naptowne.) Source http://esp.cr.usgs.gov/research/alaska/



forms seen along the Sterling Highway and explains their origins. The guide can be downloaded at http://www.dggs.alaska.gov/webpubs/dggs/gb/text/gb008.PDF (the pdf is over 19 MB in size so may take a few minutes to download). This watershedipedia entry is largely excerpted and modified from that guide. A useful supplement to the guide is *Ecosystem and Climate History of Alaska* (2004) by the US Geological Survey. The **map above** is from that source and gives the link.



The **drawing at left** should make it easier to understand terms describing glacial landforms; which are also discussed under Landforms. The drawing is from http://www.kgs.ku.edu/Publications/PIC/pic28.html, which has good general discussions about the last Ice Age in the Lower 48.

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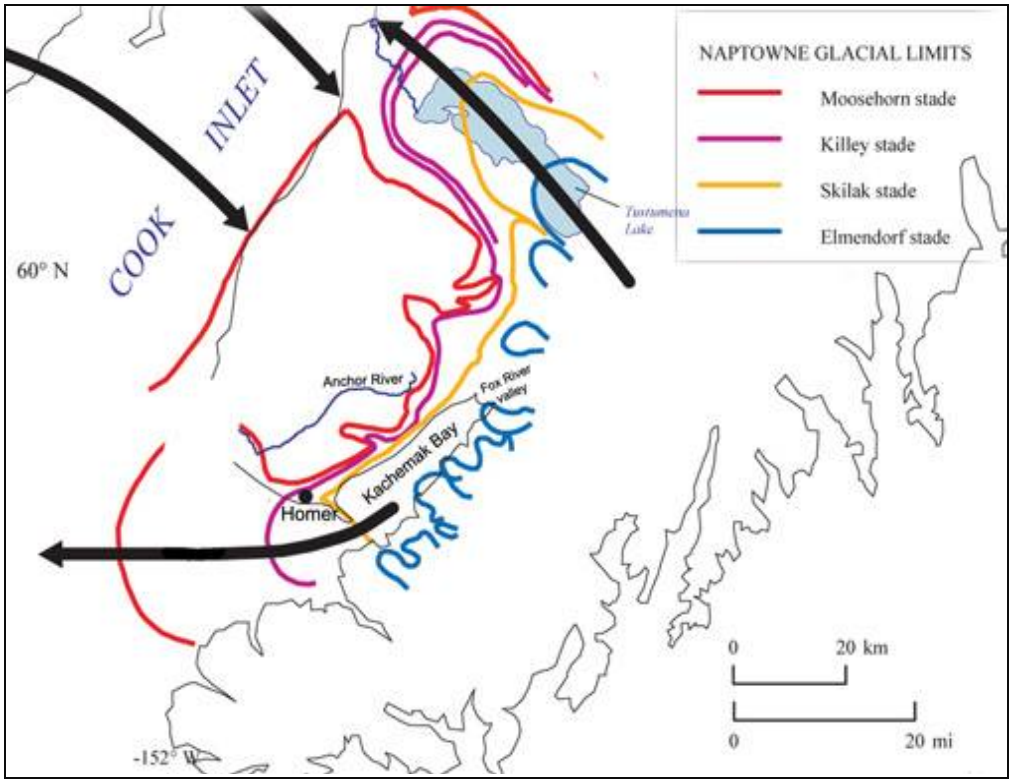
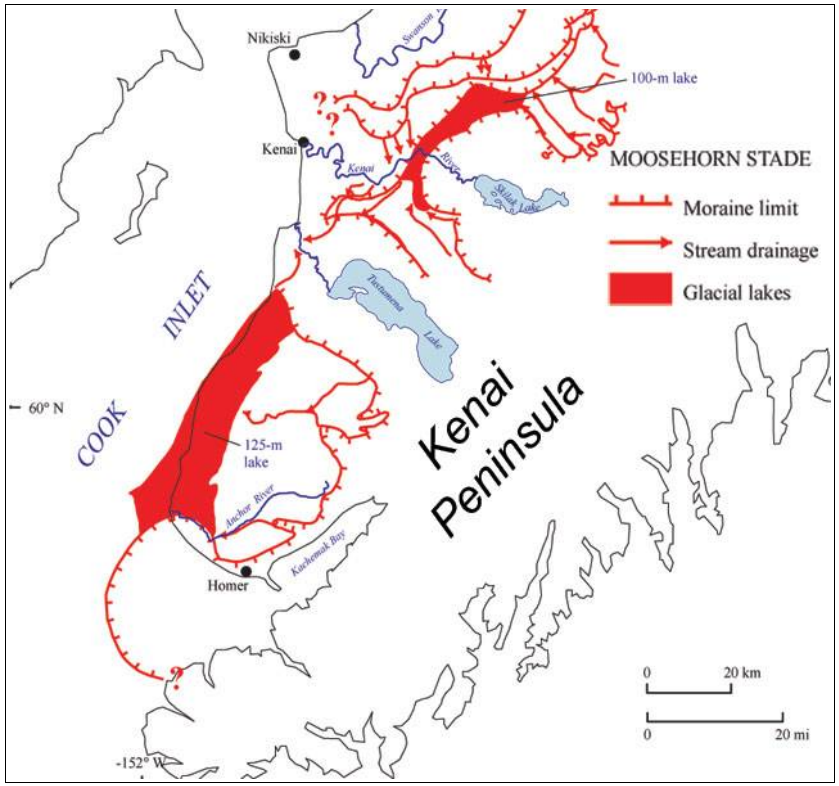
The Kenai Lowland's glacial history and its large glacial lake
(as noted, the following material is largely excerpted and modified from the Quaternary Guidebook described above, http://www.dggs.alaska.gov/webpubs/dggs/gb/text/ gb008.PDF.)

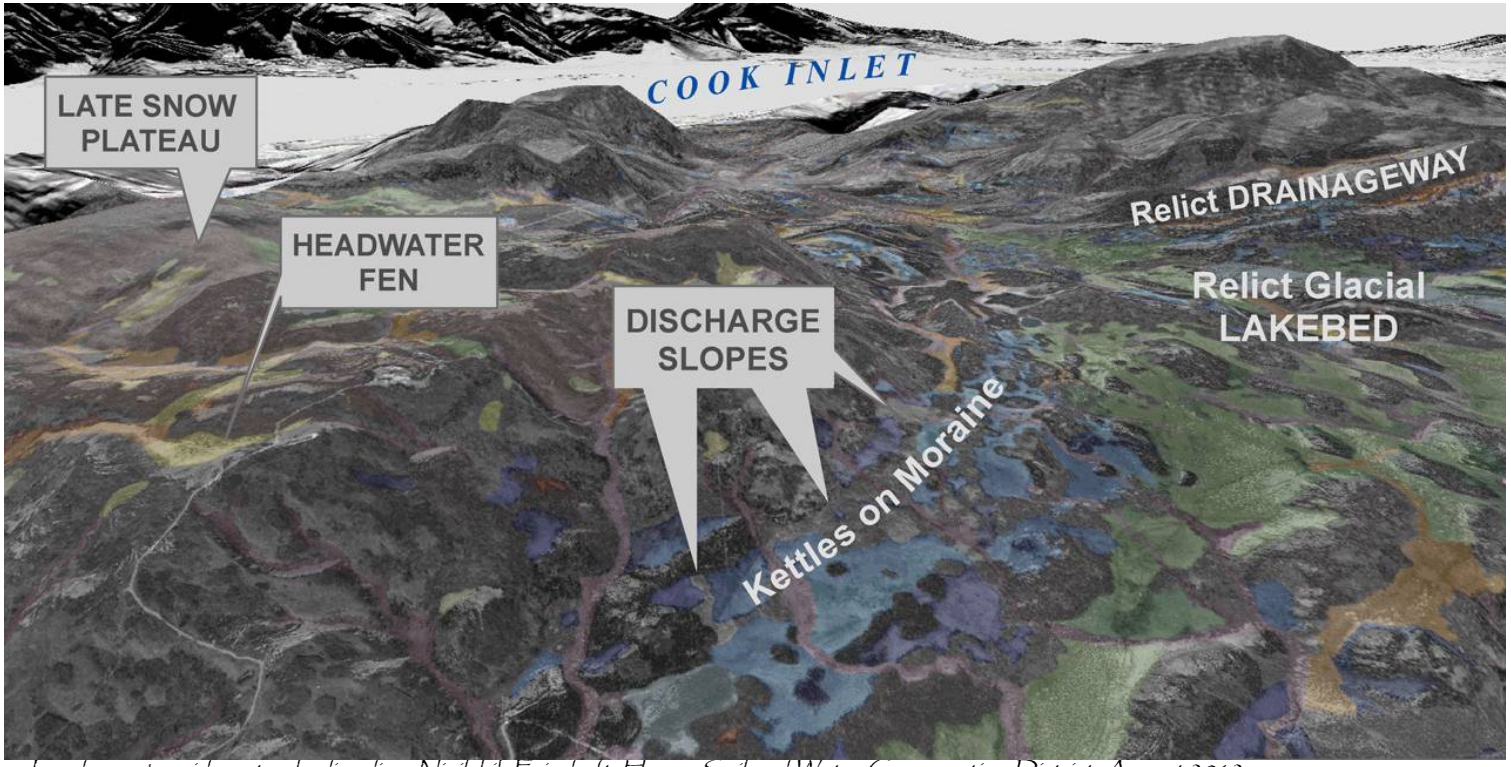
Most of our landscapes reflect the work of Naptowne glaciation (although older glacial periods also left their marks, particularly at the higher elevations of the Caribou Hills). As currently understood by geologists, the Naptowne glaciation saw four major glacial advances, each less extensive than the previous (see **map lower left**). These four advances or "stade" were—from oldest to youngest—Moosehorn (peak ~23,000 yrs ago), Killey (peak ~17,000 yrs ago), Skilak (peak ~16,500 yrs ago), and Elmendorf (peak ~14,500 yrs ago). During the peak of the Moosehorn advance—some 23,000 years ago, glaciers from the southern Kenai Mountains (for example, from across Kachemak Bay) flowed out into Cook Inlet (see **map lower left**). There, these westward grinding glaciers jammed up against a compound ice sheet that advanced across Cook Inlet from the mountains on its west, where glaciers can still be seen today. At the same time, worldwide sea levels were dropping as more of the earth's water was tied up in glaciers. Eventually, the massive and partly floating ice barrier that filled the mouth of Cook Inlet grounded like a barge left stuck in the mud by the receding tide. Glacial meltwater collected behind the ice dam in Cook Inlet (see **map lower right**), creating a lake of regional dimensions, maybe twice the size of Tustumena Lake. Vast areas of the southern Kenai Peninsula lowlands were inundated by this meltwater lake where it was impounded between the Caribou Hills (which remained largely ice free during Naptowne glaciation) and the





Cook Inlet ice sheet to the west. Pre-existing stream valleys on the lowlands south of Tustumena Lake were flooded and then drowned by the glacial lake, including large portions of Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. Lakebed sediments slowly settled over what was once dry land, and lakeshore terraces were eroded into the slopes of the Caribou Hills. (A drawing of these terraces can be found under Caribou Hills.) **Maps on the next three pages** show various water levels of the glacier-dammed lake (red dashed lines) and other landform features left by Naptowne glaciation.

As the glacier dam thinned with the end of the Moosehorn stade, impounded water levels dropped incrementally. Over time, the glacial lakebed was exposed, along with its sediments. Braided and meandering streams drained the emerging lowlands, wandering back and forth across the former lake bottom and downcutting channels in response to isostatic rebound and retreat of coastal bluffs. (Isostatic rebound occurs when land formerly compressed by the weight of glaciers begins to rise as the pressure is removed; the retreat of coastal bluffs changes a stream's base level.) Drainage patterns developed as tributaries lengthened and paleovalleys and river channels deepened. Stream "piracy" occurred where channels eroded headward until they reached another stream and intercepted its flow. (Diamond Creek, for example, flowed into the Anchor River until Diamond Gulch Creek eroded headward and intercepted Diamond Creek flow.) The rivers we know today—the Anchor, Ninilchik, Stariski, and Deep—each developed its individual course and stream channel "anatomy" as it cut its channels through lake deposits and glacial drift. In some cases, channels downcut deep enough to erode into older (Tertiary) bedrock below more recent glacial deposits, enabling bedrock structures like faults to take control of stream orientation. (*Here we end the discussion derived from the Quaternary guidebook described above, available at* http://www.dggs.alaska.gov/webpubs/dggs/gb/text/ gb008.PDF).



Post-glacial processes came to dominate as the glacial lake drained and glaciers receded: huge volumes of meltwater carved immense drainageways down slopes and across the lowlands, saturated hillsides gave way in powerful debris flows, sedimentation buried channels as stream discharge decreased and streams dropped their loads. The interplay of processes like these over thousands of years gave rise to the landscapes we see today. Such relationships are illustrated in the **image at left**, which shows how different kinds of present-day wetlands are correlated with the glacial past (used by kind permission of Mike Gracz, see http:// cookinletwetlands.info/.)

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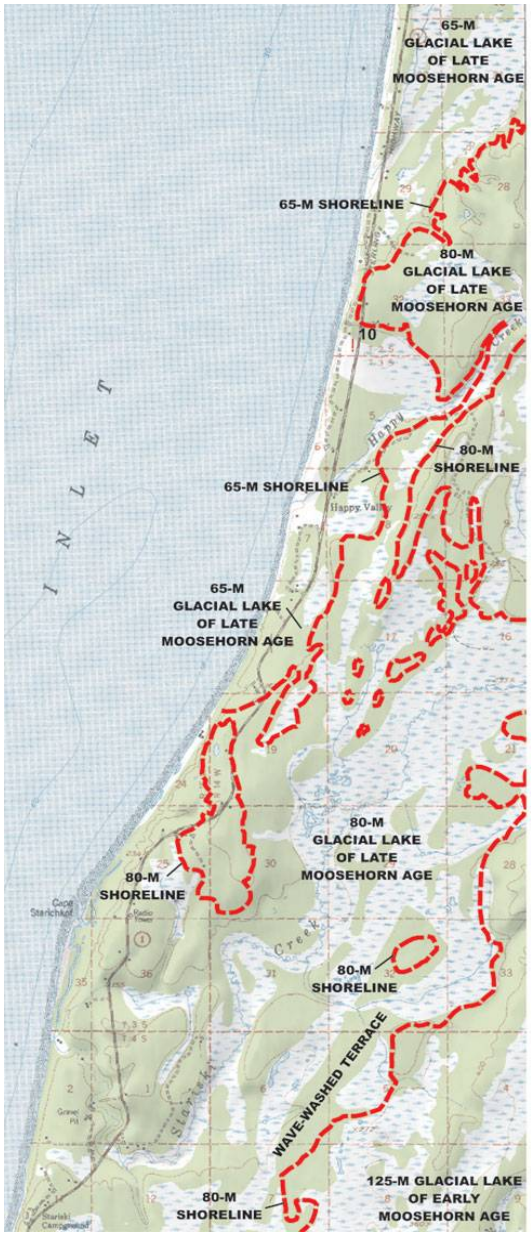
Maps on this and the next two pages show various glacial features found in parts of the Anchor River and Stariski Creek watersheds (this page and the next) and upper Ninilchik River watershed (third page). The legend shown on this page applies to the following two maps as well.

These maps are from the Quaternary guidebook described at the beginning of this entry, which is available at: http://www.dggs.alaska.gov/webpubs/dggs/gb/text/ gb008.PDF).



Explanation of map symbols

The following symbols appear on at least one of the six map sheets in this guidebook set but may not be present on other map sheets

- 3 Stops
- Moraine limit, Naptowne undifferentiated
- Moraine limit, Moosehorn stade
- Moraine limit, Killey stade
- Moraine limit, Skilak stade
- Moraine limit, Elmendorf stade
- Glacial lake shoreline, Moosehorn stade
- Glacial lake shoreline, Killey stade
- Glacial lake shoreline, Skilak stade
- Meltwater drainage, pre-Naptowne glaciation
- Meltwater drainage, Moosehorn stade
- Meltwater drainage, Killey stade
- Meltwater drainage, Skilak stade
- Limit of alluvial fan, Killey stade
- Hanging delta, Moosehorn stade
- Margin of fluvial terrace, Moosehorn stade
- Margin of fluvial terrace, Killey stade
- Margin of fluvial terrace, Skilak stade
- Margin of fluvial terrace, Elmendorf stade

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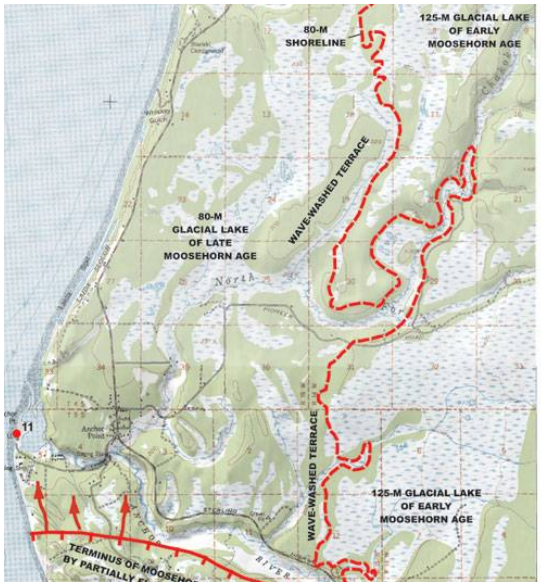
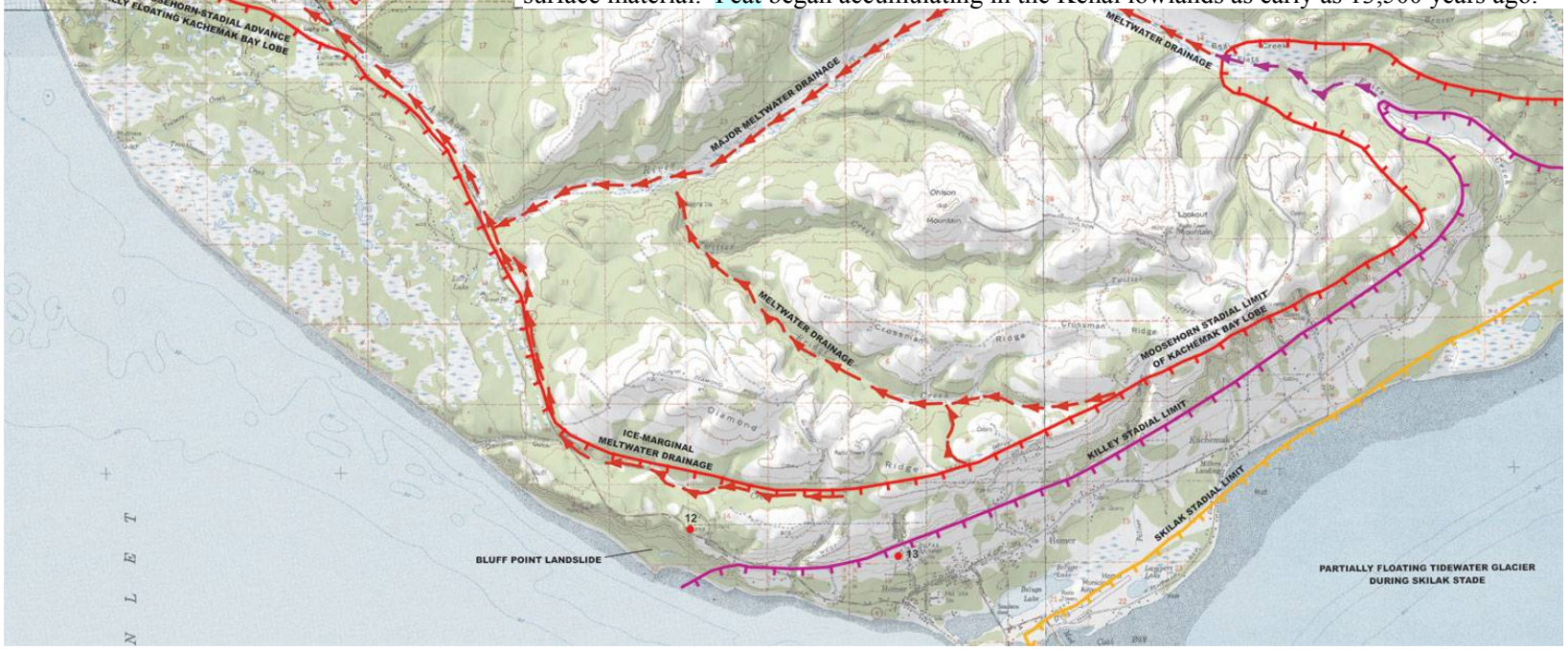


The legend for this map is shown on the first map of this series. This map shows the extent of Moosehorn (red), Killey (purple), and Skilak (yellow) stade during Naptowne glaciation, as well as meltwater channels draining the glaciers (arrows). Water levels of a glacier-dammed lake that filled parts of this area during the Moosehorn advance are shown by dashed red lines.

(The following two paragraphs are modified from http://www.dggs.dnr.state.ak.us/webpubs/dggs/pdf/text/pdf1993_050b.PDF.) You can see that the location of the present-day course of lower Anchor River was caused by diversion of the stream channel along the margin of a glacial lobe that advanced northwestward out of Kachemak Bay during the Moosehorn stade. This partially floating lobe—called the Kachemak Bay lobe—advanced into the meltwater lake to a line just south of the present mouth of Anchor River. There the glacier stagnated before receding.

The lower Anchor River then cut through lake sediments to the level of modern sea level during the Moosehorn-Killey interstade (the warmer period between glacial advances). After this, a layer of outwash gravel about 20 ft thick was deposited in lower Anchor River valley as a result of the Killey advance across Kachemak Bay (purple ticked line). Since Moosehorn time, wind-borne fine sand, silt, and numerous layers of volcanic ash from Mount Augustine and other volcanoes across Cook Inlet have accumulated to form a complex layer of fine-grained surface material. Peat began accumulating in the Kenai lowlands as early as 13,500 years ago.



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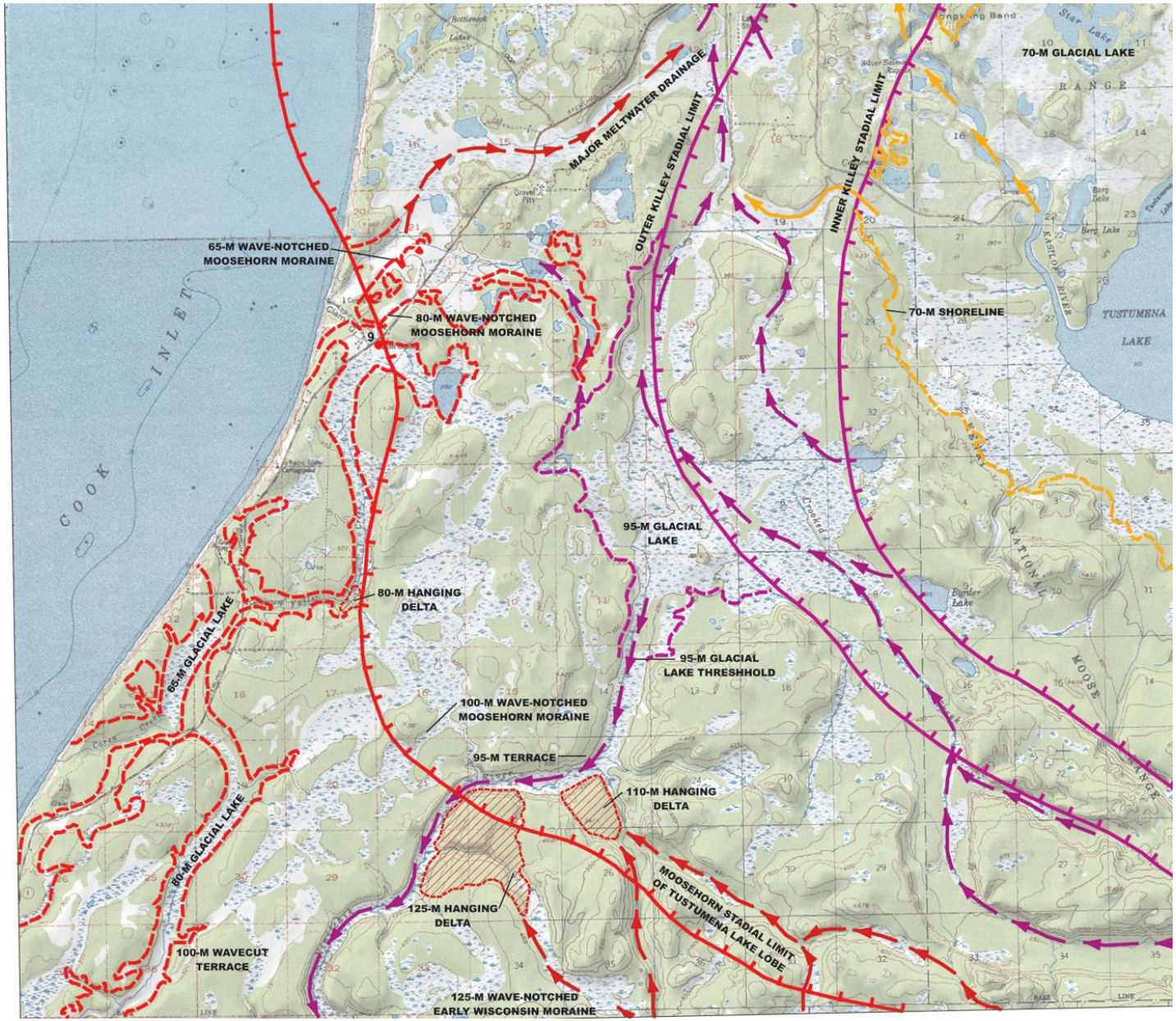
The legend for this map is shown on the first map of this series. This map shows the extent of Moosehorn (red), Killey (purple), and Skilak (yellow) stade during Naptowne glaciation, as well as meltwater channels draining the glaciers. Water levels of glacial lakes that filled parts of this area are shown by dashed lines, red for Moosehorn lakes, purple for the Killey lake.

You can see that the glacial forerunner of Ninilchik River drained a meltwater lake that no longer exists (purple dashed lines). The channel created by this meltwater river is significantly larger than needed to carry the flows characteristic of the present-day Ninilchik River. This means that Ninilchik River is "underfit" with respect to the channel in which it now flows.



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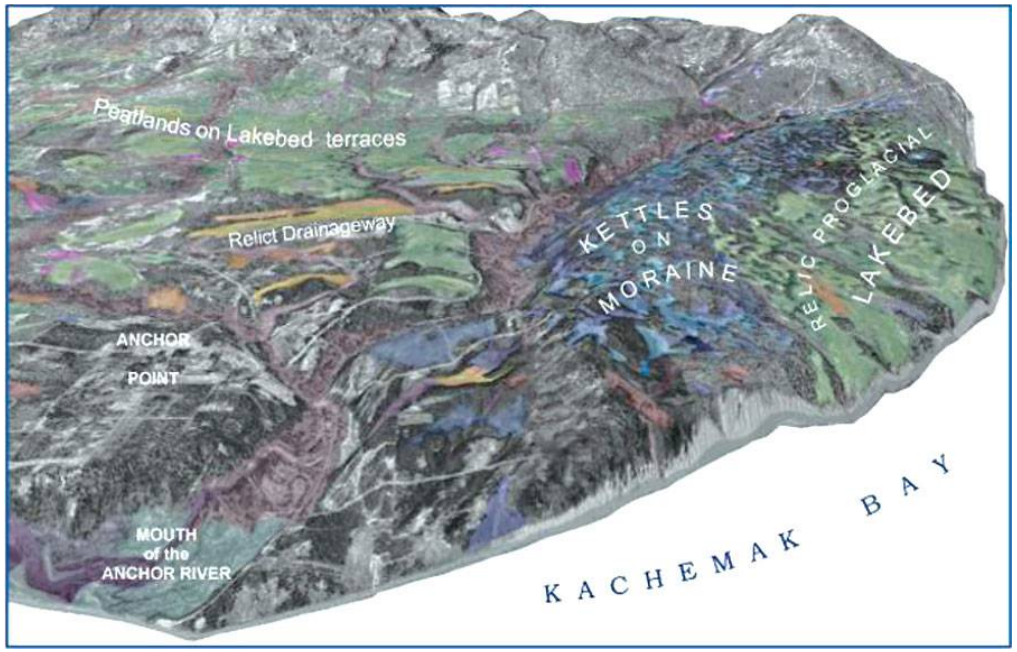
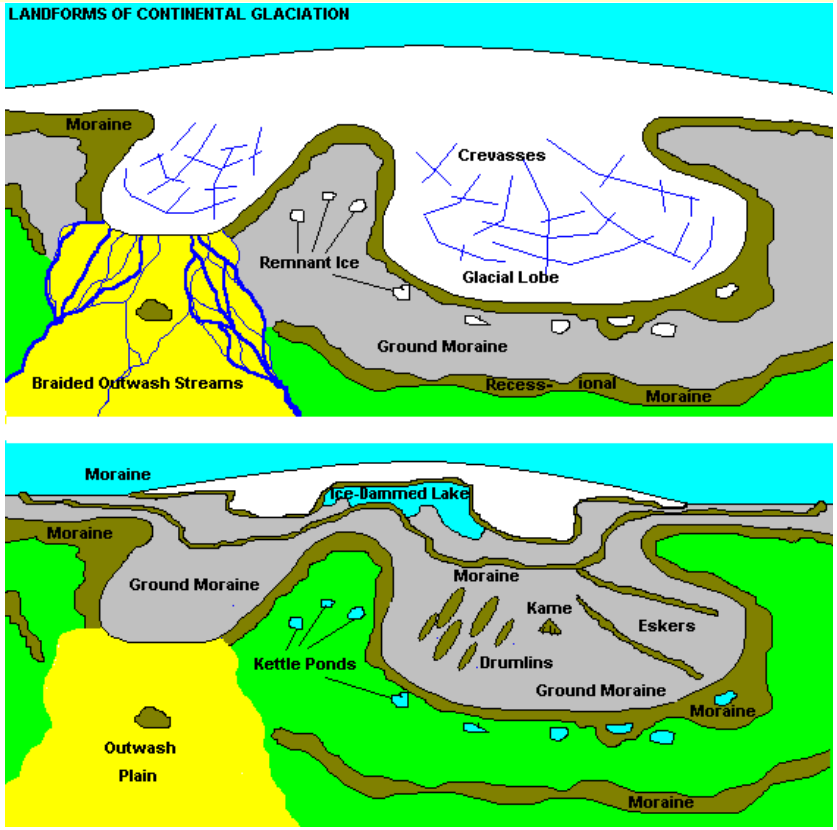
Today's watershed landscapes continue to be shaped by many processes. It's easy to notice the most dramatic, like flooding, earthquakes, landslides, tsunamis, and volcanic eruptions. Landowners can do little about these upheavals but prepare for them in advance. But many more subtle processes turn out to be equally important in the long run because they operate day in and day out, season after season, cycle by cycle—slowly but surely refining the landscapes the glaciers left behind. It's these kinds of processes that landowners end up affecting in ways that can accumulate and become significant. And that brings us back to salmon, who somehow found Kenai peninsula watersheds as streams broke loose from their long glacial winter. As conditions became more hospitable and less extreme, plants and insects and other forms of life colonized the peninsula. And with these changes in plant and animal communities came the salmon. It's pretty amazing when you think about it: to start out with glaciers and end up with salmon.

Now that the salmon are here, we can help maintain them and the varied and abundant habitats our watersheds provide. Humans have replaced glaciers as key shapers of landscapes, so it's our turn to keep our watersheds operating in salmon-friendly ways. It's our choices now that most affect the processes shaping salmon and their habitats—processes like infiltration, interception, increases in impervious cover, erosion, arrival of invasive plants, sedimentation, stormwater runoff, stream temperatures, and the like. This guide offers many choices we can make to help keep salmon returning to our streams (e.g., Best Management Practices, Buffers). But we have to know what those choices are, and we have to make them.

Image at right: glacier and resulting landforms (source: http://www.uwgb.edu/dutchs/ EarthSC202Notes/glacial.htm).
Image below: present-day wetlands on landforms created by glaciers (used by kind permission of Mike Gracz, see http://cookinletwetlands.info/.)



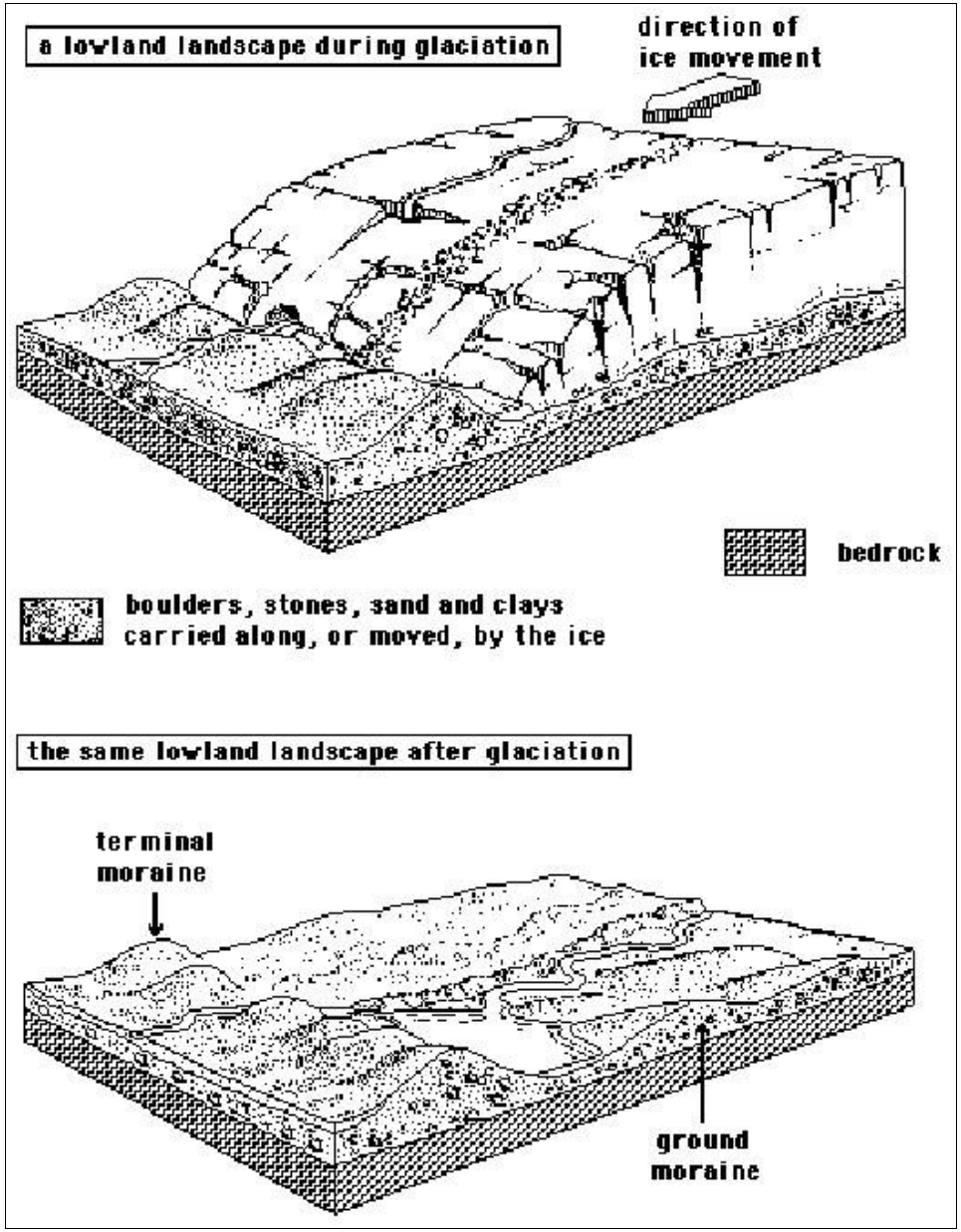


Glacial till

(Modified from http://www.physicalgeography.net/fundamentals/10af.html.) Till is a general term for the unsorted material left behind by a melted glacier. This material is a heterogeneous combination of unstratified sediments ranging in size from large boulders to minute particles of clay. These particles have not been sorted by the action of wind or water, which tend to transport and deposit particles according to particle size, thus creating what are called "well-sorted" deposits.

When till is deposited along the edge of a glacier, it tends to form irregular hills and mounds known as moraines. A till plain is a large, relatively flat plain of till that forms when a sheet of ice becomes detached from the main body of the glacier and melts in place, without further forward movement. Sometimes sediments in a till plain contain large boulders. If these have been transported some distance from their place of origin, they are called erratics

Picture at right from http://homertribune.com/wordpress/wp-content/uploads/2010/06/glacier.jpg)



Green infrastructure (GI)

(see Ecosystem services)

Greenway

(see also Connectivity and Fragmentation)

A greenway is a linear open space that is more natural than surrounding areas; it is typical of many recreational lands along rivers, lakes, and coasts. The challenge in managing greenways is to preserve their natural biodiversity and functions as much as possible while still allowing for human enjoyment.

Groundwater

(see Aquifer)

Groundwater is water that moves beneath the ground surface (see water table). Sometimes groundwater "daylights," which means it flows out onto the ground (exposing it to daylight), for example, in a pond, stream channel, or spring. At that point, the groundwater becomes surface water.

So groundwater can become surface water and surface water can disappear underground, both are part of the water cycle.

Habitat

(see also introductory article 1: Salmon species and life cycle)

The environment(s) where an animal finds the food, water, shelter, and reproductive environments it needs to survive and reproduce. Some species, like salmon, use a variety of habitats at different life stages; some spend their entire lives in a single habitat.

Habitat fragmentation

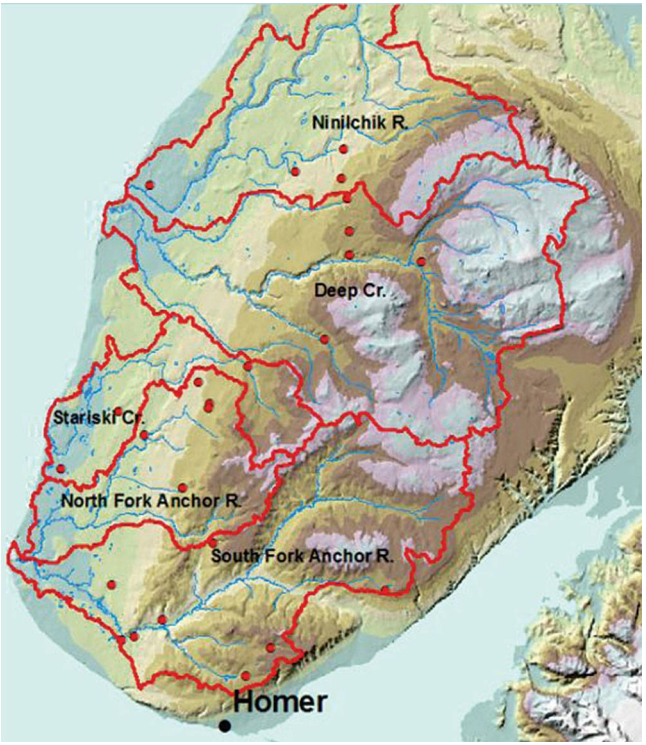
(see also Connectivity, see also introductory article 1: Salmon species and life cycle)

The breaking up of larger, contiguous habitat blocks or areas into smaller pieces separated by developments (e.g, roads, culverts, buildings) or other kinds of disturbances to natural connectivity. The remaining habitat fragments are often insufficient in size, condition, or function to sustain species whose habitat needs require larger, contiguous areas. Salmon are particularly vulnerable to habitat fragmentation because they require so many different but connected kinds of habitat during their life cycle (from freshwater gravel for nurseries, to undercut streambanks for rearing, to estuaries for transitioning to saltwater, to oceans for achieving the adult size and strength needed for spawning).

Headwaters

(see also Headwater streams)

The areas in the landscape where streams begin, generally from springs, seeps, or discharge slopes and usually at higher elevations because melting snowpack can be an important source of headwaters. Headwaters can also be lowland areas where springs or seeps give rise to enough flow to create a stream.



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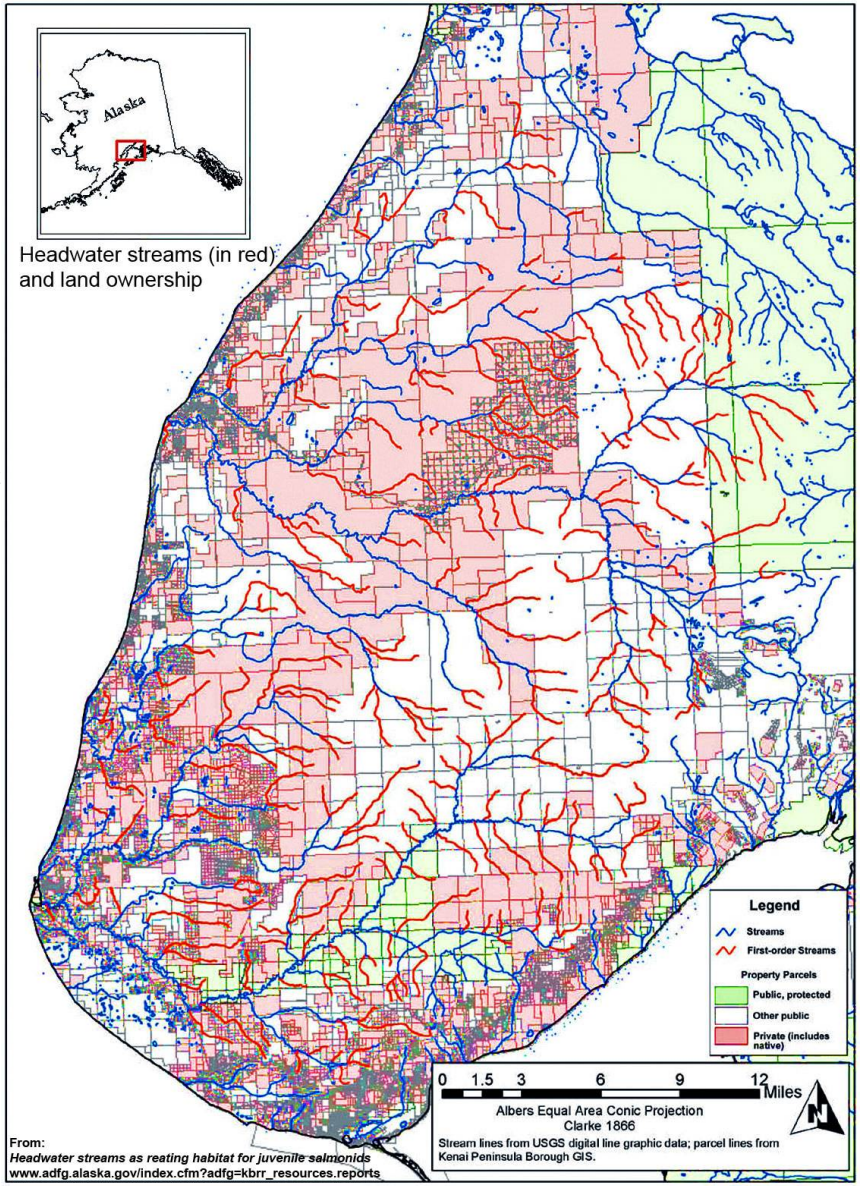
Headwater streams

(see also Stream order)

Headwater streams are a critical component of salmon rearing habitat, particularly for coho salmon. Many of these channels are so narrow they are essentially invisible beneath blankets of peat or overhanging vegetation. Slow currents, concealment from predators, cool temperatures, and abundant food make these tiny first order streams ideal for juvenile salmon.

These critical habitats are just now being studied in a systematic way. In *introductory article 4: Research in your watersheds*, you'll find a brief introduction to selected studies, see also: http://www.adfg.alaska.gov/index. cfm?adfg=kbrr_resources.reports.

The **photos below** are from the study mentioned above. They show three different kinds of headwater habitats, each of which supports juvenile salmon at different stages.



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Homer Soil and Water Conservation District (HSWCD)

In Alaska, Soil and Water Conservation Districts, such as the Homer SWCD, are established under AS 47.10. That statute invests SWCDs with certain responsibilities and authorities related to wise use, management, and stewardship of natural resources. For example, districts have an advisory role to the Commissioner of the Alaska Department of Natural Resources. As a result, although districts operate as "grassroots" organizations with a volunteer Board of Supervisors elected by district "cooperators" (see below), they are considered divisions of state government. This allows Districts to "sit at the table" as equal partners with state and federal agencies. It also makes them eligible for certain kinds of funding. Districts are established to facilitate collaborative partnerships with any entities interested in helping promote wise and sustainable use and conservation of natural resources—from individual landowners to federal agencies.

The mission of the Homer Soil and Water Conservation District is to…

> …provide education and leadership in the conservation and sustainable use of soil- and water-related resources through cooperative programs that protect, restore, and improve our environment.

Its website is www.homerswcd.org,

Information transfer—through outreach and education—is one of the core commitments of Homer Soil and Water. Working closely with landowners to provide them the information and tools they need to sustain the resources they manage has been central to the purpose of districts since they were first established during the Dust Bowl years of the 1930s. The Homer District, for example, works with and through over 200 private landowners from communities on the southern Kenai Peninsula who have signed "cooperator" agreements with the District that reflect their interest in and commitment to the wise use and management of resources they manage. These cooperators, along with dozens of other private, corporate, public, and non-profit partners, contribute to outreach efforts spearheaded by Homer Soil and Water.

The other element that underlies districts' effectiveness is their close partnerships with entities that have technical expertise potentially helpful to land managers. The Natural Resources Conservation Service (NRCS) has been the districts' closest partner since its birth as the Soil Conservation Service during the Dust Bowl era. The NRCS provides districts with many types of resource data, technical help, and planning support. But districts such as Homer Soil and Water now form strong, results-oriented collaborations with numerous other entities. Some of the technical partners who have worked closely with the Homer Soil and Water Conservation District as it carries out its mission include US Fish and Wildlife Service, University of Alaska Cooperative Extension Service, Environmental Protection Agency, Cook Inletkeeper, and the Alaska Department of Environmental Conservation, to name a few.

Humpy (pink) salmon

(see introductory article 1: Salmon species and life cycle)

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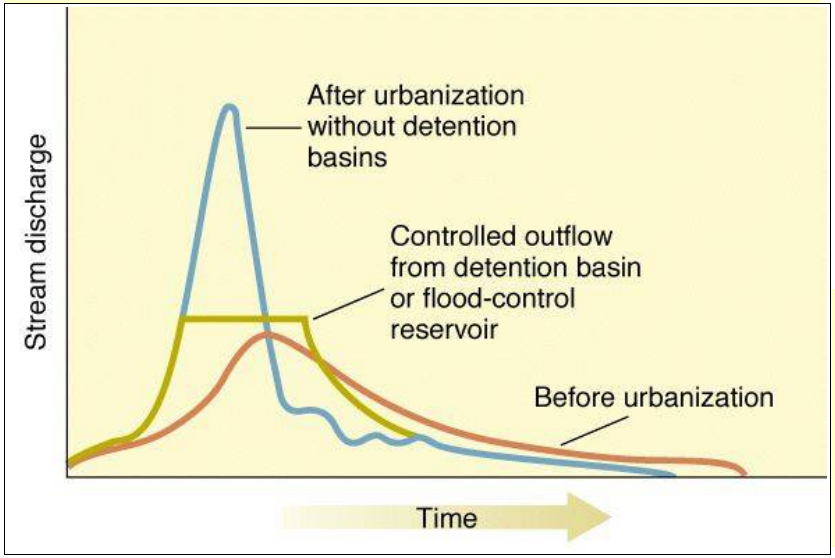
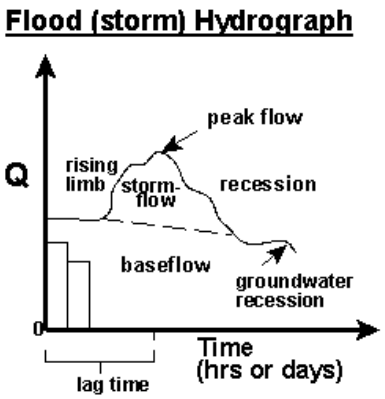
Hydrograph

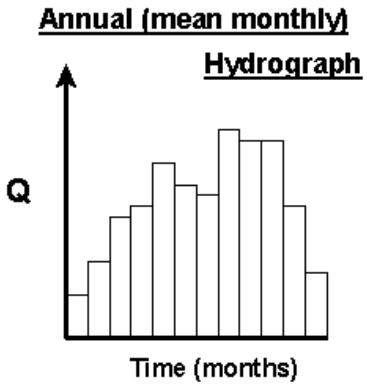
A hydrograph is a basic tool for measuring and understanding the response of an individual stream or an entire watershed to precipitation or snowmelt A hydrograph shows stream discharge (Q) or stream stage on the left side of the graph, with time intervals across the bottom. This way it's possible to see how much water flowed past a certain point in a specified period of time (hour, day, month).

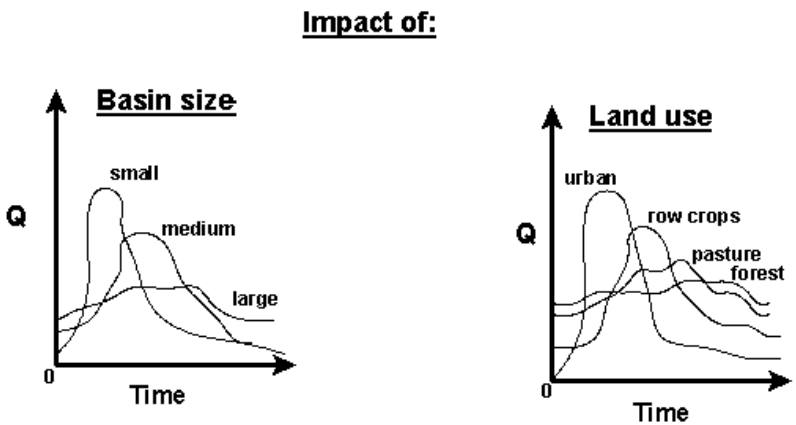
As **examples on the right** show (from http://uregina.ca/~sauchyn/geog327/hydrographs.gif), hydrographs can be used to look at many patterns of flow over time, from those of a single storm to those of monthly or annual mean discharges. Hydrographs can also show the effects of differences in watershed size or changes in land use.

The variables that exert controls on the flood hydrograph range from short-term and temporary (like storm intensity and duration) to permanent (basin geology and landforms) to somewhere in between. Land use can fall somewhere in between because it can be relatively stable (e.g., a natural forest whose hydrograph changes only after a forest fire or insect outbreak) or can change annually (crop rotation).









Obviously some land uses—like urbanization—can change an area's hydrograph permanently, as **shown at left** (from http://serc.carleton.edu/images/introgeo/socratic/examples/Hydrograph.jpg). The more a hydrograph deviates from pre-urbanization patterns (to which salmon are adapted), the more likely salmon populations will be negatively impacted. That's why anything landowners do to reduce stormwater runoff from their properties will make their land uses more salmon friendly—like using Best Management Practices, minimizing impervious surfaces, or incorporating Low Impact Development techniques like raingardens.

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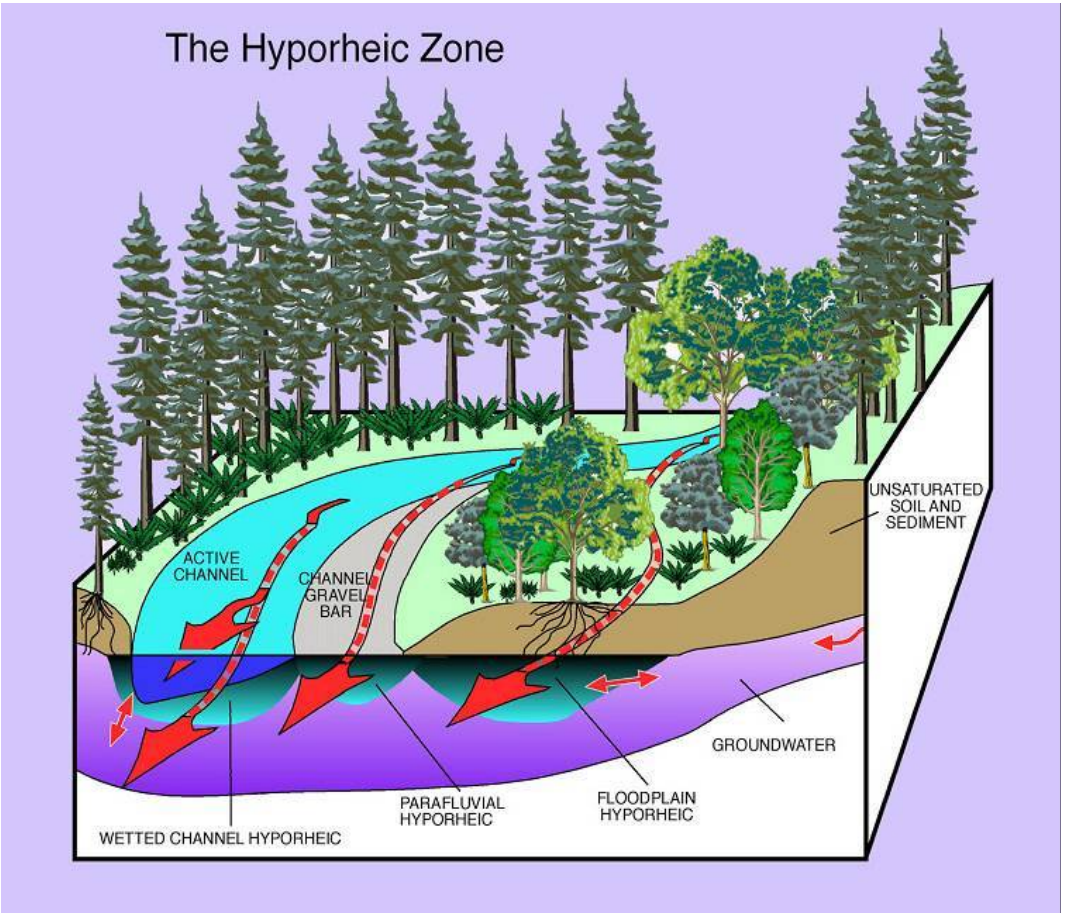
Hydrology

(see Water (hydrologic) cycle)

Hydrology is the study of water, especially of how it moves, its distribution on the landscape, and its properties—including physical and chemical properties.

Hyporheic flow and zone

(see also Water (hydrologic) cycle)



The hyporheic zone is a region beneath and alongside a stream-bed where shallow groundwater and surface water mix. Because of this mixing, the chemical and biological character of the hyporheic zone may differ markedly from adjacent surface water and groundwater. Flow in this zone is termed hyporheic flow, underflow, or interstitial flow. Hyporheic flow can come from the stream channel itself—when water "leaks" out—or from water percolating towards the stream from surrounding areas. The size and geometry of hyporheic zones vary greatly in time and space. The **image at right** illustrates the hyporheic zone (source http://pcnasa.ctc.edu/education/images/Hyporheic.jpg). For more information, see, for example, http://naturemappingfoundation.org/natmap/water/field/hyporheic_zones.html.

The hyporheic zone is an important place for many organisms, including aquatic insects and developing salmon eggs. It is also where groundwater contaminants can enter a stream.

(The following discussion is slightly modified from http://www.holon.se/folke/projects/vatpark/hyporeic.shtml.) Rheic flow is the visible, free running water we see in streams; hyporheic flow is the percolating flow of water through sand, gravel, sediments, and other permeable material under and beside the open streambed. The water flow in the hyporheic zone is rather large, and volume in the hyporheic zone can be as large as in the stream channel itself. In arid areas with sandy soils, hyporheic flow may comprise all the flow when surface waters have dried up.

In this zone, a lot of the organic material is consumed and nutrients are converted to inorganic ions. As a result, this is where much of the water purification takes place, due to the high surface areas and retention times involved. Many bacteria, insect larvae, and other small creatures live in this zone and aid in water purification. Plants that extend their roots into the hyporheic zone thus have a good source of nutrients.

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Impervious surfaces (cover)

Impervious surfaces are surface materials that block the downward movement of water into the soils (see Infiltration). As a result, areas covered by impervious surfaces prevent rainfall, snowmelt, and stormwater runoff from soaking into the ground, and this increases how much water becomes surface runoff. Impervious cover generally refers to a human generated surface with lower ability to allow water to pass through than the original natural surface at that site. Examples include roads, sidewalks, driveways, parking lots, roofs, as well as dense, short-mowed lawns and bare, compacted soil. In watersheds on the Kenai Peninsula, roadways, parking lots, and rooftops account for the majority of impervious cover.

Increased impervious surfaces alter stream flow patterns so that floods occur faster during storms and flood flows are higher (see Hydrograph), while during dry periods, stream flows are lower. With respect to water quality, where impervious cover is low, surface runoff that picks up pollutants can infiltrate into the soil, where pollutants can be filtered out before reaching streams and lakes. On the other hand, roadways and other impervious surfaces prevent any filtration of pollutants picked up by rainfall and snowmelt flowing across the land's surface, so these contaminants get concentrated and carried into nearby water bodies.

Research in recent years has shown a strong relationship between the amount of impervious cover in a watershed and the health of local streams: the higher the percent of impervious surfaces, the more the local streams are stressed by changes in water quality and flow patterns. Researchers generally agree that stream degradation becomes significant as amounts of impervious cover reach and start exceeding about 10% in a watershed. A recent urbanization study conducted by the U. S. Geological Survey in five watersheds in Anchorage found cause for concern from impervious cover at much lower levels: 4.4 –5.8% impervious area (Ourso, R.T., and S.A. Frenzel. 2003. Identification of linear and threshold responses in streams along a gradient of urbanization in Anchorage, Alaska. *Hydrobiologia* 501(July):117-131. The abstract is available at: http://dx.doi.org/10.1023/A:1026211808745, and the pdf of the article can be downloaded there). As the amount of impervious surface in a landscape increases, a chain of events is set in motion that alters the way water is transported across and stored in the landscape. These changes can affect the local water cycle. Once this chain of events begins, effects are far-reaching, and can include degraded fish and wildlife habitat, decreased water quality, and impacts to nearshore estuarine habitat.

Kenai Watershed Forum (KWF) has measured how much impervious cover occurs in the Anchor River, Stariski Creek, Deep Creek, and Ninilchik River watersheds. The mapping project relied on new GIS software that identified unique attributes of satellite imagery and translated this data into reliable coverages of impervious surfaces. As satellite imagery improves, this method will become a useful tool for tracking how much the amount of impervious surface in an area changes over time. An example of an impervious surface map by the KWF is included in *introductory article 3: Exploring your watershed with online tools*.

Inletkeeper has analyzed differences in water quality and quantity and macroinvertebrates between developed and undeveloped portions of selected watersheds. The results of CIK's study are reported in "Mapping Impervious Cover to Correlate Land Use Activities with Salmon Health & Habitat on the Lower Kenai Peninsula," (online at: http://inletkeeper.org/resources/contents/mapping-impervious-cover-report/view). At the time of the study, analyzed watersheds had less than 2.6% impervious cover. Not surprisingly, Ninilchik and Anchor Point areas had the greatest amount of impervious cover, while the upper reaches of Deep Creek watershed had the least. (Seismic lines and trails were not included in calculating impervious cover.) The report provides landowners and other resource managers with an understanding of where impervious cover currently occurs and provides a tool to track this environmental indicator and help prevent loss of important habitat. CIK recommends that impervious cover analysis be undertaken again in 5 to 10 years.

With awareness, foresight, advanced planning, and identification of at-risk watersheds, total impervious cover can be reduced during development. Low Impact Development techniques provide examples. Landowners can minimize impervious surfaces on their property by using Best Management Practices.

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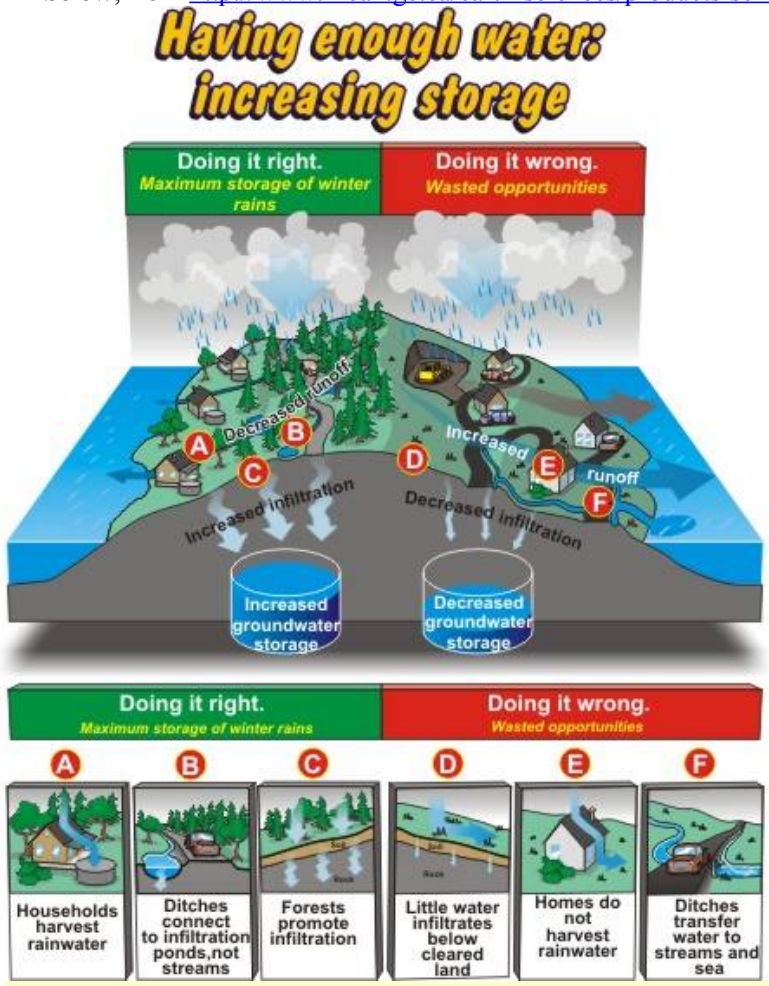
Infiltration

Infiltration is the movement of water from the land's surface into the unsaturated zone of the soil and underlying subsurface sediments or rocks (see **drawing below**, from http://www.nrcan.gc.ca/earth-sciences/products-services/mapping-product/geoscape/waterscape/gulf-islands/6148). Infiltration is a critical part of the water cycle because how much water infiltrates determines how much water is stored between the ground surface and the water table, where it is available to plant roots. Infiltration also contributes to the amount of water stored as groundwater, and groundwater feeds water wells and streams (see baseflows). Also, water that infiltrates does not become overland flow and surface runoff. As explained in this watershedipedia, excess surface runoff (runoff levels above "natural") can lead to many problems for both landowners and salmon, including (a) erosion, gullying, and transport of sediments to places where sediment deposits cause problems (like into spawning gravels); (b) movement of pollutants into streams, lakes, wetlands, and groundwater; (c) increased risks of flooding, including "flashier" floods (see Hydrographs); and (d) reduction in the amount of water available for groundwater recharge and stream baseflows.



The infiltration rate is determined by a soil's porosity (the size and interconnectedness of the pore spaces between soil particles), by how saturated the soil already is (how many of its pore spaces are already filled with water), and by the depth of the water table (when soils are so saturated that the water table is at the ground surface, rainfall can't infiltrate no matter how porous the soil.) The soil property that most affects infiltration rate is soil texture (that is, the percentages of sand, silt, and clay in the soil). But even on very porous soils with high infiltration rates—like sands and gravels—rain can fall faster than the soil can take it in. When this happens, the top layer of the soil becomes saturated, and any additional rainfall runs off as overland flow, as happened during the heavy rainstorms that caused flooding in 2002. With heavy, sustained rainfall, water can start pouring off surfaces that rarely shed water. During winter, infiltration is reduced to zero when the ground surface is covered by ice, which means that any rain or melting snow will run off. But vegetated buffers with dense coverage of plant parts poking through ice can at least slow winter surface runoff, even when no infiltration is occurring.

Anything that landowners do to maintain infiltration on their land will ultimately benefit salmon (while lowering risks of surface flooding). Rain gardens, Low Impact Development, Best Management Practices, reducing impervious surfaces—any efforts that keep land functioning as much like a sponge as possible—will help water to soak in, not run off.

Instream flow

(See also Water reservation)

Instream flow is the amount of water flowing in a river or stream or the volume of water in lake or pond.

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Interactive parcel viewer

(see introductory article 3: Exploring your watershed with online tools)

Interception

(Modified from http://uregina.ca/~sauchyn/geog327/intercept.html.)
Interception is the capture and storage of water above the ground surface, mostly on leaves and other plant parts (see p**hoto on right**, from HSWCD). Interception is a critical part of how a watershed functions because it lowers the amount of rainfall reaching the ground and slows the rate at which that happens (through drippage and stemflow, see below). As a result, *interception reduces the likelihood that rainfall will become surface runoff*. In fact, interception and infiltration are the two key "sponge functions" that protect watersheds from excess stormwater runoff—with all its potential erosive, polluting, and flood-causing effects.

Once rainfall, snow, fog, or other atmospheric moisture is intercepted by plants, three things can happen to the intercepted moisture:

- The moisture is absorbed by leaves or evaporates from them and other plant parts. (This process is called *evapotranspiration—evaporation* is the name for all processes that turn liquid water on the earth's surface back into atmospheric water; *transpiration* is evaporation from the vascular system of plants; both processes combined equals evapotranspiration.)
- The moisture slowly drips to the ground (this is called drippage).
- The moisture gradually trickles down stems, branches, and trunks, finally reaching the ground (this is called stemflow).

Secondary interception occurs when drippage from a taller tree drips onto and is intercepted by a shorter tree or shrub beneath it. You can see that the more stratified—or layered—a plant community is, the more interception and secondary interception will occur.

When you think about it, the growth forms of shrubs and trees create elaborate 3-dimensional scaffoldings of surfaces that can capture and hold rain, snow, and other atmospheric moisture. Coniferous trees like spruce generally intercept 25-35% of the annual precipitation; deciduous trees like birch and cottonwood, 15-25%. During the growing season, deciduous trees intercept just as much precipitation as conifers; but because they lose their leaves during winter, they intercept relatively little snowfall then. Spruce trees, on the other hand, intercept A LOT of snow—think about the deep depressions that form under spruce trees during winter as snow outside the tree's drip line (marked by the outer tips of the longest branches) gets deeper and deeper compared to the almost snowless area nearest the trunk. Trees native to regions of heavy snowfall have flexible branches and trunks to support and shed heavy snow loads, which can weigh more than 15 lbs per cubic ft for wet snow (1 cubic foot of water equals 7.48 gallons and weighs about 62.4 pounds).

Trees have a greater interception capacity than shrubs because they project higher above the ground into the wind. This creates turbulence that drives water on the lee side into the interior of the tree. Also, wind increases both evaporation and sublimation (the conversion of snow directly into atmospheric moisture without first becoming liquid).

A variety of other factors affect how much precipitation is intercepted in any particular situation. For example, interception increases exponentially during a storm until the interception capacity of plants is achieved; the weight of more rain then overcomes the surface tension holding water on the plants. Similarly, when a tree branch's capacity to intercept snow is reached, snow periodically sloughs off. The greater the density of plants—that is, the extent of ground coverage and canopy closure provided by leaves and branches—the more precipitation will be intercepted. Interception is also affected by plant structure, such as the number, size, flexibility, strength, and pattern of branches and the texture, surface area, and orientation of leaves Noticing which plants hold more snow can give a sense of which plants have structures that intercept more precipitation. A larger proportion of short duration precipitation is intercepted than the proportion intercepted during a long storm. In a short storm, all precipitation can be intercepted, *(*so there is no drippage or stemflow), but in a long storm, drippage and stremflow transfer intercepted moisture to the ground at a relatively steady state once the plant community's interception capacity is reached.

The influence of wind on interception is complex and depends on wind speed and type of precipitation. In general, higher wind speeds increase interception by increasing evaporation, but initially wind reduces interception because it keeps foliage dry longer, and since water sticks to water (as seen with surface tension), an initial layer of water or snow needs to collect on plant parts to support further storage of moisture. Wind also increases interception by blowing water into the interior of plants and plastering wet snow against trees and shrubs. The type of precipitation also affects interception. Liquid water has high surface tension and forms an initial layer sooner than snow, to which subsequent rain coheres. At temperatures around freezing, rain can freeze to plants, dramatically increasing interception. Snow is often easily blown off plants, but once snow starts to stick, snowflakes (depending on size, shape, and liquid water content) can bridge the gaps between leaves, stems, and branches, and as a result, sticky, wet snow can result in considerable plant interception.

The point of all this for landowners is that plants, particularly large trees, intercept a significant amount of precipitation (see **photo on right**, from HSWCD). Clearing native vegetation for homes, businesses, schools and playgrounds, or other kinds of development, or for logging, reduces interception and leads to increased surface runoff. Changing how much water is delivered to streams, or the timing of when that water arrives, can have significant effects on salmon habitats—and not in good ways. Landowners can recognize and value the interception role their plants play in the watershed water cycle—especially large trees on their land. Doing so can help provide the motivation to protect and maintain well-vegetated landscapes. Given the changes in interception patterns that have already occurred because of the loss of live trees due to spruce bark beetles and the logging that followed, protecting remaining forests, woodlands, and shrublands is a prudent thing to do to be salmon friendly.

This write-up also suggests just how complicated and dynamic many of the relationships are that contribute to how a watershed functions. Helping maintain those complicated relationships and natural functions is critical for the long-term health of salmon habitats and populations. The easiest way to do that—given how little we know about some of these things—is to keep our lands and waters as natural and well-vegetated as we possibly can.

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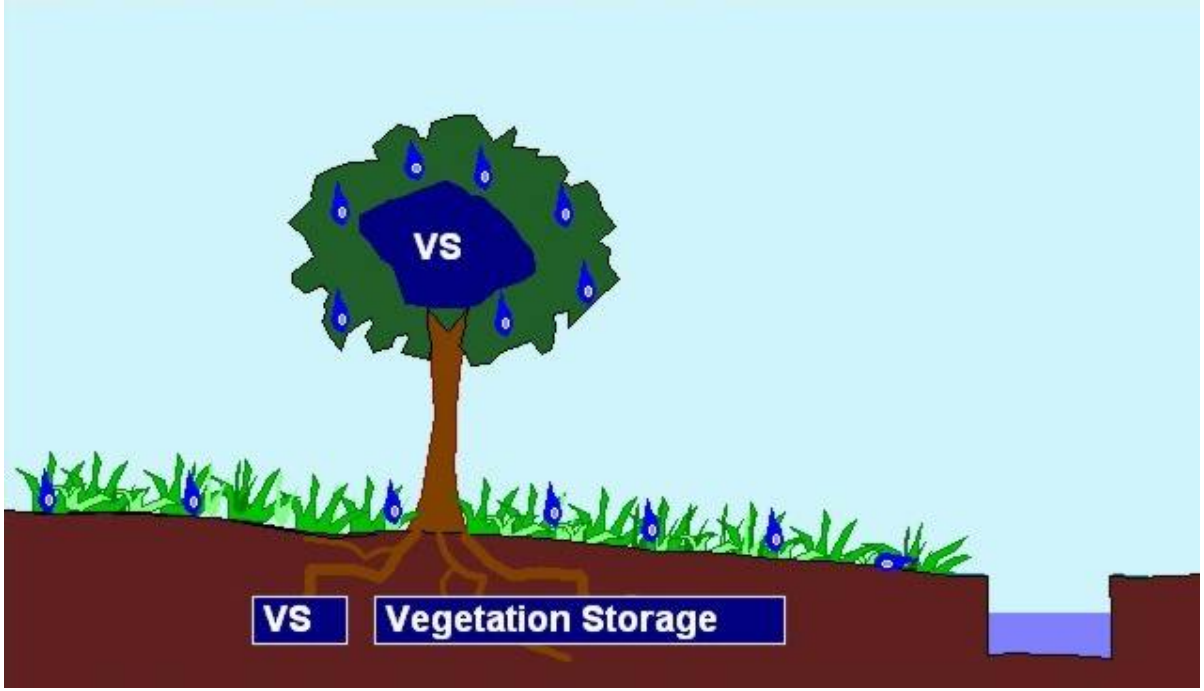
The drawing below shows vegetation and interception of precipitation; VS stands for vegetation storage of precipitation (from http://learning.covcollege.ac.uk/content/Jorum/cat3_cp/catch088.htm).



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Invasive plants

(see also Reed canary grass)

When the spread of a non-native species threatens the health, abundance, or diversity of native plants and animals, that species is considered *invasive*. Although some non-native animals have become invasive on the peninsula (e.g., Northern pike, house mouse), in our watersheds, invasive plants are the bigger problem.

Invasive plants come from out-of-state or other countries—many arriving through Anchorage and spreading from there. Generally, invasives arrive as a result of human activities. In most cases, these introductions are accidental, for example in seed mixes, potting soil, on shoes or clothing, in pet hair or on livestock, or on heavy equipment. Some invasive species were intentionally introduced as ornamentals, like orange hawkweed, which can completely blanket large areas, strangling out all other plants.

Both the Alaska Natural Heritage Program (AKNHP, http://aknhp.uaa.alaska.edu/) and the Kenai Peninsula Cooperative Weed Management Area (CWMA, see http://www.kenaiweeds.org/) track invasive species. AKNHP maintains data and the website for the the Alaska Exotic Plants Information Clearinghouse (AKEPIC, http://aknhp.uaa.alaska.edu/ maps/akepic/), which is a cooperative effort also involving both state and federal agencies and supporting the Alaska Committee for Noxious and Invasive Plants Management (CNIPM) and the Strategic Plan for Noxious and Invasive Plants Management in Alaska. Much of the information here is from AKEPIC. At http://aknhp.uaa.alaska.edu/ maps/akepic/, you can type in the common or scientific name of an invasive plant and quickly find much more information about it and where it's been recorded. There's even an online form to report new infestations.

Distribution of invasive reed canary grass (RCG) along the North Fork of the Anchor River. Each dot represents an infestation averaging about 300 ft (100 meters) in length. Reed canary grass can alter stream hydrology and eliminate salmon habitat.

As invasive plants push out native species, they change ecosystems, altering habitats needed by local fish and wildlife. On the peninsula, for example, reed canary grass is invading stream corridors, where it grows so profusely that it chokes streams, blocking flows and eliminating salmon habitats.

Unchecked, invasives can do serious damage to local environments, fish and wildlife populations, economies, and community well-being. Landowners can be on the frontline in fighting invasives by taking a few simple actions. The most important is to **get familiar with the appearance of invasive plants** of greatest concern, some of which are shown in the table on the next page. To stop invasives, it's critical to eliminate infestations when they're small and before they spread. Eliminating an invasive is **much** easier when it's established only a few, small infestations; landowners can really help to keep an eye out for new infestations in an area. Once an invasive is as widespread as, say, dandelions, it's probably never going to be eliminated from an ecosystem. Below, we

provide photos of some invasives of most concern on the peninsula so that you can start learning to recognize them. If you see a manageable number of these plants growing somewhere, carefully pick and bag them BEFORE they go to seed (getting as much of their roots as possible); such "weed pulls" can make a huge difference in an invasive's rate of spread. Other simple but effective things that landowners can do include:

- Clean borrowed, used, or rented equipment **before** it's brought onsite, for example, by pressure washing at a car wash.
- Be vigilant when obtaining soil and gravel, and look for weed-free sources; be observant of the material once it's offloaded and in place so that you can pick and destroy any invasives that appear.
- Learn the proper way to handle particular invasive species so that you'll know how to pick and dispose of them in ways that won't spread them. (Sometimes mowing can be the wrong thing to do!)
- If collecting vegetative mats for replanting (see Soil bioengineering), be sure to collect only from sites that are free of invasive species.
- Do not seed an area with seeds of invasive species or with seed mixes that may contain invasives. Tell nursery or greenhouse staff that you want to be sure that seed mixes contain no invasives.

For larger infestations, landowners will probably need to work with organizations like those listed above. Homer Soil and Water is a good place to start if you want more information (http://www.homerswcd.org/ or or 907-235-8177), and you may be eligible for cost sharing if you're trying to eliminate a significant infestation on your property.

Some invasive species of particular concern in Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds

Invasive plant common name, scientific name, and link to AKEPIC species bio, which includes information about method of spread and recommendations for controlling infestations	Photo, from AKEPIC species bio http://aknhp.uaa.alaska.edu/botany/akepic
Bird vetch *Vicia cracca* http://aknhp.uaa.alaska.edu/services/AKNHP.cfc?method=downloadDocumentByUsdaCode&documentType=species_bio&usdaCode=VICRC	
Canada thistle *Cirsium arvense* http://aknhp.uaa.alaska.edu/services/AKNHP.cfc?method=downloadDocumentByUsdaCode&documentType=species_bio&usdaCode=CIAR4	

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Orange hawkweed *Hieracium aurantiacum* http://aknhp.uaa.alaska.edu/services/AKNHP.cfc?method=downloadDocumentByUsdaCode&documentType=species_bio&usdaCode=HIAU	
Reed canarygrass *Phalaris arundinacea* http://aknhp.uaa.alaska.edu/services/AKNHP.cfc?method=downloadDocumentByUsdaCode&documentType=species_bio&usdaCode=PHAR3	
White sweet clover (*Melilotus alba*) http://aknhp.uaa.alaska.edu/services/AKNHP.cfc?method=downloadDocumentByUsdaCode&documentType=species_bio&usdaCode=MEAL12	

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Invertebrates

Invertebrates are animals that lack a backbone. Invertebrates account for more than 97% of all species alive today. They include animal groups such as worms, insects, bugs (hemipterans), spiders, and many other lesser-known groups of animals (http://animals.about.com/od/i/g/invertebrate.htm). Invertebrates represent an important source of food for juvenile salmon, as well as for other kinds of fish and wildlife.

Kachemak Bay Research Reserve (KBRR)

(http://www.adfg.alaska.gov/index.cfm?adfg=kbrr.home)
In 1999, Kachemak Bay was designated as part of the National Estuarine Research Reserve system. The Kachemak Bay National Estuarine Research Reserve is part of the National Estuarine Research Reserve (NERR) System, a network of 27 estuaries representing different biogeographic regions of the United States that are protected for long-term research, water-quality monitoring, education, and coastal stewardship. An estuary is a partially enclosed body of water where freshwater from the land mixes with the ocean's saltwater. The Kachemak Bay NERR, more commonly known as the Kachemak Bay Research Reserve (KBRR), is the only research reserve in Alaska.

KBRR's mission is to enhance understanding and appreciation of the Kachemak Bay estuary and adjacent waters to ensure that these ecosystems remain healthy and productive. KBRR is non-regulatory and focuses on environmental research and education. At KBRR, researchers, educators and support staff work to develop a better understanding of ecological processes in the Gulf of Alaska, with emphasis on Lower Cook Inlet and Kachemak Bay.

KBRR is managed by the Alaska Department of Fish and Game in partnership with the National Oceanic and Atmospheric Administration (NOAA)—and the greater Kachemak Bay community.

Kachemak Heritage Land Trust (KHLT)

(www.kachemaklandtrust.org)
Kachemak Heritage Land Trust (KHLT) is a non-profit organization established in 1989 to preserve, for public benefit, land with significant natural, recreational, or cultural values by working with willing landowners on Alaska's Kenai Peninsula… Kachemak Heritage Land Trust was established as Alaska's first land trust. Since its inception, KHLT has helped to preserve forest, wetlands and riverfront, recreational areas, historic and cultural sites, and urban natural areas on the Kenai Peninsula through donations of land and conservation easements. KHLT is primarily supported by individuals, foundations, corporations, and businesses who believe that the protection of natural land is vital if we are to retain the quality of life and economic base that make the Kenai Peninsula so attractive for residents and visitors.

To date, Kachemak Heritage Land Trust has helped preserve nearly 3,000 acres on the Kenai Peninsula through acquisition of land and conservation easements. Properties protected to date are in three general regions, one of which is the Anchor River and Stariski Creek area. Properties protected by KHLT in those watersheds are identified at: http://www.kachemaklandtrust.org/pages/Anchor-River-Stariski-Creek.php.

Kachemak Heritage Land Trust also works in partnership with other organizations to protect additional acres of important conservation lands for public benefit. One of these areas is approximately 57 acres at the mouth of the Anchor River, purchased by The Nature Conservancy with funds from the US Fish & Wildlife Service, the Exxon Valdez Oil Spill Trustee Council, and Ducks Unlimited, along with substantial private donations obtained by Kachemak Heritage Land Trust.

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Kenai Area Plan

(see also Oil and gas)

In 2001, the Alaska Department of Natural Resources published the Kenai Area Plan (KAP). The KAP identifies key uses for state-owned lands in the Kenai Peninsula Borough. Each parcel of state-owned land was given an identifying number, and then appropriate uses were designated for each numbered parcel. The plan can be downloaded in its entirety or chapter-by-chapter at http://dnr.alaska.gov/mlw/planning/areaplans/kenai/index.htm.

Deep Creek, Ninilchik River, Stariski Creek, and Anchor River watersheds are covered in Region 7, which is divided into three subregions: 7A, 7B, and 7C. Maps for these three subregions are included below, along with the land use designations for each numbered parcel on each map. The legend for these maps is shown to the right.

Looking at the maps, you'll notice that there's a lot of state-owned land in your watershed (as well as Native-owned land in 7A and 7B). What happens on state-owned lands—and how it happens—will be critical to local salmon populations. The state has recognized this and designated many of its parcels for uses compatible with protecting the quality of salmon habitats. But oil and gas leases can occur on any state-owned lands, irrespective of other designated uses. You may not be able to read the numbers of the state-owned parcels on the maps included here, so for each map, we also give you the link to its original pdf at the state's KAP website. You can enlarge pdfs at that website to get much better resolution than provided here.

The table below shows the land uses (and their codes) that the state considered in developing the Kenai Area Plan. The codes are used in tables showing which land uses were assigned to specific parcels. For many parcels, more than one land use was designated. Definitions of each land use can be found in Chapter 3 of the area plan (pages 3-4 to 3-8), see http://dnr.alaska.gov/mlw/planning/areaplans/kenai/pdfs/chap_3_intro.pdf.

Land use	Code	Land use	Code	Land use	Code
Agriculture	ag	Heritage	hr	Resource management – high value	rh
Coal	co	Materials	ma	Settlement	se
Forestry	fo	Public facilities - retain	pr	Shoreline use	sh
Grazing	gr	Public facilities - transfer	pt	Transportation	tr
General use	gu	Public recreation and tourism- dispersed use	rd	Water resources and use	wa
Habitat	ha	Public recreation and tourism – public use site	rp	Waterfront development	wd
Harvest	hv				

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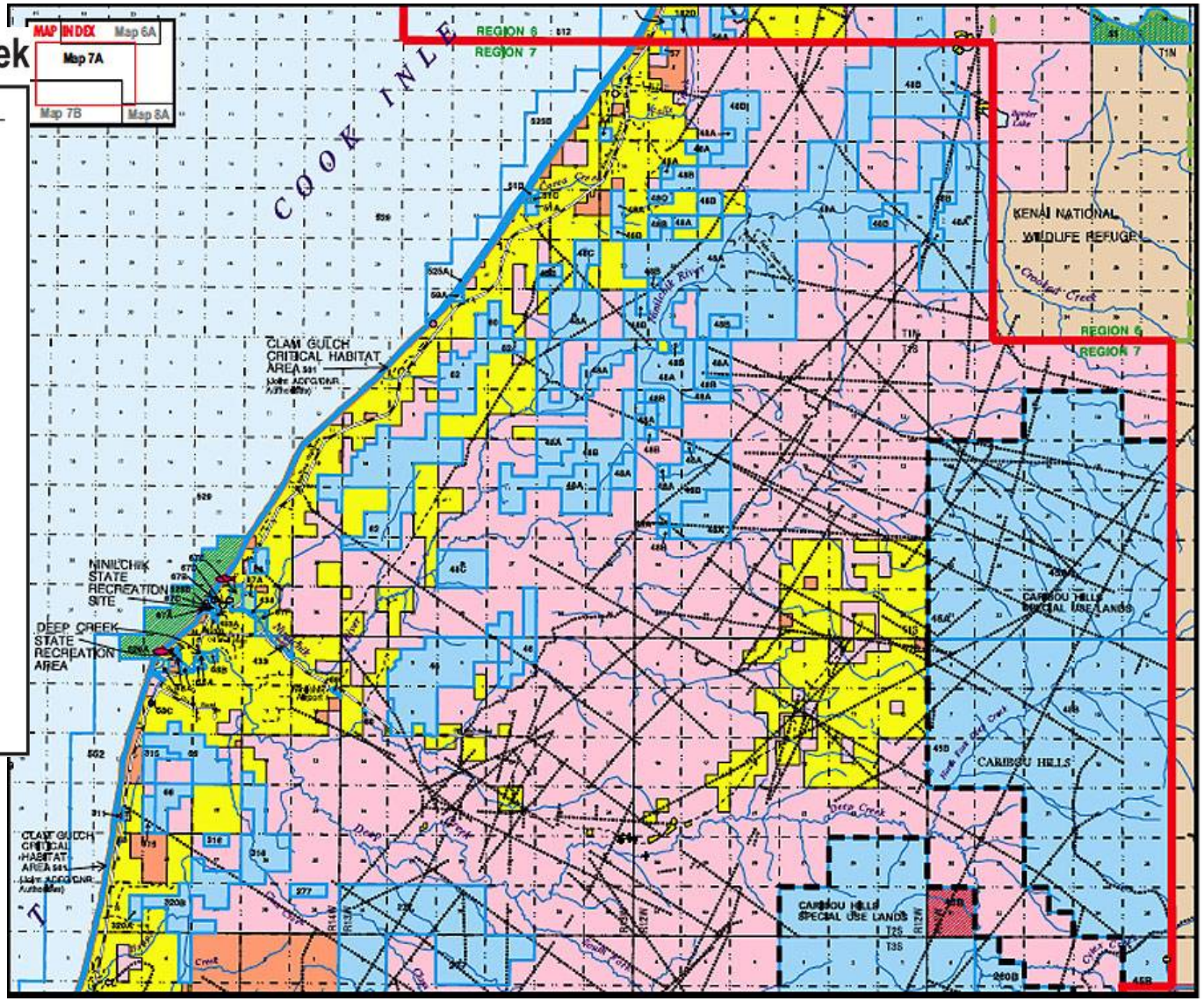
The map on this page covers Region 7A, which includes Ninilchik River and part of Deep Creek and Stariski Creek watersheds. The table below shows the land use designations for each of the numbered parcels of state-owned land on this map. To see the original pdf of this map, which has much better resolution, go to: http://dnr.alaska.gov/mlw/planning/areaplans/kenai/pdfs/7a.pdf.

Map 7A - Deep Creek

Unit	Designation		Unit	Designation		
45A	rd		68B	ha	rd	
45B	ha	rd	68C	ma	tr	
46	gu		69	pr		
48A	fo	ha	182C	se		
48B	gu		182D	gu		
48C	gu		260B	rd		
51A	se		277	fo	ha	
51B	se		311	ma		
51C	rd		315	rh		
54	gu		316	fo	ha	
55	ha	rd	320A	se		
56A	gu		320B	gu		
57	gu		434	ha	hv	rd
59A	se		435	ha	rd	
60	rh		453A	pr		
62	rh		453B	ma		
64	gu		512	gu		
66	gu		525A	rd		
67A	rp		525B	gu		
67B	ha	rd	526A	rp		
67C	pr		526B	wd		
67D	ha	hv	529	gu		
67E	ha	hv	552	ha	hv	rd
67F	ha	hv	601	ha	hv	rd
68A	rd					



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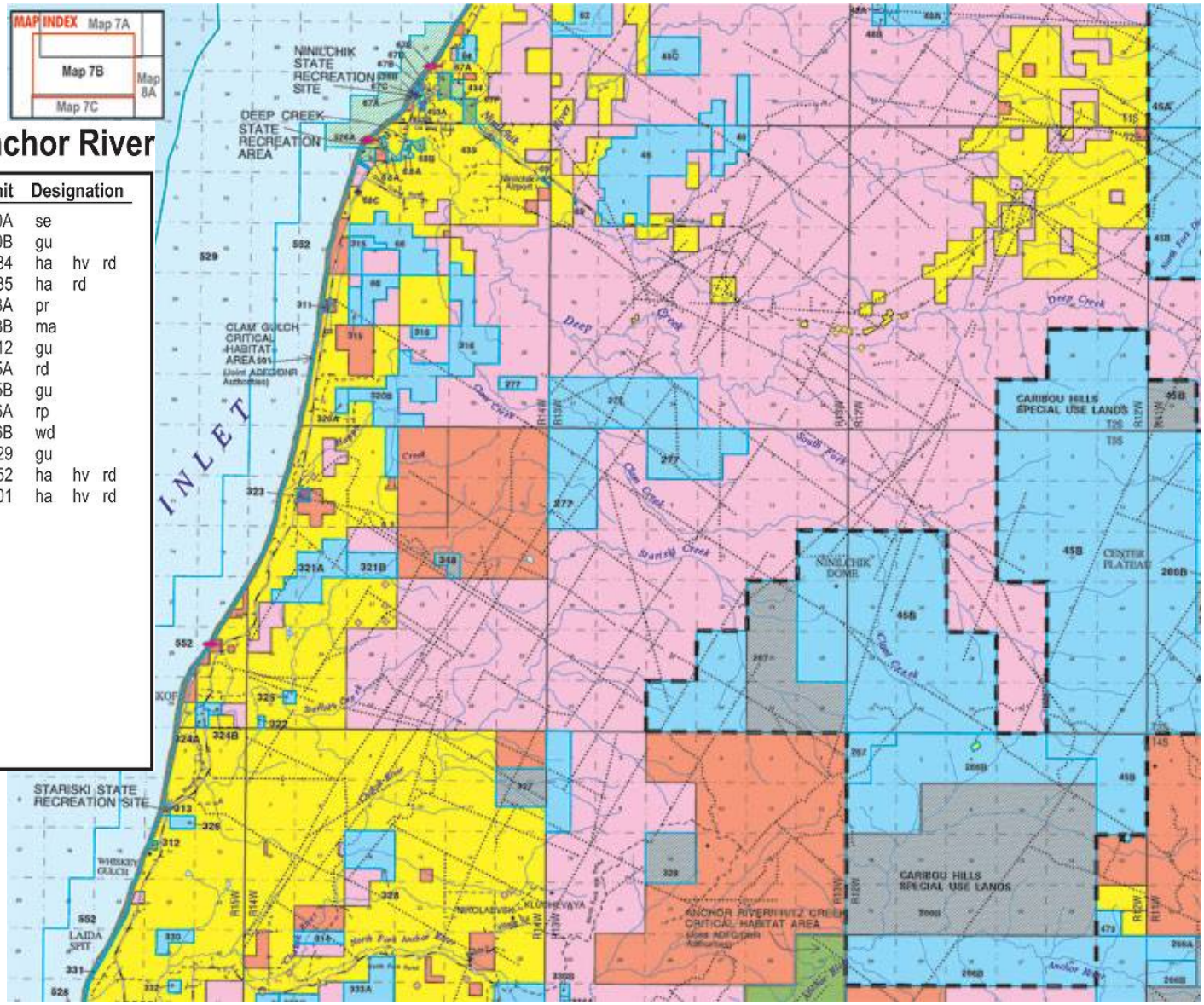
The map on this page covers Region 7B, which includes Stariski Creek and part of Deep Creek watersheds. The table below shows the land use designations for each of the numbered parcels of state-owned land on this map. To see the original pdf of this map, which has much better resolution, go to: http://dnr.alaska.gov/mlw/planning/areaplans/kenai/pdfs/7b.pdf.



Map 7B - Anchor River

Unit	Designation		Unit	Designation		Unit	Designation		
45A	rd		314	gu		320A	se		
45B	ha	rd	315	rh		320B	gu		
46	gu		316	fo	ha	434	ha	hv	rd
48A	fo	ha	320A	se		435	ha	rd	
48B	gu		320B	gu		453A	pr		
62	rh		321A	gu		453B	ma		
64	gu		321B	ha		512	gu		
66	gu		322	rh		525A	rd		
67A	rp		323	ma		525B	gu		
67B	ha	rd	324A	se		526A	rp		
67C	pr		324B	ha	rd	526B	wd		
67D	ha	hv	325	rh		529	gu		
67E	ha	hv	326	gu		552	ha	hv	rd
67F	ha	hv	327	gu		601	ha	hv	rd
68A	rd		328	gu					
68B	ha	rd	329	rh					
68C	ma	tr	68B	ha	rd				
69	pr		68C	ma	tr				
260B	rd		69	pr					
266A	rd		182C	se					
266B	ha	rd	182D	gu					
267	ha	rd	260B	rd					
277	fo	ha	277	fo	ha				
311	ma		311	ma					
312	rp		315	rh					
313	rp		316	fo	ha				

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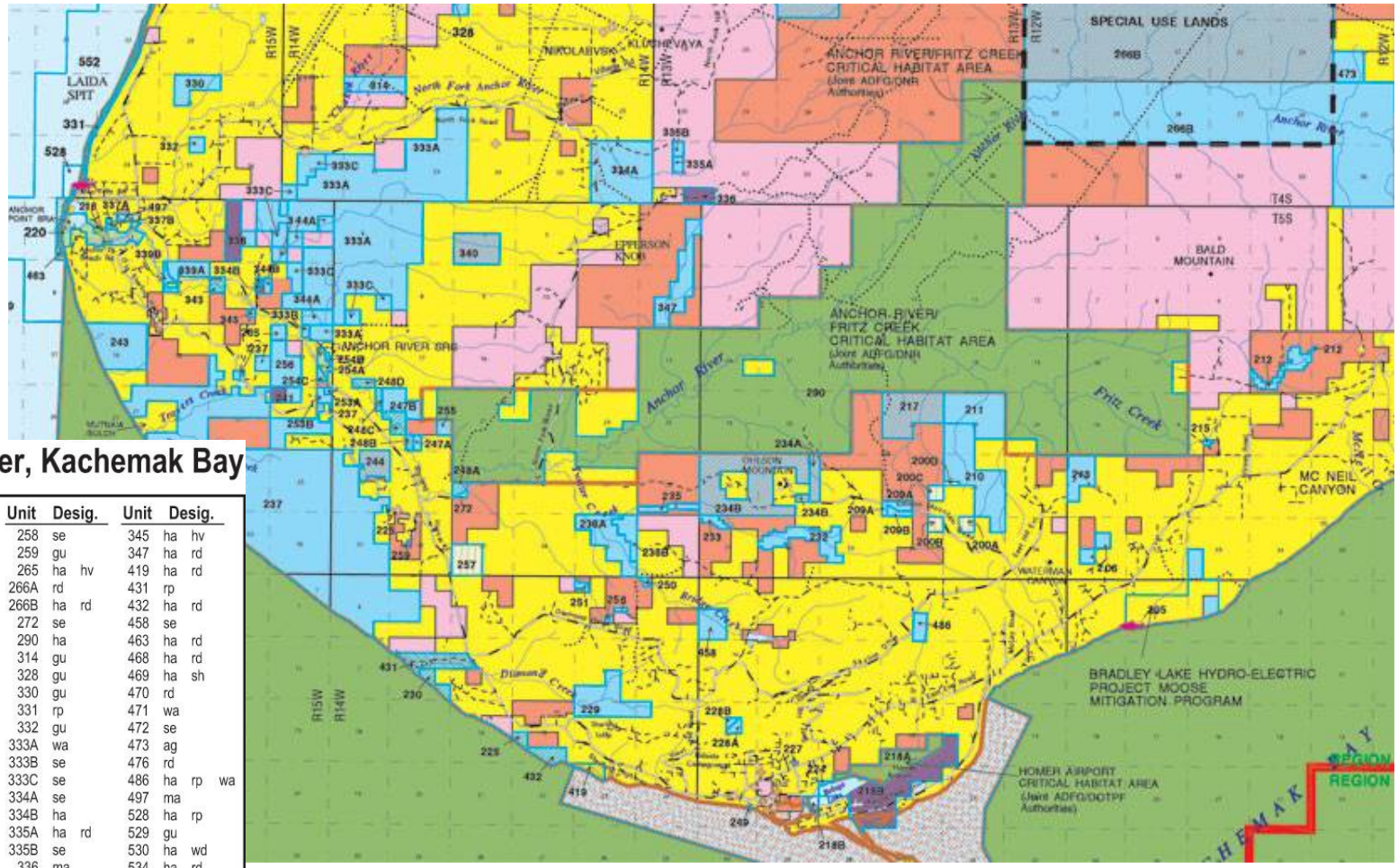
The map on this page covers Region 7C, which includes Anchor River and surrounding watersheds. The table below shows the land use designations for each of the numbered parcels of state-owned land. To see the original pdf of this map, which has much better resolution, go to: http://dnr.alaska.gov/mlw/planning/areaplans/kenai/pdfs/7c.pdf.



Map 7C - Homer, Kachemak Bay

Unit	Desig.				Unit	Desig.				Unit	Desig.				Unit	Desig.			
190	rp				230	rd				258	se				345	ha	hv		
200A	rd				232	ha				259	gu				347	ha	rd		
200B	se				233	ha				265	ha	hv			419	ha	rd		
200C	se				234A	ma				266A	rd				431	rp			
200D	rd				234B	rd				266B	ha	rd			432	ha	rd		
205	ha				235	ha				272	se				458	se			
206	rd				236A	ha	rd	wa		290	ha				463	ha	rd		
209A	se				236B	se				314	gu				468	ha	rd		
209B	rp				237	rh				328	gu				469	ha	sh		
210	rd				241	se				330	gu				470	rd			
211	rd				243	se				331	rp				471	wa			
212	ha				244	gu				332	gu				472	se			
213	se				247A	rd				333A	wa				473	ag			
214A	se				247B	rh				333B	se				476	rd			
214B	rd				248A	ha	hv	rd		333C	se				486	ha	rp	wa	
215	se				248B	ha	hv			334A	se				497	ma			
216	hv	rp			248C	ha	hv			334B	ha				528	ha	rp		
217	rd				248D	ha	hv			335A	ha	rd			529	gu			
218A	ha	pr			249	rp				335B	se				530	ha	wd		
218B	pr				250	ha	wa			336	ma				534	ha	rd		
220	rp				251	ha				337A	rd				535	ha	rd		
221	rd				253A	ma				337B	ha	rd			536	ha			
224	ha				253B	gu				338	rh				537	ha	rd		
225	rd				254A	ha	rp			339A	gu				552	ha	hv	rd	
226	se				254B	ha	hv			339B	ha	hv			562A	ha	hv		
227	pr				254C	rh				340	gu				601	ha	hv	rd	
228A	rd	ha	wa		255	se				343	ha	hv							
228B	se				256	gu				344A	ha	hv							
229	fo	ha	rp		257	gu				344B	ma								

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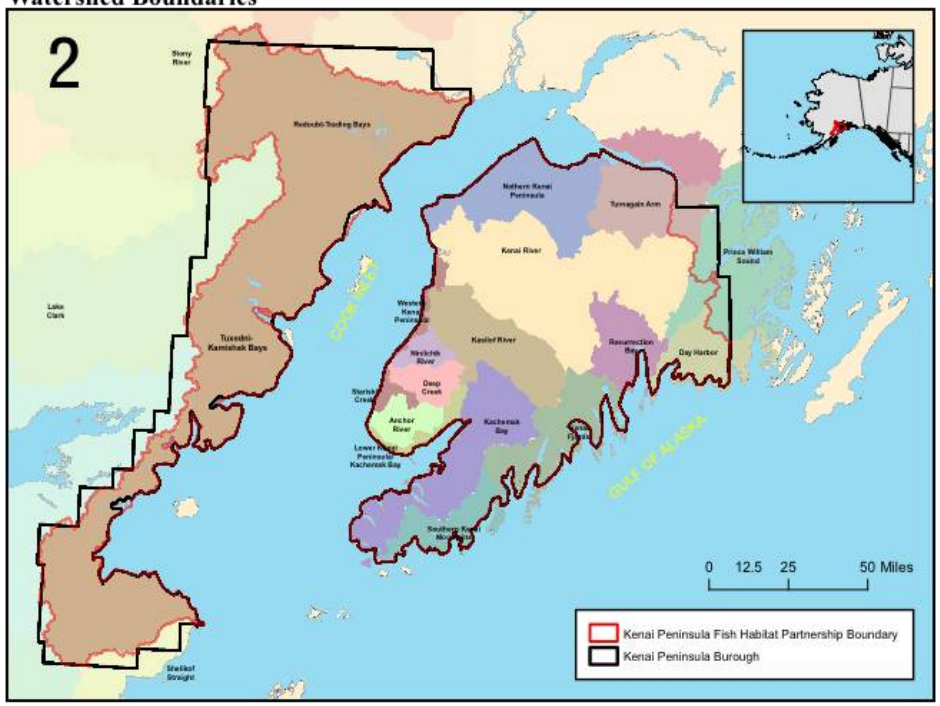
Kenai Peninsula Fish Habitat Partnership (KPFHP)

This partnership of agencies, local governments, non-profits, businesses, and other organizations on the Kenai Peninsula is working with the National Fish Habitat Action Plan to protect, restore, and enhance fish and aquatic communities on the peninsula. Such Fish Habitat Partnerships (FHPs) are developed concurrently with the National Fish Habitat Plan and are designed to help raise awareness of fish initiatives, assign priorities, and generate congressional support to protect and improve aquatic habitat. KPFHP was recognized as an approved Fish Habitat Partnership on January 15, 2010. KPFHP becomes the 15th regional fish habitat partnership in the U. S. and the third in Alaska. To find out more, go to: http://office.kenaiwatershed.org/KPFHP/about.

Kenai Peninsula Fish Habitat Partnership Watershed Boundaries



The following overview of KPFHP mission, approaches, and activities is from: http://office.kenaiwatershed.org/KPFHP/KPFHP_Plan_2011.doc. The Kenai Peninsula Fish Habitat Partnership formed to foster and create effective collaborations to maintain healthy fish, healthy people, healthy habitat, and healthy economies within the Kenai Peninsula Borough. The geographic area covered by the Partnership is approximately 25,000 square miles, encompasses 14 major watersheds, and contains over 20,000 miles of stream habitat, as well as more than 350,000 acres of wetland habitat... The peninsula's salmon stocks and resident fish species, like rainbow trout, Arctic grayling, and lake trout, support vital commercial, sport, and subsistence fisheries, are important sources of food for brown and black bears, bald eagles, marine mammals and a variety of other animals, and are a key source of nutrients for both terrestrial and aquatic environments. The national importance of these resources is particularly evident when compared to habitats and fish populations elsewhere in the nation, where many resources have been severely impacted by human expansion and development.

Increased population growth, unregulated development, habitat fragmentation, degraded water quality, loss of water quantity, and climate change are all threats faced by fish habitat in the Kenai Peninsula. Partnership members and other stakeholders are challenged by these threats as they work towards maintaining healthy fish habitat that supports self-sustaining fish populations. The Kenai Peninsula Fish Habitat Partnership will address habitat needs of freshwater and marine fish species that reside in the waters of the Kenai Peninsula Borough at some point in their life cycle. The Partnership is taking a strategic approach to protecting healthy aquatic systems while working to restore degraded systems in support of the National Fish Habitat Action Plan by drafting a strategic action plan that identifies the partnership, biological complexity, water quality and quantity, science and technology, education, and policy as the highest priority areas to focus its efforts.

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Kenai Peninsula Wetland Who's Who

T*he Kenai Peninsula Wetland Who's Who* is an annotated directory of all entities (state and federal agencies, nonprofits, local governments, Native organizations, etc.) that have anything to do with wetlands on the Kenai Peninsula (see http://www.homerswcd.org/user-files/Wetland%20Whos%20Who%20July%202011.pdf). The directory is in PDF format and has hot links to all of the listed entities and many of their most useful products. For example, under the listing for the US Army Corps of Engineers, you can jump to "Getting Corps permits." Or from the Alaska Department of Natural Resources listing, you can jump to the *Kenai Area Plan*, which is the state's plan for all state-owned lands on the peninsula.

Entities are listed alphabetically in logical categories (like state agencies, federal agencies, local nonprofits, etc.) and are easy to find using the Table of Contents. All contact information for each entity is listed, including physical address, phone number, and website.

Kenai Watershed Forum (KWF) and atlas

(see introductory article 3: Exploring your watershed with online tools, also Anchor River Restoration Project)

Kettle wetland ecosystems

(see also Glacial history of the western Kenai Peninsula, Landforms)

Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands. Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia entry wetland functions and values.

(Slightly modified from http://www.kenaiwetlands.net/ EcosystemDescriptions/Kettle.htm.) Kettle wetland ecosystems are typically present on a kettle and kame landscape. Landscapes with kettle and kame topography are created at the margins of retreating glaciers under zones of stagnant melting ice. Supra-glacial streams transport material, which is deposited in ice surface depressions. When the ice melts, the stream-deposited material is left behind as a hill of moderately stratified sands and gravels, forming an upland kame. Kames are deposited on a flat (wetland) surface of fine materials, leaving a distinctive reticulate pattern on the landscape. The fine materials are predominantly silts, which were formerly trapped in the glacial ice, but now are left behind, perching a water table. Kettles are peatlands that form on the flat silts, which perch a water table. The perched water table combined with local climate creates conditions conducive to peat formation.

On the Kenai Lowlands, there are at least five distinct kettle-and-kame landscapes. One is located between Homer and Anchor Point along the Old Sterling Highway. The largest covers the extensive series of moraines north of Soldotna, re-worked by glaciers from the Tordrillo Mountains during the late-Wisconsin maximum (Moosehorn glacial advance, discussed in Glacial history of the western Kenai Peninsula). A third lies in a band at about 350 meters elevation along the north shore of Kachemak Bay, between Caribou Lake and McNeil Canyon, behind the Moosehorn maximum of glaciers from across Kachemak Bay. While the previous three kettle-and-kame landscapes all occupy a position behind Moosehorn moraines, the fourth area of kettles and kame-like features lies in front of the Moosehorn maximum of the Tustumena Glacier, in a heterogeneous band from Clam Gulch to Soldotna. This area was probably created by Tustumena Glacier ice meeting ice originating in the Aleutian Range, across Cook Inlet. The final, and smallest, kettle-and-kame

landscape wraps around the west end of diamond Ridge, above the Old Sterling Highway Kettles, including the hills and peatlands near the Homer Landfill and Homer Demonstration Forest. This fifth area probably lies behind the early Wisconsin maximum (Knik) of the same glacier that created the Old Sterling Highway kettle-and-kame country.

Not all Kettle wetlands occur on a kettle-and-kame landscape. Many small Kettles lie on the upper terrace tread of the west slope of the Caribou Hills (see Caribou Hills geology), especially on the northwest slope of Ptarmigan Head. These Kettle wetlands are often adjacent to Riparian, Discharge Slope, or Relict Glacial Drainageway wetland ecosystems that connect to streams. Kettle wetlands are connected to each other by streams, adjacent kettles, or by peatlands, which have formed in the Relict Glacial Drainageway wetlands that sometimes occur between larger kettles.

A K13 wetland near the Boxcar Hills, 20 miles northeast of Homer (wetland polygon 30730)

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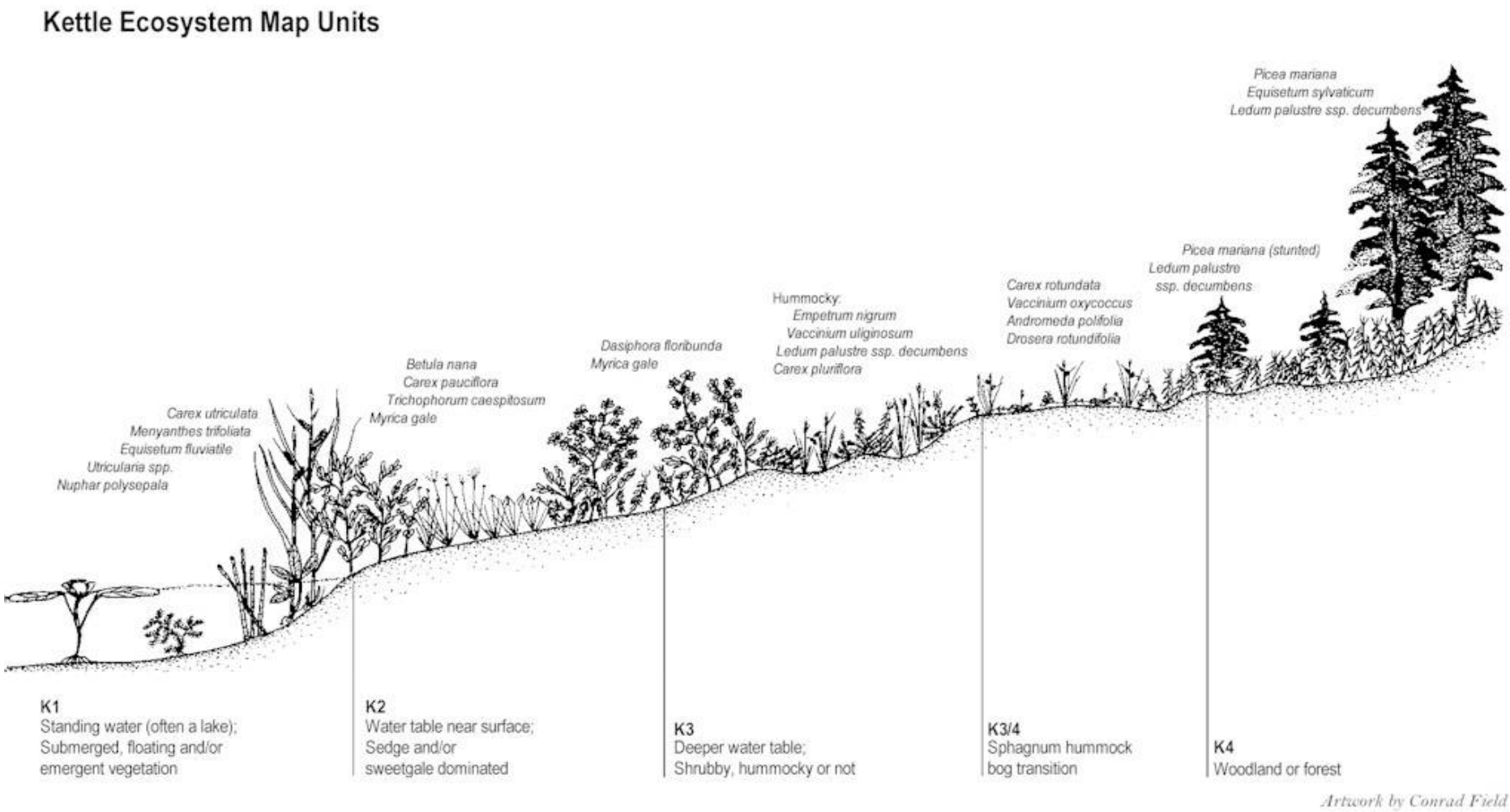
Idealized plant relationships along the gradient from kettle pool to forested margin.



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KHLT
(see Kachemak Heritage Land Trust)

King (chinook) salmon
(see introductory article1: Salmon species and life cycle)

KWF
(see Kenai Watershed Forum)

Lakebed wetland ecosystem
(See Relict glacial lakebed wetland ecosystem)

Landforms
(see also Caribou Hills geology, Glacial history of the western Kenai Peninsula)

The landforms in peninsula watersheds have been shaped by many geological forces and processes. (The study of landforms and how they are created is called *geomorphology*.) In most cases, glaciation is the dominant force that has created local landforms, but other land-shaping processes have acted on these glacial landscapes (and our glacial landscapes reflect earlier geological processes). Non-glacial processes include those associated with streams and rivers (fluvial processes)—like those that shape stream channels (see Stream channel processes); processes caused primarily by gravity (*colluvial* processes)—like landslides, bluff erosion, and mass wasting; earthquake processes (particularly shaking, faulting, subsidence, and uplift); and volcanic processes—particularly repeated deposition of layers of volcanic ash across Kenai Peninsula landscapes. Because of the significance of glacial processes in shaping peninsula landforms, however, they are the focus here.

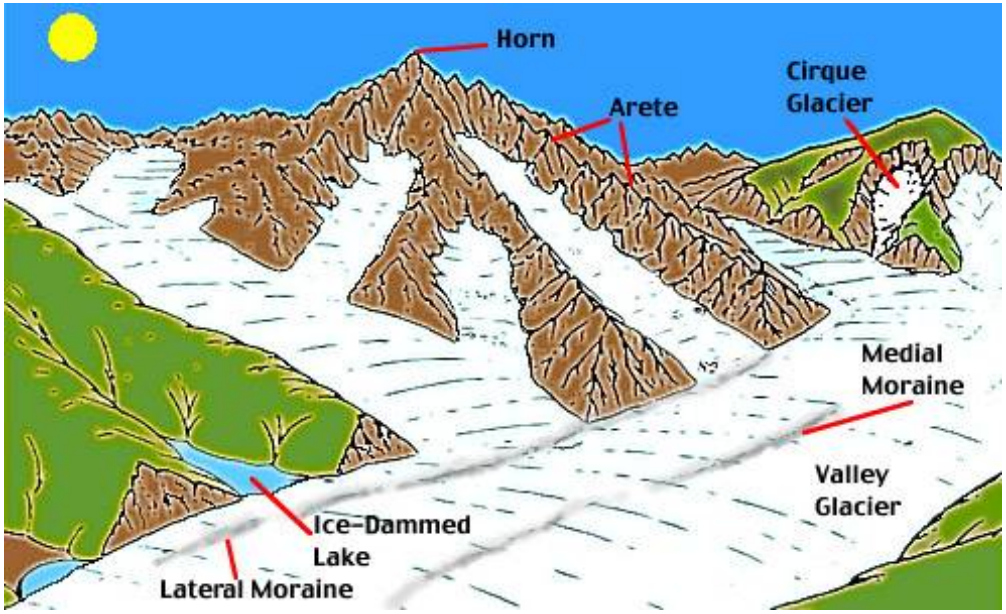
Glacial landforms

(Modified from http://en.wikipedia.org/wiki/Glacial_landforms and http://www.physicalgeography.net/fundamentals/10af.html, the latter link goes to some excellent photographs of glacial landforms, including moraines, kames, drumlins, and eskers. The **drawing on the next page** is from this source.) Glacial landforms are landforms created by the action of glaciers. Most of today's glacial landforms were created by the movement of large ice sheets during the Quaternary glaciations (see Glacial history of the western Kenai Peninsula). **Glaciers** generally flow over the land surface along a path of least resistance. The flow of an **alpine glacier** into a valley causes the glacier to rapidly advance producing a swollen tongue of ice at the glacier's **snout**, known as a **lobe**. As the lobe moves down the valley it often encounters the lobes of other glaciers from connecting valleys. The glacier grows in size with addition of the flow of connected sub-valleys. The following **image** illustrates one of these networks of connected alpine glaciers

There are a variety of glacial landforms:

Erosional glacial landforms: Glaciers erode the bottoms and sides of the valleys down which they flow through processes called abrasion and plucking. This erosion causes the bottoms and sides of glaciated valleys to become wider and deeper over time. Glacial erosion also results in a change in the valley's cross-sectional shape. Glacial valleys tend to have a pronounced U-shape that contrasts sharply with the V-shaped valleys created by stream erosion. Small adjoining feeder valleys entering a large valley in a glaciated mountainous region tend to have their floors elevated some distance above the level of the main valley's floor. Geomorphologist call this landform a **hanging valley**. Hanging valleys develop for two reasons: 1) larger, more massive glaciers create greater

erosion and subsequently a deeper valley, and 2) some valleys have seen more glaciers pass through them, which results in more erosion and a deeper valley.



In addition to being picked up by the grinding action of moving ice against land, sediments are also added to the surface of glaciers from the valley walls through various types of **mass movement,** such as landslides. Regardless of how material gets added to and moved by glaciers, much of this debris is eventually delivered to the glacier's "snout" because of the continual forward flow of ice.

Depositional glacial landforms (created where glaciers drop and deposit the material they've been carrying): Every time Kenai Peninsula and Cook Inlet glaciers retreated, they left behind their freight of crushed rock and sand (called glacial drift), and in the process created a variety of depositional landforms. Examples include moraines, eskers, kames, drumlins and outwash fans. (See http://www.physicalgeography.net/fundamentals/10af.html for good color photos showing Canadian examples of each.) In many cases, these glacial landforms give rise to wetland ecosystems—which are described throughout this watershedipedia.

- Eskers: These are built-up beds of sub-glacial streams. These hidden streams of meltwater travel through often sinuous tunnels they carve in the ice. The beds of these streams are composed of layers of sand, gravel, and other sediments carried by the meltwater. When the ice melts from around these meltwater tunnels, the streambed materials are deposited on the land surface as long twisting ridges that mark where the sub-glacial streams once flowed.
- Kames: Irregularly shaped mounds created where sediment-rich glacial meltwater once flowed into a crevasse or depression in the ice, leaving behind a somewhat conical- or linear-shaped pile of sand and gravel after the glacier melts (think of how an hourglass creates a mound of sand).
- Moraine: These can be terminal (at the end of a glacier), lateral (along the sides of a glacier), or medial (where two lateral moraines from two adjoining glaciers meet, creating a moraine down the middle of the larger glacier created by the merging of the two glaciers).
- Drumlin: These are hill shaped deposits of till. The streamline shape of these glacial features resembles an extended teaspoon laying bowl down. The gently sloping tapered end of the drumlin points in the general direction the glacier traveled. A couple theories exist to explain their formation. The most accepted suggests that they formed when saturated ground sediments oozed up into hollows at the base of an advancing glacier. These sediments were then stretched out and molded into a streamlined form as ice moved forward.
- Outwash fans: Not unlike river deltas or alluvial fans, outwash fans are deposited by braided streams flowing from the front of a glacier. Sediments being deposited in front of Exit Glacier near Seward provide an example of this process in action.

Glacial lakes and ponds: Lakes may be created by glaciers. A lake between the front of a glacier and its terminal moraine is called a glacial lake. (Grewingk Lake is an existing example.) Kettle lakes form when a retreating glacier leaves behind an underground or surface chunk of ice that later melts. If glacial drift is deposited around the melting chunk, a depression on the surface, called a kettle hole, may be created, and if this hole remains filled with water, it creates a kettle lake. Kettle holes and lakes are common on moraine and outwash plain deposits.

Many Kenai Peninsula wetlands occur on relict glacial lakebed deposits and former kettle lakes, the former are called Relict Glacial Lakebed wetland ecosystems, the latter are Kettle wetland ecosystems. Large kettle ponds that intersect the water table may remain as permanent lakes.

Large woody debris (LWD)

(Modified from http://www.spawnusa.org/pages/page-136.) Many of us have been conditioned to think of fallen trees as unsightly or even possible barriers to fish migration. In fact, fish need woody debris to survive and thrive. Woody debris is extremely important salmon habitat, as it can provide cover for juvenile salmon (see Fry and Fingerling), as well as attract and support invertebrates that are important food sources for growing fish. In addition, fallen trees create both habitat diversity and complexity, shade the stream (reducing Stream temperatures), and divert water to form pools, riffles and runs, potentially improving both spawning habitat for adult salmon and rearing habitat for juveniles. Woody debris can also slow water velocity, thus limiting excessive streambed scour and bank erosion. The **photo upper right** is of large woody debris in and along Ninilchik River (source: Cook Inletkeeper, LWPWHP).

(From http://www.briangrass.com/Portfolio/SalmonFire/index.htm.) Large woody debris also supports food webs in streams and rivers and controls the rate of particulate matter transport—which in turn influences patterns of nutrient cycling and sediment deposition. Finally, woody debris can accumulate to form highly productive flats, which trap organic matter and augment the digestive function of stream systems. These debris accumulations provide food and habitat for aquatic invertebrates, which in turn are important food sources for salmon in their freshwater habitats.

For Best Management Practices for woody debris, go to http://www.spawnusa.org/ cgi-files/0/pdfs/1165872032_BMPS_for_Woody_Debris.pdf.

Logging

(see Forests and spruce bark beetle)

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Low Impact Development (LID)
(*see also Best Management Practices, Raingardens, Stormwater runoff*)

Low Impact Development is a term used to describe strategies for reducing the negative impacts of stormwater and meltwater runoff and related pollution by managing runoff in a dispersed, onsite fashion instead of with expensive collection, detention, and treatment facilities. With respect to runoff, LID approaches can be thought of as designed to "slow it, spread it, sink it" (see below).

By implementing LID principles and practices, water can be managed in ways that reduces the impacts of built areas on stream channel processes and aquatic habitats (including salmon habitats), while also promoting the natural movement of water within an ecosystem or watershed (see Water cycle). Applied on a broad scale, LID strategies can maintain or restore a watershed's hydrologic and ecological functions. Incorporating LIDs increases the sustainability of land uses and developments.

(Slightly modified from http://www.epa.gov/owow/NPS/lid/costs07/factsheet.html.) LID encompasses *site design* approaches and *small-scale* stormwater management practices that promote using natural systems to maximize infiltration, interception, evapotranspiration, and reuse of rainwater. These practices can effectively remove nutrients, pathogens, and metals from stormwater, and they reduce the volume and intensity of stormwater flows and related flooding.

Traditional approaches to stormwater management typically involve hard infrastructure, such as curbs, gutters, and piping. LID-based designs, in contrast, use natural drainage features or engineered swales and vegetated contours to convey and treat runoff. In terms of costs, LID techniques can reduce the amount of material needed for paving roads and driveways and for installing curbs and gutters. Also, by infiltrating or evaporating runoff, LID techniques can reduce the size and cost of flood-control structures. Note that in some circumstances LID techniques might result in higher costs because of more expensive plant material, site preparation, soil amendments, underdrains and connections to municipal stormwater systems, as well as increased project management costs. Other considerations include land required to implement a management practice and differences in maintenance requirements. Finally, in some circumstances LID practices can offset the costs associated with regulatory requirements for stormwater control.

To evaluate differences in cost between LID and traditional approaches to stormwater management, EPA reviewed 17 case studies and reported its findings. (The full report is available for download at www.epa.gov/nps/lid.) In most cases, LID practices were shown to be both fiscally and environmentally beneficial to communities. In general, LID practices reduced project costs and improved environmental performance. Although not all project benefits highlighted in the case studies were monetized, with a few exceptions, LID practices were shown to be both fiscally and environmentally beneficial to communities. In a few case studies, initial project costs were higher than for conventional designs; in most cases, however, significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping. Total capital cost savings ranged

from 15 to 80 percent when LID methods were used, with a few exceptions in which LID project costs were higher than conventional stormwater management costs. Examples of benefits not considered in the study were: improved aesthetics, expanded recreational opportunities, increased property values due to the desirability of the lots and their proximity to open space, increased total number of units developed, increased marketing potential, and faster sales. Examples of environmental benefits found in the study included reduced runoff volumes and pollutant loadings to downstream waters, and reduced incidences of combined sewer overflows.

The EPA is a good place to start if you want to learn more about LIDs: http://www.epa.gov/owow/NPS/lid/. Washington state also provides much useful information on LIDs related to conditions not unlike those found on the Kenai Peninsula: Low Impact Development Technical Manual with design guidance for all the BMPs in the WA State Stormwater Manual; Seattle's Green Stormwater Infrastructure, Natural Drainage Systems, and RainWise website; Rain Garden Handbook for Western Washington. Another useful link is: http://www.soilsforsalmon.org/how.htm.

A series of short publications describing LID practices has been developed by Oregon Sea Grant's watershed education and outreach team. These factsheets lay out guidelines for choosing, building, maintaining and testing a variety of "green" options for handling stormwater runoff from residential, commercial and public property. (For greater detail, see also: **The Oregon Rain Garden Guide**)

- **Rain Gardens.** ORESU-G-11-001. [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11001-LID-rain-gardens.pdf
- **Porous Pavement.** ORESU-G-11-002 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11002-LID-porous-pavement.pdf
- **Vegetated Filter Strips**. ORESU-G-11-003 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11003-LID-vegetated-filter-strips.pdf
- **Drywells**. ORESU-G-11-004 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11004-LID-drywells.pdf
- **Stormwater Planters.** ORESU-G-11-005 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11005-LID-stormwater-planters.pdf
- **Swales**. ORESU-G-11-006 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11006-LID-swales.pdf
- **Green Roofs**. ORESU-G-11-007 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11007-LID-green-roofs.pdf
- **Infiltration Testing.** ORESU-G-11-008 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11008-LID-infiltration-testing.pdf
- **Soakage Trenches.** ORESU-G-11-009 [.pdf][HTML] http://seagrant.oregonstate.edu/sgpubs/onlinepubs/g11009-LID-soakage-trenches.pdf

Macroinvertebrates

(From: www.pnwwaterweb.com/Downloads/Collman-Macroinvertebrates.doc.)
Macroinvertebrates are invertebrates large enough to be seen without a dissecting scope or hand lens (though these tools aid in seeing details used in identification). Mosquitoes are macroinvertebrates, as are dragonflies, earthworms, and beetles. Many kinds of macroinvertebrates are abundant in rivers, streams, and ponds. Macroinvertebrates are a critical food source for growing salmon and other kinds of fish. The "flies" used by fly fishermen mimic common macroinvertebrates.

Mosquito larvae are nutrient-rich snacks for hungry fish and other aquatic wildlife (source: http://www.mosquitobarrier.com/images/larvae.jpg).

Macroinvertebrates are good subjects for study because they are relatively easy to find and sample. In addition, many invertebrates have specific requirements with respect to water temperature, chemistry, velocity, etc., so their presence in a water body can indicate water quality. Aquatic insects and other organisms are bio-indicators of good water quality and can alert us to pollution. As a result, macroinvertebrate sampling is a common method for assessing water quality in streams, rivers, lakes, and estuaries. A good source of information on this topic is: Water Quality Monitoring Using Aquatic Macroinvertebrates - Water Quality; in addition, EPA maintains a website with a wealth of information on invertebrates and their importance in water quality monitoring: http://www.epa.gov/bioindicators/html/invertebrate.html. Both websites have links to other interesting information about macroinvertebrates and their use in water sampling.

Cook Inletkeeper has been sampling macroinvertebrates in Anchor River, Deep Creek, Ninilchik River, and Stariski Creek for a number of years. Macroinvertebrate communities in these streams are dominated by larval insects. As larva, insects live a completely aquatic existence, feeding voraciously on organic matter and other invertebrates (and themselves providing nutritious food for hungry juvenile salmon). Each insect group has specific requirements for food, substrate, temperature, and dissolved oxygen concentrations. The presence (or absence) of particular insects, therefore, indicates certain water quality and habitat conditions. The following comments about Cook Inletkeeper's macroinvertebrate sampling program are slightly modified from http://inletkeeper.org/healthy-habitat/lower-kenai-peninsula/macroinvertebrates.

> In Fall 2002, the lower Kenai Peninsula experienced two, 100-year flood events [see Flooding]. Major habitat alteration reshaped salmon stream channels and riparian habitat, especially in the lower reaches of the Anchor River and Deep Creek. In order to track the biological communities in these streams and to understand flood effects on stream productivity, Inletkeeper expanded its bioassessment program in the summer of 2003 to include sampling on all four salmon streams using University of Alaska Anchorage, Environment and Natural Resources Institute's (ENRI) technical-level methods.
>
> Inletkeeper collects samples in June and August annually to compare with pre-flood samples collected by ENRI in 1997 and 1999. A downward trend in abundance values on the Anchor River and Deep Creek suggests a poor recovery pattern in stream productivity. Kicknets samples are considered semi-quantitative, so the abundance values cannot be expressed as a measure of density. The trend is very consistent in both watersheds, and the degree of change is so great that the pattern is not likely to be a sampling anomaly or a measure of natural variation, especially when different patterns are evident in Ninilchik River and Stariski Creek.

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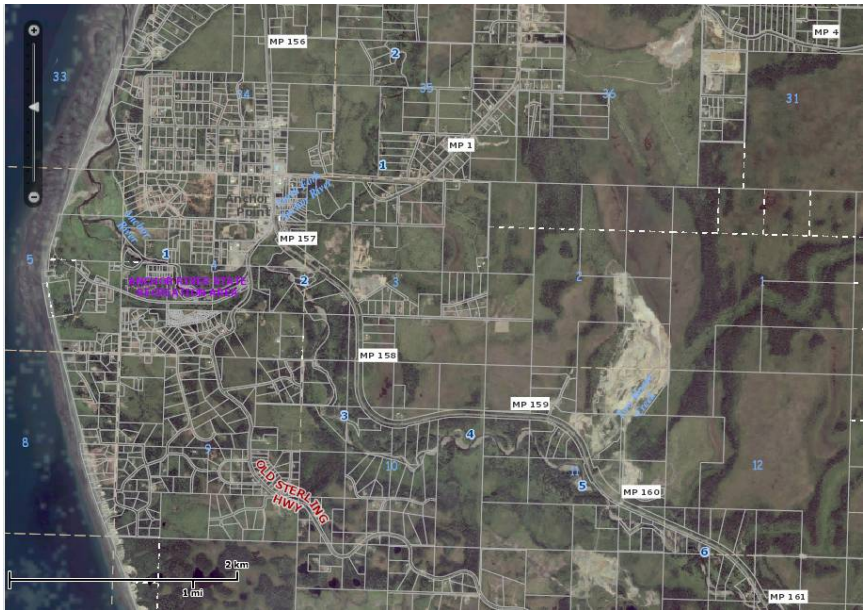
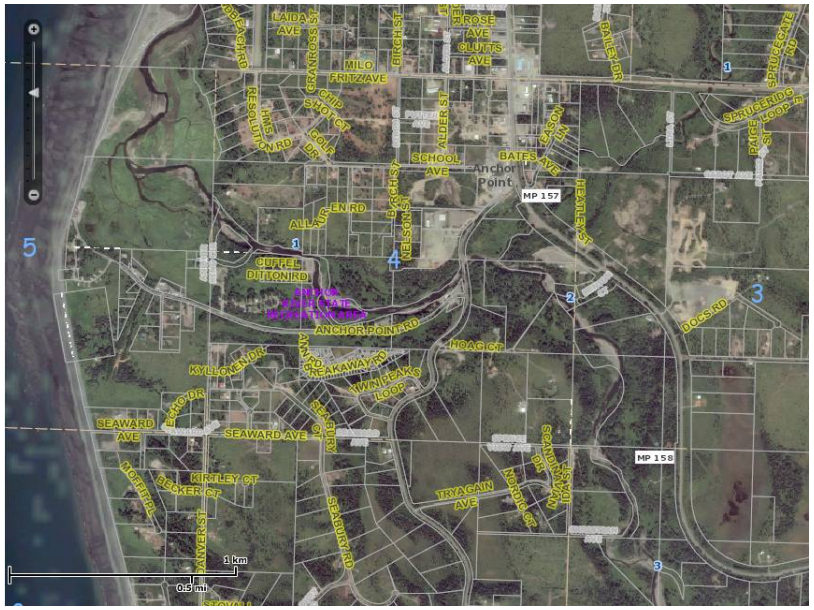
The rate of recovery of macroinvertebrate communities after a flood event may depend on the severity of flooding, availability of refugia, and seasonal timing. The two 100-year-flood events in October and November of 2002 were both severe and late in the season for quick recovery. The extensive bank sloughing and channel widening on Anchor River and Deep Creek may have limited the availability of places where macroinvertebrates could find a safe refuge from flood effects, particularly strong water velocities that resulted in the deaths of many insects and other small invertebrates. On Beaver Creek, higher up in the Anchor River watershed, the recovery pattern of macroinvertebrate populations is more typical and, with an increase in Fine Sediment Biotic Index scores, suggests a positive flood effect of moving sediment out of the stream bottom.

Map (and aerial photo) scale

It's useful to understand "scale" when using maps like those shown and discussed throughout this watershedipedia. Maps (and aerial photos from which they're made) show 3-dimensional reality on a flat (2-dimensional) surface. Map (or photo) scale compares a linear distance shown on the map to the same real-life distance on the ground. This can be done by using scales expressed as ratios, for example, 1:15,000, or by using a bar scale. A bar scale remains accurate if the map is reduced or enlarged, whereas a ratio scale becomes inaccurate if the original map size is altered. Maps of the Anchor River at two scales are shown below. Maps were much reduced to fit below, so scales are now a much smaller ratio than reported. Note the relationships of the two bar scales.



Map of same area as on right, but with a *reported* scale of 1:31,250



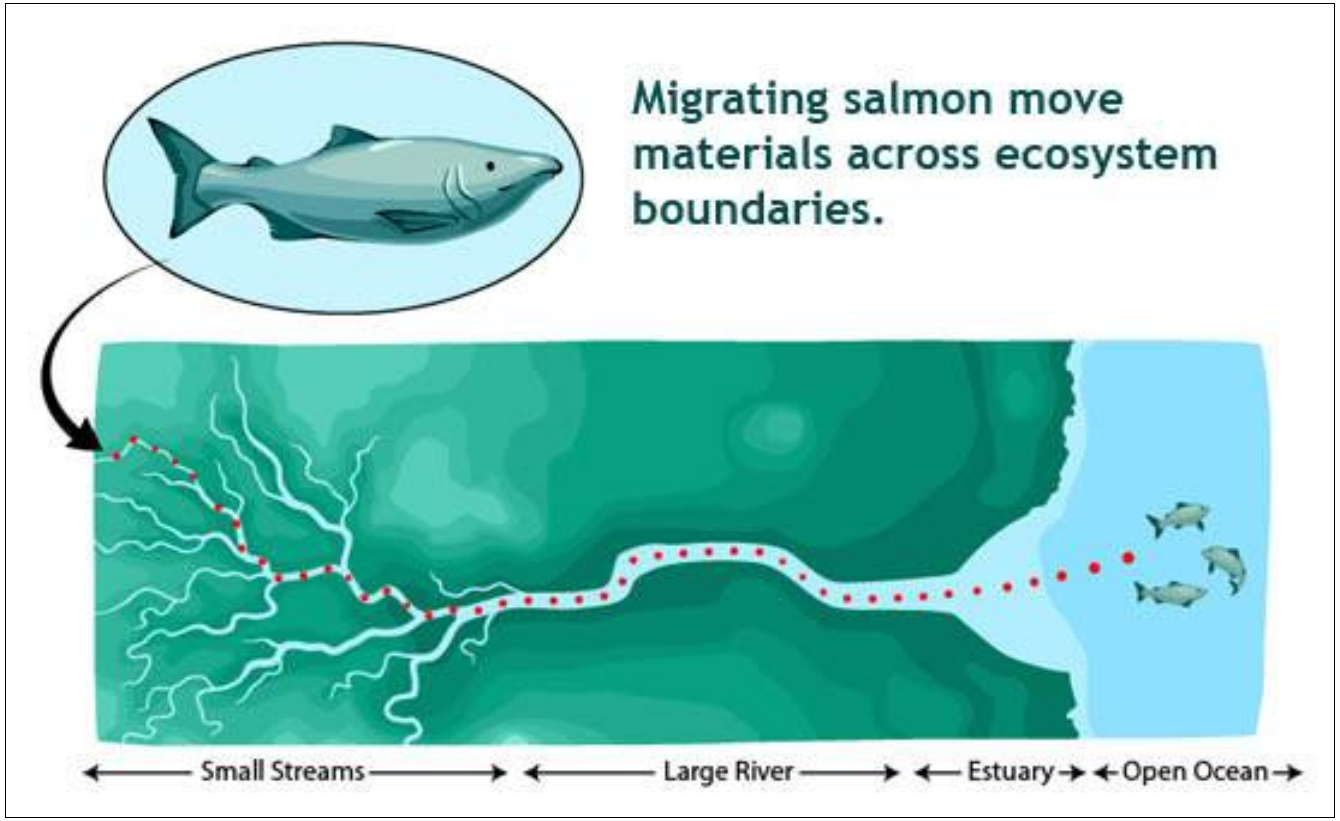
Map of same area as on left, but with a *reported* scale of 1:15,600

A map showing distances "life size" would have a scale of 1:1 (read "one to one"), meaning that one inch of distance on the map would equal one inch of distance on the ground. The commonly used scale of 1:63,360 means that a line one inch long on the map corresponds to a line 63,360 inches long on the ground. As it turns out 63,360 inches equal 1 mile; so a scale of 1:63,360 is sometimes also called "inch to the mile." It's important to understand that maps are most accurate if viewed at the scale at which they were made. Published maps reflect the level of detail that the mapmaker could see and draw on the map given the scale at which he or she was working. Maps with a scale of 1:25,000 (the scale used for Kenai Peninsula soil maps and wetlands maps) can show

more detail than maps at a scale of 1:63,360; so mapmakers using the former scale could distinguish smaller features than mapmakers working at inch-to-a-mile. When maps are enlarged, the information will no longer reflect what mapmakers could discern and draw at the less-detailed scale at which the maps were made. This can cause misinterpretation of mapped data.

Marine derived nutrients (MDN)

As explained in introductory article 1: Salmon species and life cycle, salmon spend many years growing to adult size in the ocean, feeding on marine fish and invertebrates. Once they enter freshwater to return to their natal streams to spawn, they cease eating. As a result, as they travel upstream they carry in their tissues nutrients stored from their life at sea, and these are called "marine derived nutrients" (MDN), see **figure below** (from http://askabiologist.asu.edu/explore/ecosystem-connections). In streams with large numbers of spawning salmon, marine-derived nutrients can be a significant source of nitrogen and an important driver of primary and secondary production (that is, the production of plant life and of the things that eat plants).



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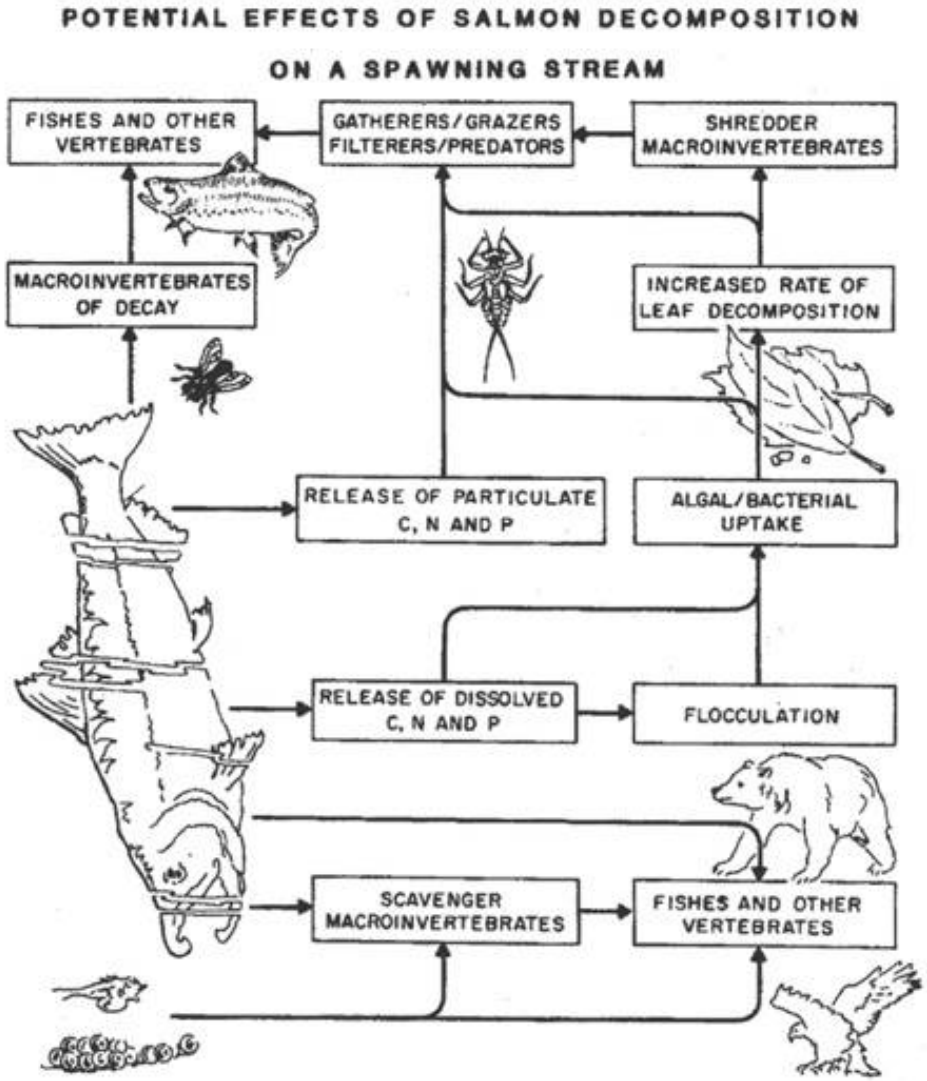
Many of the animals that feed on salmon carry the carcasses away from the river to eat them, which means that large numbers of salmon carcasses end up in the plant communities along and near spawning streams and rivers. Animals that eat spawning salmon and/or their eggs include many species of mammals (e.g., black and brown bears, wolves, foxes, river otters, mink), birds (e.g., eagles, gulls, crows, ravens, even dippers—who eat salmon eggs), other fish, and invertebrates such as insects. The **figure below left** shows effects decomposing salmon can have in and along spawning streams (from http://academic.reed.edu/biology/professors/srenn/pages/melati_website/story2). The **photo below top** shows a wolf carrying off a salmon carcass (from http://blogs.nature.com/news/2008/09/let_them_eat_fish.html). The **photo below bottom** shows salmon carcasses that have been dropped in leaf litter (from www.pnwsalmoncenter.org/x515.xml).



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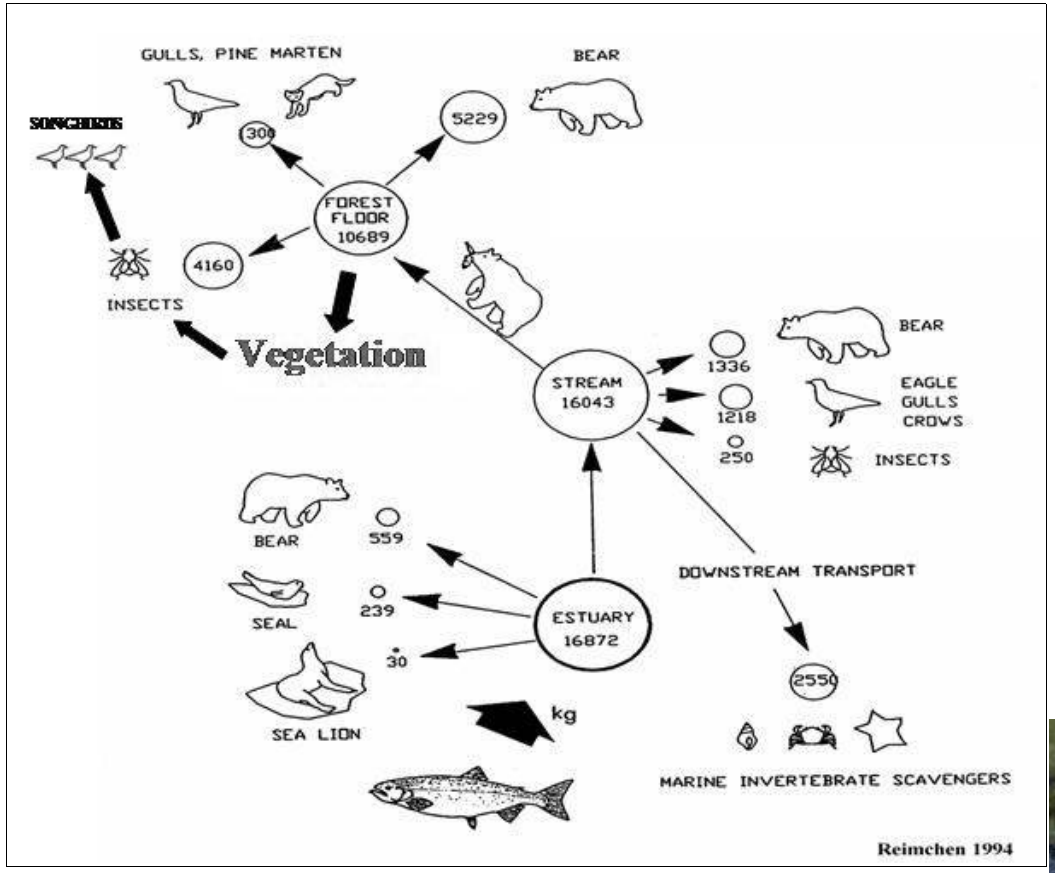

The **figure above** summarizes data on movement and transfer of chum salmon tissues from Bag Harbour Stream, British Columbia, Canada, between September 24 and October 31, 1993. Numbers in or below the circles represent kg of salmon. For example, 5420 coho salmon entered the stream during the study period, with an estimated total weight of 16,043 kg (about 35,370 lbs). (Source: http://web.uvic.ca/~reimlab/FURTHER%20STUDIES%20BAG%20HARBOUR0001.pdf.) **Figure at right**, salmon carcass and black bear feet (from http://www.salmoninthetrees.org/index.htm).

A study on Moresby Island in British Columbia (http://web.uvic.ca/~reimlab/FURTHER%20STUDIES%20BA%20HARBOUR0001.pdf) estimated that each of eight bears transferred about 2200 lbs of salmon carcasses into the forest. Marine derived nutrients from the salmon carcasses fertilize forest soils and provide food for many scavengers, including foxes, marten, eagles, crows, ravens, gulls, and insects. With respect to insects, researchers reported:

> After the tissues were fully consumed, thousands of maggots could be observed moving off the bony remnants onto the moss substrate and dispersing outwards in all directions. The frontal edge of these maggot migrations were occasionally encountered 3 m (10 ft) from the central carcass remains. Results of followup studies indicate that the yearly transfer of these MDNs is detectable in the yearly growth rings of conifers growing along streams and rivers (http://web.uvic.ca/ ~reimlab/Treering.html). These nutrients can contribute up to 75% of the total nitrogen in the wood of trees from watersheds where salmon are abundant."

Rearing salmon are voracious insect eaters. You can imagine how greatly insect population pulses like this can enrich food webs in and along salmon streams.

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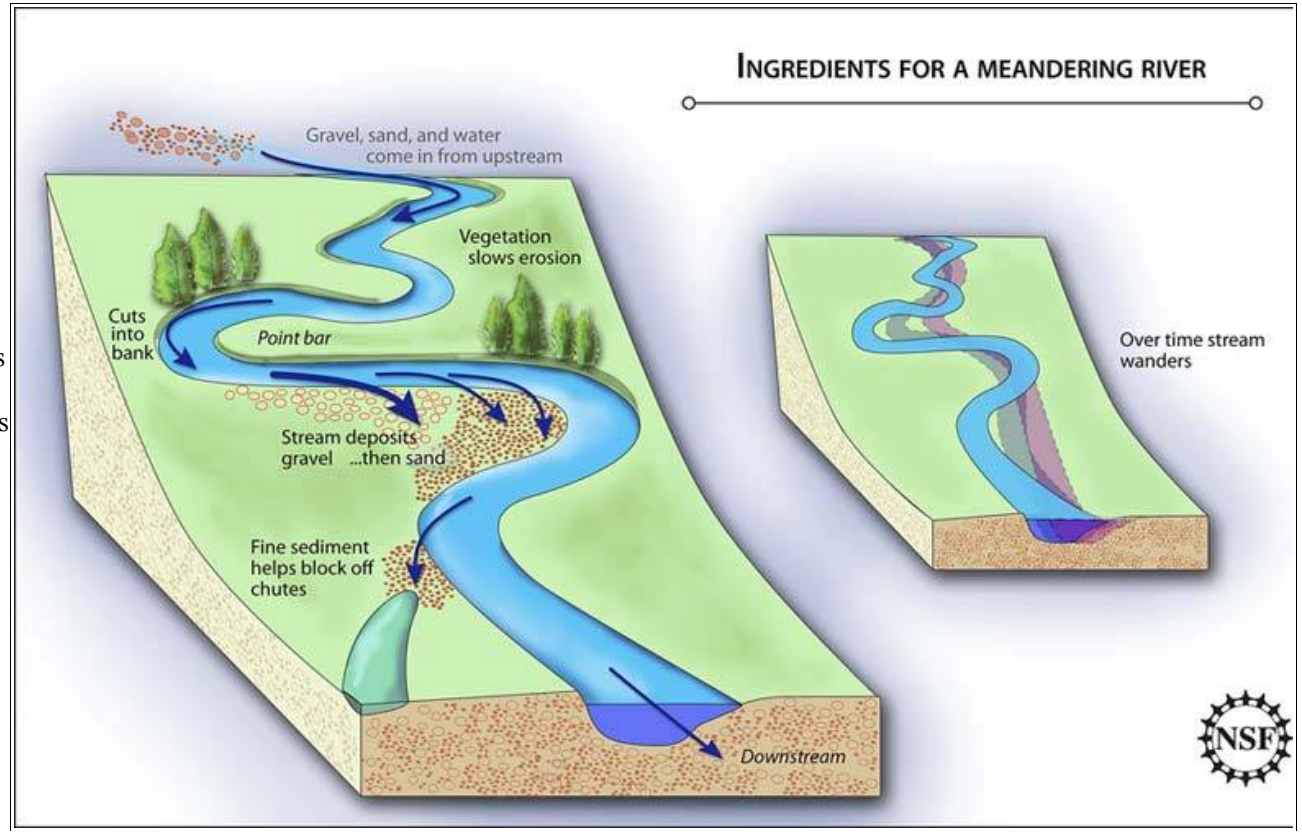
Meanders

(see also Meander belt, Stream channel "anatomy," Stream channel processes)

A stream's pattern develops naturally, both to dissipate energy and in response to stream sediment load. Meanders dissipate energy as flows are forced along a winding path and around meander bends. Energy is also used up through friction of the water against the streambed and banks. Meanders in a river are like switchbacks on a mountain road; they reduce the slope of the river's channel (the river's longitudinal profile) and, therefore, reduce flow velocities.



Anatomy of meanders (source: http://berkeley.edu/news/media/releases/2009/10/05_meanders.shtml).

Research has shown that meanders have a predictable size and shape. A regular meander pattern can often be seen from a distance. Each meander bend might look different, but the elements of the basic pattern repeat over significant distances. Each meander bend has a similar "anatomy." Cutbanks are created on "outside bends"—where flow velocities are fastest and have the greatest force (just like the outer person goes fastest when you play crack-the-whip). Point bars are created on "inside bends"—where flows are slower and have less force, so the river can't carry as much sediment and ends up dropping some.

We can see that natural meander patterns reflect how a river's variables—its sediment load, flow volume and velocity, channel slope, etc.—have adjusted to each other and to the topography. As a result, natural meander patterns are fundamental features of a particular stretch of river, reflecting a dynamic equilibrium characteristic of that river stretch given all current conditions. You can't change just one river variable because as soon as one is changed, the others also change to re-establish a new dynamic equilibrium.

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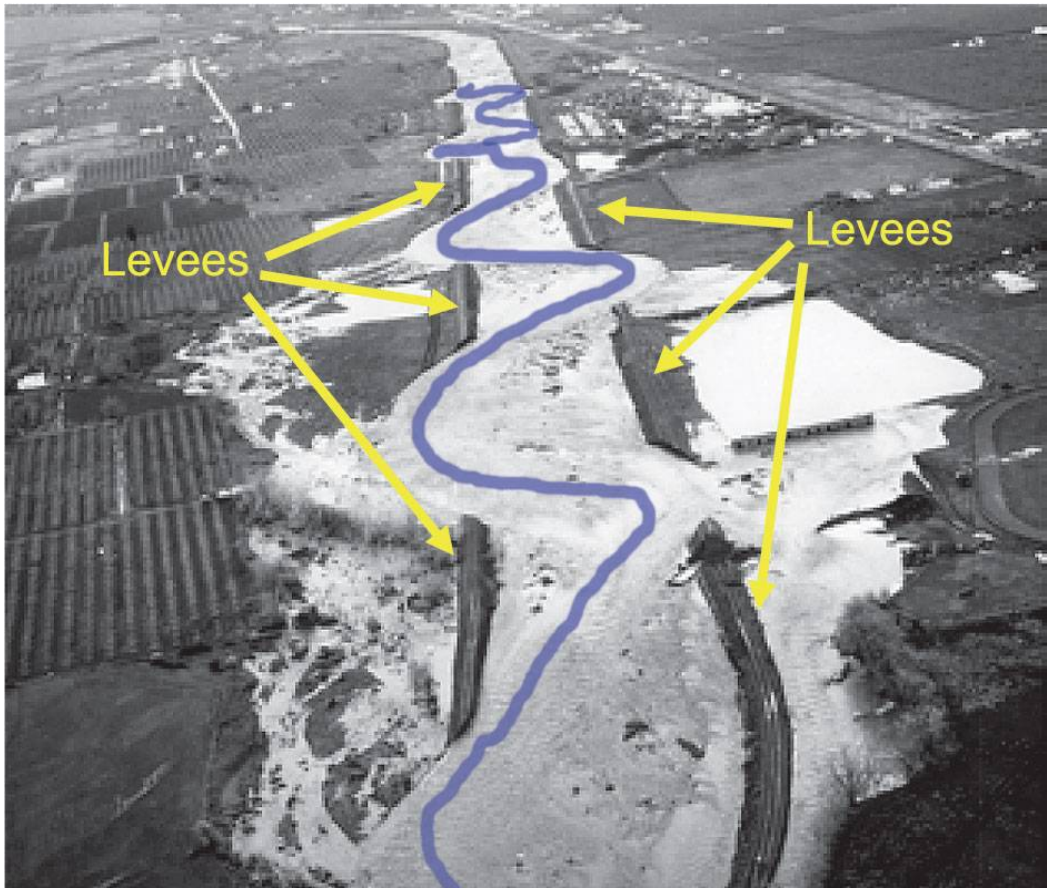
The photo at right shows what one river did when one of its variables was changed. In this case, the Walla Walla River was channelized and diked for flood control. During flooding in 1964, the river broke through the dikes (or levees) in several places when flow exceeded the capacity of the artificial channel. After overtopping the manmade levees, the river re-established a regular meander pattern that, as the photo shows, is superimposed over the artificially straightened channel. The new pattern reflected the river's own dynamic equilibrium.

By reverse-engineering a meandering stream, National Science Foundation researchers have shown two ingredients to be very important in maintaining natural meander patterns: vegetation to reinforce banks and slow down erosion, and sediments to build point bars and block cut-off channels and chutes. This is useful for landowners to know, since it emphasizes the importance of keeping streambanks well vegetated and sediment loads at natural levels, both of which landowners can help do (see Best Management Practices).



Walla Walla River in Oregon showing meanders re-established in a channelized section near Milton-Freewater during flooding in 1964. The river is flowing from the bottom of the photo to the top. (Modified from: http://seagrant.oregonstate.edu/ sgpubs/onlinepubs/t01003.pdf.)

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Meander belt or zone

(see also Meander, Sinuosity)

As a river or stream meanders, it defines a corridor within which meanders remain as they snake back and forth. That corridor is called the meander belt or zone.

A meandering stream channel with the approximate meander belt outlined in yellow. Notice the very large abandoned meander channels left of the outlined belt. Note also how dynamic the area around the confluence of the tributary and the main stem appears. To protect salmon habitat, it's important to allow stream channels to migrate naturally within their meander belts. Structures within the meander belt are susceptible to erosion and flooding. (Photo: Devony Lehner.)

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Moraines

(see also Glacial history of the western Kenai Peninsula, Landforms)

(Slightly modified from http://en.wikipedia.org/wiki/Moraine; because the following is from a Wikipedia article, we have left in the active links to other, related Wikipedia entries.)

A **moraine** is any glacially formed accumulation of unconsolidated glacial debris (soil and rock) which can occur in currently glaciated and formerly glaciated regions, such as those areas acted upon by a past glacial maximum. This debris may have been plucked off a valley floor as a glacier advanced or it may have fallen off the valley walls as a result of frost wedging or landslide. Moraines may be composed of debris ranging in size from silt-sized glacial flour to large boulders. The debris is typically sub-angular to rounded in shape. Moraines may be on the glacier's surface or deposited as piles or sheets of debris where the glacier has melted. Moraines may also occur when glacier- or iceberg-transported rocks fall into a body of water as the ice melts... Moraines can be classified either by their origin or shape. The first approach is suitable for moraines associated to contemporary glaciers but more difficult to apply to old moraines whose glaciers have disappeared long ago... medial moraines of valley glaciers are poorly preserved and difficult to distinguish after the retreat or melting of the glacier.

Lateral moraines are parallel ridges of debris deposited along the sides of a glacier. The unconsolidated debris can be deposited on top of the glacier by frost shattering of the valley walls and/or from tributary streams flowing into the valley. The till is carried along the glacial margin until the glacier melts. Because lateral moraines are deposited on top of the glacier, they do not experience the postglacial erosion of the valley floor and therefore, as the glacier melts, lateral moraines are usually preserved as high ridges.

Ground moraines are till covered areas with irregular topography and no ridges, often forming gently rolling hills or plains. It is accumulated at the base of the ice as lodgment till, but may also be deposited as the glacier retreats.

End moraines, or terminal moraines, are ridges of unconsolidated debris deposited at the snout or end of the glacier. They usually reflect the shape of the glacier's terminus. Glaciers act much like a conveyor belt, carrying debris from the top of the glacier to the bottom where it deposits it in end moraines. End moraine size and shape is determined by whether the glacier is advancing, receding or at equilibrium. The longer the terminus of the glacier stays in one place the more debris will accumulate in the moraine. There are two types of end moraines; terminal and recessional. Terminal moraines mark the maximum advance of the glacier. Recessional moraines are small ridges left as a glacier pauses during its retreat. After a glacier retreats the end moraine may be destroyed by postglacial erosion.

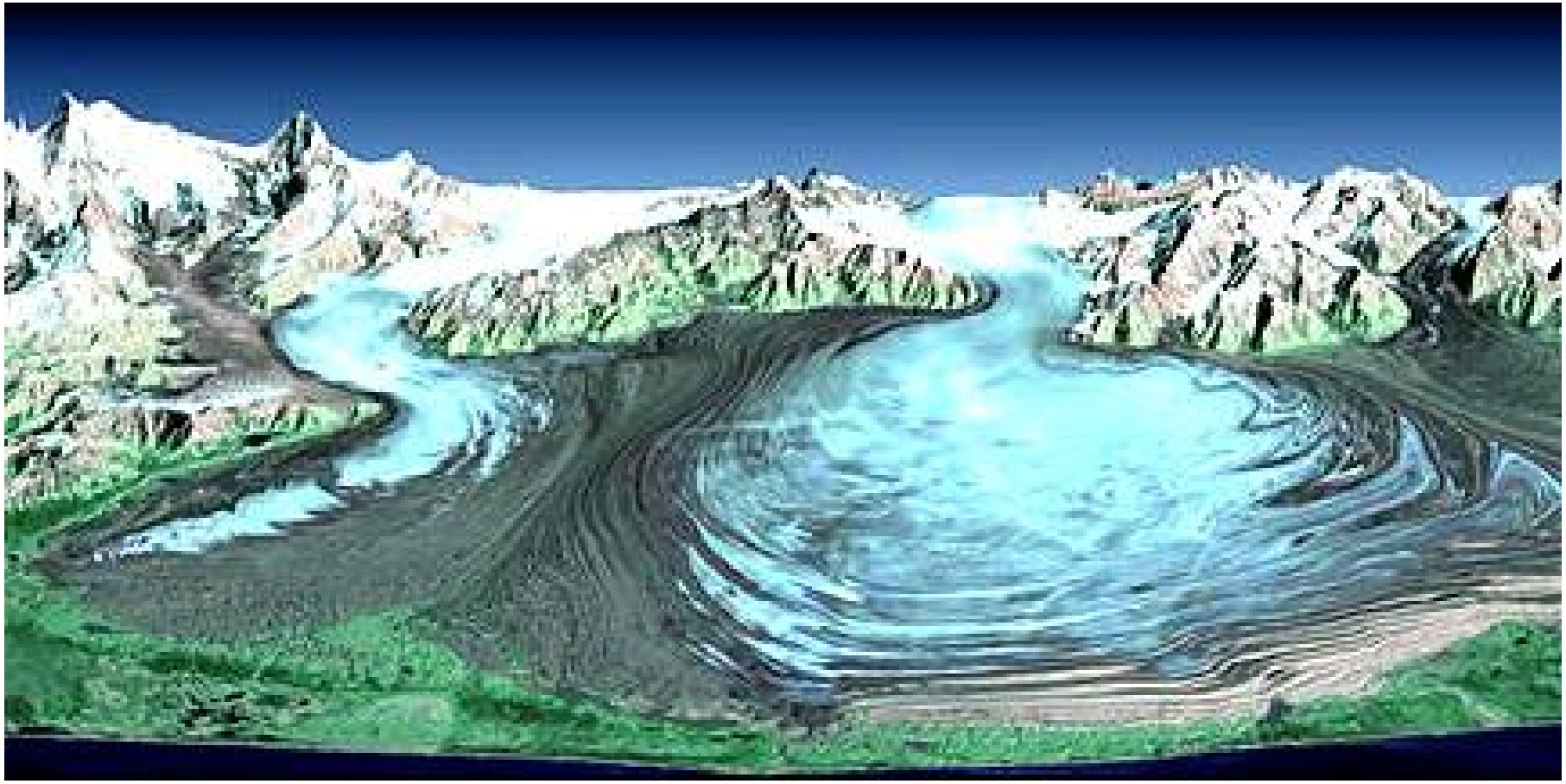
Recessional moraines are often observed as a series of transverse ridges running across a valley behind a terminal moraine. They form perpendicular to the lateral moraines that they reside between and are composed of unconsolidated debris deposited by the glacier. They are created during temporary halts in a glacier's retreat.

A **medial moraine** is a ridge of moraine that runs down the center of a valley floor. It is formed when two glaciers meet and the debris on the edges of the adjacent valley sides join and are carried on top of the enlarged glacier. As the glacier melts or retreats, the debris is deposited and a ridge down the middle of the valley floor is created.

Glaciers tend to have black streaks on their surfaces - these are medial moraine deposits formed as rock falls loose at the head of the glacier and continues this

process over the years, so that the debris are strung out as streaks that move over the years.

The perspective view of this glacier as it creeps towards the Gulf of Alaska shows it in context with its mountain source; the image was made by combining Landsat and STRM data; from http://www.fas.org/irp/imint/docs/rst/Sect17/Sect17_5.html.



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Natural Resources Conservation Service (NRCS)

The NRCS is an agency within the US Department of Agriculture. Its origins go back to the Dust Bowl era of the 1930s, when soil erosion got so bad that dust storms from the Great Plains actually blackened skies as far away as Washington, D.C. The damage and heartache caused were incalculable. To reduce soil erosion, Congress created the Soil Conservation Service. As the roles of the SCS expanded, its name was changed to the Natural Resources Conservation Service. The website of the NRCS in Alaska is http://www.ak.nrcs.usda.gov/.

The NRCS mission is "helping people help the land." It works through local landowners, managers, and other partners—such as the Homer Soil and Water Conservation District—assisting them with conserving their soil, water, and other natural resources through appropriate conservation practices and management systems. NRCS technical assistance is tailored to each land manager's needs. Cost sharing and financial incentives are available in some cases. Participation in NRCS programs is voluntary, and the agency has no regulatory authority.

In the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds, NRCS works in close partnership with Homer Soil and Water to help land-owners, farmers, developers, ranchers, loggers, and others use and manage their soil, water, and other natural resources in environmentally sound and sustainable ways.

Left photo: A giant dust storm blackens the sky of Goodwell, OK, during the Dust Bowl (http://science.howstuffworks.com/environmental/green-science/dust-bowl-cause.htm Chris Johns/ National Geographic). **Right photo**: Dust storms buried everything in their path. www.atmos.washington.edu/~dennis/dust_car_gs.jpg

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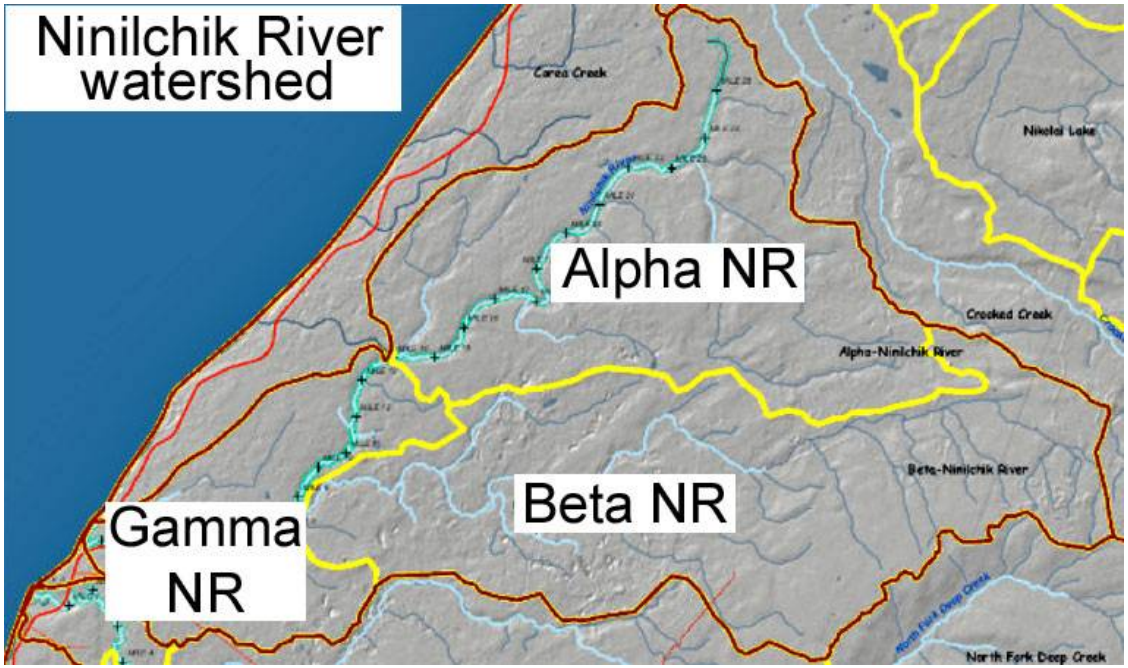
Natural variability
(see Biodiversity)

NatureMapping

(From http://www.naturemappingfoundation.org/index.html.) Landowners interested in participating in science may want to explore NatureMapping, which is a program that links citizens, scientists, and property owners. The program is designed to engage citizens of all ages in hands-on, technology-enabled exploration of natural environments. It fosters the open exchange of scientific information among a growing network of universities, government agencies, science and nature centers, landowners, civic organizations, businesses and interested citizens. NatureMapping taps into the growing interest of citizens, governments and businesses who are all seeking better decisions based on solid scientific understanding of the facts. They recognize that a robust economy and continued high-quality of life must be based on our ability to adopt practices sustainable both financially and environmentally. The NatureMapping Foundation is a neutral, nonpartisan organization dedicated to the integrity of its scientific processes, protocols and data analysis. It seeks to inform and improve public understanding and decision-making through its objectivity and independence.

Ninilchik River and watershed

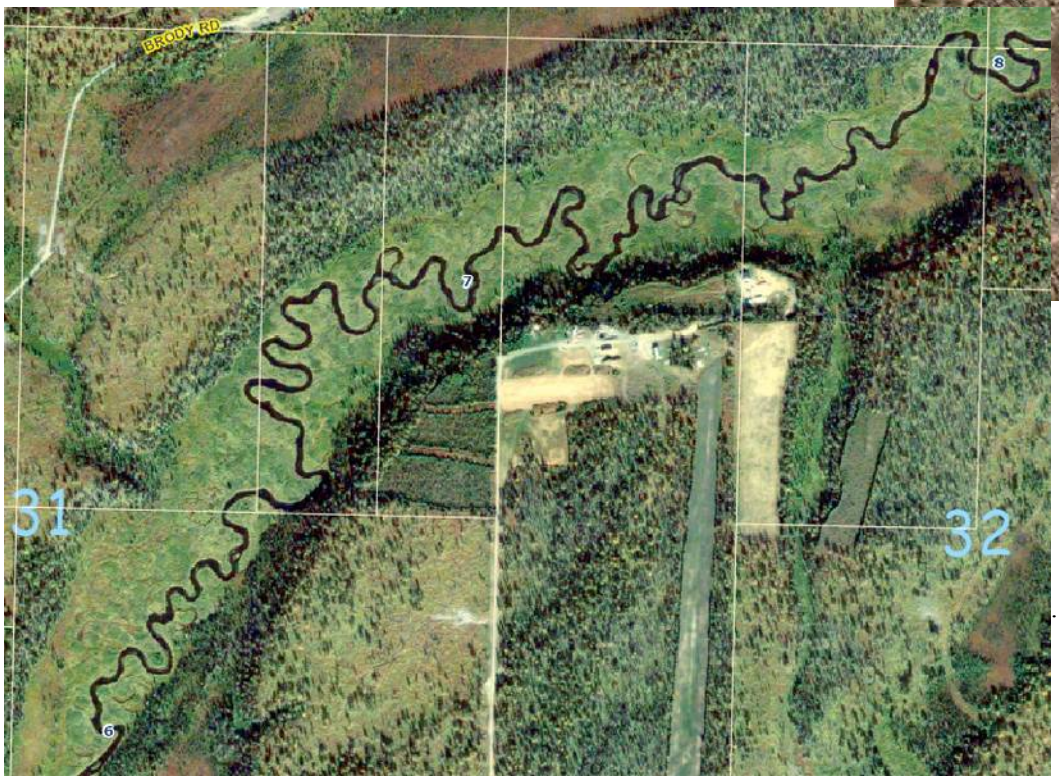
The Ninilchik River (NR) watershed covers roughly 137 sq mi (nearly 88,000 acres) and headwaters in the Caribou Hills. Corea Creek and Kasilof River watersheds bound it on the north; and Deep Creek watershed bounds it on the south. The mouth of Ninilchik River is about 4 mi. north of the mouth of Deep Creek. The mainstem channel of the Ninilchik River, marked in turquoise on the map below, is about 26 miles long measured "as the boat floats." Ninilchik River follows channels carved by much larger flows that drained melting glaciers (see Caribou Hills and Glacial history of the western Kenai Peninsula), and as a result, meanders extensively within its meander belt, as shown in photos below.



As described in *introductory article 3: Exploring your watershed with online tools*, the Kenai Watershed Forum has developed an atlas showing many features of peninsula watersheds, including plant communities, land uses, land ownership, wetlands, fire history, logging, and impervious surfaces, among others (http://www.kenaiwatershed.org/Atlas/index.html). The **map at left** is from that source. In the atlas, as you zoom in on your watershed, different background layers appear, each with more detail; the image at left is the least detailed but clearly shows the main stream channels in the watershed. The KWF atlas divides the Ninilchik River watershed into three subwatersheds, designated Alpha, Beta, and Gamma.

Images at right and below show how the Ninilchik River meanders within its meander belt. (Both photos are of the same general area.) The **image at right** is from Google Maps, at http://maps.google.com/, the **image below** is from the Kenai Peninsula Borough's interactive parcel viewer (http://mapserver. borough.kenai.ak.us/kpbmapviewer/), discussed at length in introductory article 3. Google Maps allows you to look at landscapes from an angle, as shown in the image at right.

As described in *introductory article 1: Salmon species and life cycle*, Ninilchik River supports chinook, coho, and pink salmon, as well as steelhead and rainbow trout and Dolly Varden (along with other resident fish species.) Like Deep Creek and Anchor River, Ninilchik River supports a road-accessible recreational fishery for chinook. Historic information indicated that Ninilchik River supported a relatively small return of chinook salmon, thought to number roughly 1,500 fish. Concerns about the adverse impacts that increasing levels of harvest could have on the Ninilchik River chinook salmon stock, and to increase recreational fishing opportunities, ADF&G Sport Fish Division began stocking chinook salmon in the river in 1988 from fish spawned artificially at the Ninilchik River weir in 1987. A report describing assessment and supplementation of Ninilchik River chinook salmon stocks as of 2008 is available at http://www.sf.adfg.state.ak.us/FedAidPDFs/FDS11-54.pdf.



The **table on the following page** compares the Ninilchik River watershed to Anchor River, Deep Creek, Stariski Creek, and Kenai River watersheds. Maps and data are from the KWF atlas mentioned above.

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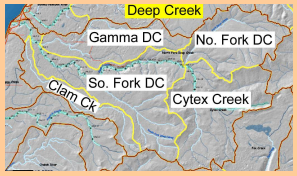
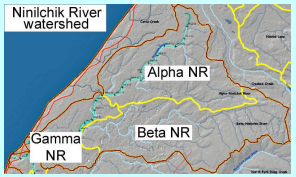
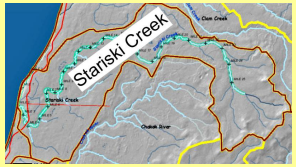
Comparison of five Kenai Peninsula watersheds and rivers.

(Really big rivers like the Yukon have immense watersheds—the Yukon drains about 225,000 sq mi.)

If you're looking at this table as a pdf, you can zoom in to see thumbnail maps in more detail.

Source for maps and all information summarized below is the Kenai Watershed Forum atlas: www.kenaiwatershed.org/atlas.html.

	Anchor River (AR)	Deep Creek (DC)	Ninilchik River (NR)	Stariski Creek (SC)	Kenai River
Watershed length: Rough length as the crow files **Watershed Area:** Areas are shown in sq miles. To calculate acres, multiply sq mi by 640 (1 sq mi = 640 ac). Area changes with more detailed mapping.	 Watershed length ≈ 29 mi	 Watershed length ≈ 26 mi	 Watershed length ≈ 22 mi	 Watershed length ≈ 14 mi	 Watershed length ≈ 80 mi
Total watershed area: sq mi	**About 225 sq mi**	**About 218 sq mi**	**About 137 sq mi**	**About 52 sq mi**	**About 2,119 sq mi**
Subwatershed 1 area	North Fork AR 31	North Fork DC 38	Alpha-NR 53		(43 subwatersheds are mapped in the KWF atlas, http://www.kenaiwatershed.org/Atlas/index.html#.)
Subwatershed 2 area	West Anchor R 55	South Fork DC 67	Beta-NR 62		
Subwatershed 3 area	East Anchor R 65	Gamma-DC 34	Gamma-NR 22		
Subwatershed 4 area	Chakok River 38	Cytex Creek 58			
Subwatershed 5 area	Beaver Creek 20	Clam Creek 21			
Subwatershed 6 area	Twitter Creek 16				
River mainstem length "as-the-boat-floats" miles*	**About 62 miles**	**About 40 miles**	**About 26 miles**	**About 26 miles**	**About 81 mi to Kenai Lake**
Combined length of main-stem and tributaries	308 miles	270 miles	162 miles	67 miles	1,648 river miles
Subwatershed 1 length	North Fork AR 39	North Fork DC 56	Alpha-NR 52		(43 subwatersheds are mapped in the KWF atlas, http://www.kenaiwatershed.org/Atlas/index.html#.)
Subwatershed 2 length	West Anchor R 84	South Fork DC 83	Beta-NR 82		
Subwatershed 3 length	East Anchor 78	Gamma-DC 35	Gamma-NR 28		
Subwatershed 4 length	Chakok River 54	Cytex Creek 72			
Subwatershed 5 length	Beaver Creek 31	Clam Creek 24			
Subwatershed 6 length	Twitter Creek 22				

* River length information is from the National Hydrography Dataset (NHD) at a map scale of 1:63,360; measurements will change as more detailed maps are generated.

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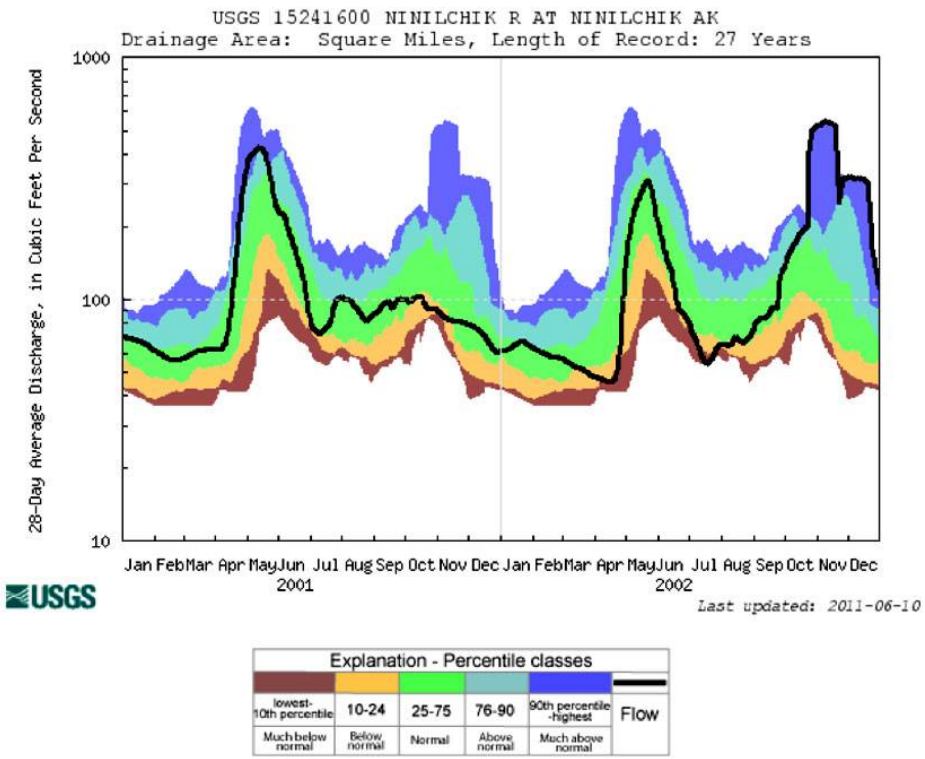

Up through September 2003, the USGS collected a variety of data on the Ninilchik River (see http://waterdata.usgs.gov/ak/nwis/uv?15241600). (The period of record is from April 1963 to September 1985 for a wire weight gauge and from October 1998 to October 2003 for a continuous stage recording, see Stream discharge and Stream stage. The hydrograph at right shows 28-day average Ninilchik River discharge measured at Ninilchik in 2001 and 2002. Notice that flows were "much above average" during October and November of 2002, when many lower Kenai Peninsula streams flooded (compare with the black line showing flow in October-November 2001).

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Nonpoint source pollution (NPS) and NPDES permits
(see also Stormwater runoff, Water quality)

(Slightly modified from: http://www.epa.gov/owow_keep/NPS/index.html, see also the Alaska Department of Environmental Conservation NPS website at http://dec.alaska.gov/water/wnpspc/index.htm) Unlike pollution from industrial sources or sewage treatment plants—which tends to come from a "point," like the end of a pipe—nonpoint source (NPS) pollution comes from numerous, spread out sources. That's because NPS pollution starts with rainfall or snowmelt moving over and through the ground; as this runoff moves across cleared soils, roads and parking lots, dog yards and livestock paddocks, and other areas where sediments are exposed or pollutants have collected, it carries away whatever pollutants flowing water can pick up, either physically or by dissolving them. Eventually the surface and subsurface stormwater runoff (or snowmelt) deposits its load of sediments, chemicals, bacteria, and other pollutants into lakes, rivers, wetlands, and coastal waters. Some of these pollutants may reach groundwater sources as well. Since this pollution comes from such diffuse and widespread sources, it's called nonpoint source pollution. NPS pollution has to be managed very differently from point-source pollution.

Nonpoint source pollution can include:

- Excess fertilizers, herbicides and insecticides from residential or agricultural areas;
- Oil, grease, and toxic chemicals from urban runoff and energy production;
- Sediment from improperly managed construction sites, crop and forest lands, and eroding streambanks,
- Salt from irrigation practices and acid drainage from abandoned mines;
- Bacteria and nutrients from livestock, pet wastes, and faulty septic systems;
- Atmospheric deposition and hydromodification.

Nonpoint source pollution is distinguished from *point source pollution.* Point source pollution is defined in Section 502(14) of the Clean Water Act as follows:

> The term "**point source**" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture.

NPDES permits

Point source pollution is regulated through state water quality standards and the National Pollutant Discharge Elimination System (NPDES). In 2008, the Environmental Protection Agency formally approved Alaska's application to administer the NPDES Program. The state's approved program is the Alaska Pollutant Discharge Elimination System (APDES) Program. For more information, go to: http://yosemite.epa.gov/r10/water.nsf/NPDES+Permits/Permits+Homepage and http://www.dec.state.ak.us/water/wwdp/online_permitting/permitentry.htm.

Wash cars, trucks, boats, and other vehicles where wash water runoff will collect on a vegetated, sandy, or gravelly surface where it can infiltrate into the ground instead of running into roadside ditches or onto paved surfaces. Use environmentally safe soap.

Obviously, nonpoint source pollution carried into salmon streams threatens the salmon in those streams. Salmon eggs are particularly susceptible to very low levels of some pollutants. One thing landowners can do to keep their lands and waters salmon friendly is to reduce the chance of causing nonpoint source pollution. Here are some things landowners can do to prevent nonpoint source pollution:

Around your home:

- Keep litter, pet wastes, leaves and debris from washing off your property or into road ditches; well vegetated buffers where stormwater can slow down, spread out, and infiltrate, will help clean and reduce runoff from your property (see Best Management Practices and Buffers).
- Apply lawn and garden chemicals sparingly and according to directions.
- Dispose of used oil, antifreeze, paints and other household chemicals properly—take them to the

Homer Baling Facility or Soldotna Landfill, don't dump them on the ground. (Go to http://www2.borough.kenai.ak.us/SolidWaste/Informational%20pages/hwastescdl.htm for more information.)

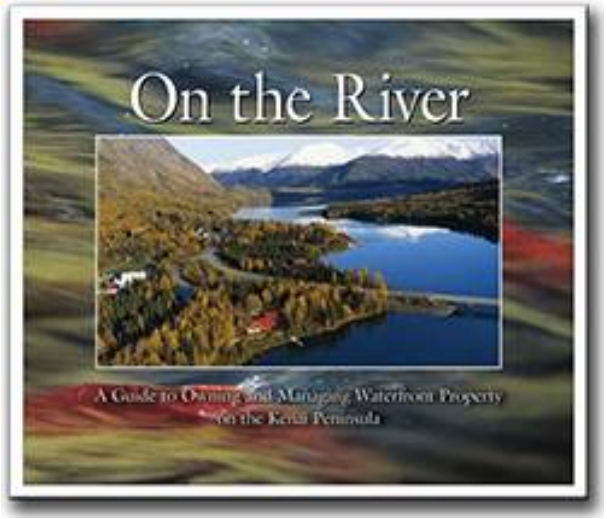
- Store household hazardous wastes safely until the next hazardous waste collection day at the Homer Baling Facility or Soldotna Landfill. (Go to http://www2.borough.kenai.ak.us/SolidWaste/Informational%20pages/hwastescdl.htm for more information.)
- Clean up spilled brake fluid, oil, grease, and antifreeze. Do not hose them into the street or into roadside ditches, where they can eventually reach local streams and lakes. (And remember, antifreeze is fatal to pets and wild animals but often attracts them to drink because of its sweet taste.)
- Control soil erosion on your property by protecting native vegetation, planting groundcover, and stabilizing erosion-prone areas.
- Follow local construction-related erosion and sediment control ordinances in your community, and if you're doing construction, check to see if you need to develop and follow a Stormwater Pollution Prevention Plan (SWPPP).
- Have your septic system inspected and pumped every 3 to 5 years so that it operates properly.
- Purchase household detergents and cleaners that are low in phosphorous to reduce the amount of nutrients discharged into local water bodies.

If you have livestock or conduct agricultural activities:

- Manage animal waste to minimize contamination of surface water and groundwater; a well vegetated buffer (e.g., 30 ft wide, at least) downslope of any paddocks, corrals, barns, or manure sites can help reduce offsite flows of runoff that's been contaminated with bacteria from animal wastes)
- Protect drinking water by minimizing fertilizer use and by learning how to prevent pest problems. When pesticides are used, minimize detrimental impacts by using least toxic pesticides and by following all label directions. Contact the Natural Resources Conservation Service (NRCS) Homer Field Office for information on "nutrient and pest management."
- Reduce soil erosion by using Best Management Practices. Contact the NRCS Homer Field Office for information about conservation practices.
- Use planned grazing systems on pasture and rangeland. Contact the NRCS Homer Field Office for information on grazing land management.
- Dispose of pesticides, containers, and tank rinsate in an approved manner.

On the Coast & On the River

These are two excellent books developed to help landowners understand riverine and coastal environments and how to live with their dynamic conditions. This landowner's guide and watershedipedia can be seen as supplementing those two readable sources of useful information.



On the River provides an introduction to waterfront property management. It guides landowners through the basics of developing a plan for their property, taking into consideration location, the level of planned use, and landowner goals. You will learn how to manage your property to protect both your investment and the natural resources that make it such a special place. There are chapters on river dynamics, wetlands, floodplains, choosing your building site, wells and groundwater, living with wildlife, laws property owners should be aware of and more. Full-color illustrations and photographs accompany each section. ***On the coast*** provides an introduction to property management along the coastal region. It is a companion to *On the River* for coastal property owners. You can download both books from http://www.kenairivercenter.org/general/krcpublications.html:

Oil and gas

Under Kenai Area Plan, we discuss the process that the Alaska Department of Natural Resources uses to plan how best to use state-owned lands. This process addresses all land uses but one: oil and gas. Oil and gas includes exploration, development, and production. All oil and gas activities on state-owned lands are reviewed and administered by DNR's Division of Oil and Gas (http://dog.dnr.alaska.gov/index.htm) and its sections (http://dog.dnr.alaska.gov/Sections.htm). DOG also administers oil and gas operations on lands not owned by the state but where the state owns the "subsurface estate." Landowners other than the state can also lease their lands for oil and gas activities if they hold the subsurface estate themselves. In this watershedipedia, we can provide only the briefest introduction to oil and gas activities in the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek watersheds. Interested landowners are encouraged to use the links provided to explore this topic further.

(The following is slightly modified from http://dog.dnr.alaska.gov/Leasing/LeasingHome.htm.) The first step in oil and gas development is leasing the rights to explore for oil and gas. DOG conducts a program of regularly scheduled competitive oil and gas lease sales on state lands. A new Five-Year Oil and Gas Leasing Program is submitted to the Alaska State Legislature each January. The program outlines a schedule of proposed lease sales, and Cook Inlet is one of the lease sale areas (see http://dog.dnr.alaska.gov/Publications/CookInlet.htm#cilease). The current year's lease sale report is available at the Leasing Reports Page (http://dog.dnr.alaska.gov/ Leasing/LeaseReports.htm#5lease). Upcoming sales are listed in a Five Year Lease Sale Schedule. Following a lease sale, the *Lease Administration Unit* issues the leases and ensures that their terms are met. It also maintains a list of all noncompetitive and competitive lease sales (http://dog.dnr.alaska.gov/Leasing/LeaseSales.htm) held, indicating sale number, sale location, lease effective dates, and lease forms used. Each lease is assigned an ADL (Alaska Division of Land) number, and a case file is established. To research information about a particular lease, the legal description or ADL number is needed. Before DOG sells, leases, or otherwise disposes of state land, resources, property, or interests in them, the director determines in a written finding that the interests of the state will be best served by doing so. The written finding, known as a *best interest finding*, discusses relevant information that DOG considers in determining whether or not a particular action is in the state's best interest.

The state grants leases tract by tract, but if a number of tracts in an area are leased by a single entity or partnership, the state can combine them into a *unit*. This allows multiple leases to be explored and developed in a coordinated way rather than lease-by-lease. (A unit can include lands owned and leased by different landowners, for example by the state and by Cook Inlet Region, Inc.). AS 38.05.180(p) gives DNR the authority to form oil and gas units, and the Commissioner of DNR reviews unit applications under AS 38.05.180(p) and 11 AAC 83.301 – 11 AAC 83.395. Approval of a unit agreement does not by itself convey authority to conduct operations on unitized leases. That requires state approval of, first, a Unit Plan of Exploration and, then, a Unit Plan of Development. In reviewing these plans, DOG can consider the unit operator's ability to compensate surface owners for damage sustained to the surface estate and plans for restoration and rehabilitation of the unit area. Clearly, the process of leasing lands for oil and gas is just the first step in a long and complex process.

Numerous tracts have been leased in the lower Kenai Peninsula (e.g., Tracts 790 and 813 in the Anchor River watershed), and four units have been established. The Cook Inlet lease sale held in 2011 had the highest number of bids (110) since 1983. As noted in the *Alaska Dispatch*, "Apache Alaska Corp., was the big bidder, picking up about 500,000 acres throughout the inlet in about 90 bids. Apache was generally the high bidder in the Cosmopolitan prospect [see map below], a confirmed oil discovery where some leases were relinquished earlier this year. Apache's acreage is on the east side of Cook Inlet, near Anchor Point. According to state records, the company appears to now be the largest leaseholder in Cook Inlet" (http://www.alaskadispatch.com/article/banner-day-cook-inlet-oil-and-gas).

Units are listed below. On the following pages is a map of units, as well as of CIRI leases, some of which are for oil and gas and have been incorporated into a unit. For maps of specific units, which also show ADL numbers, go to http://dog.dnr.alaska.gov/Units/UnitMaps.htm.

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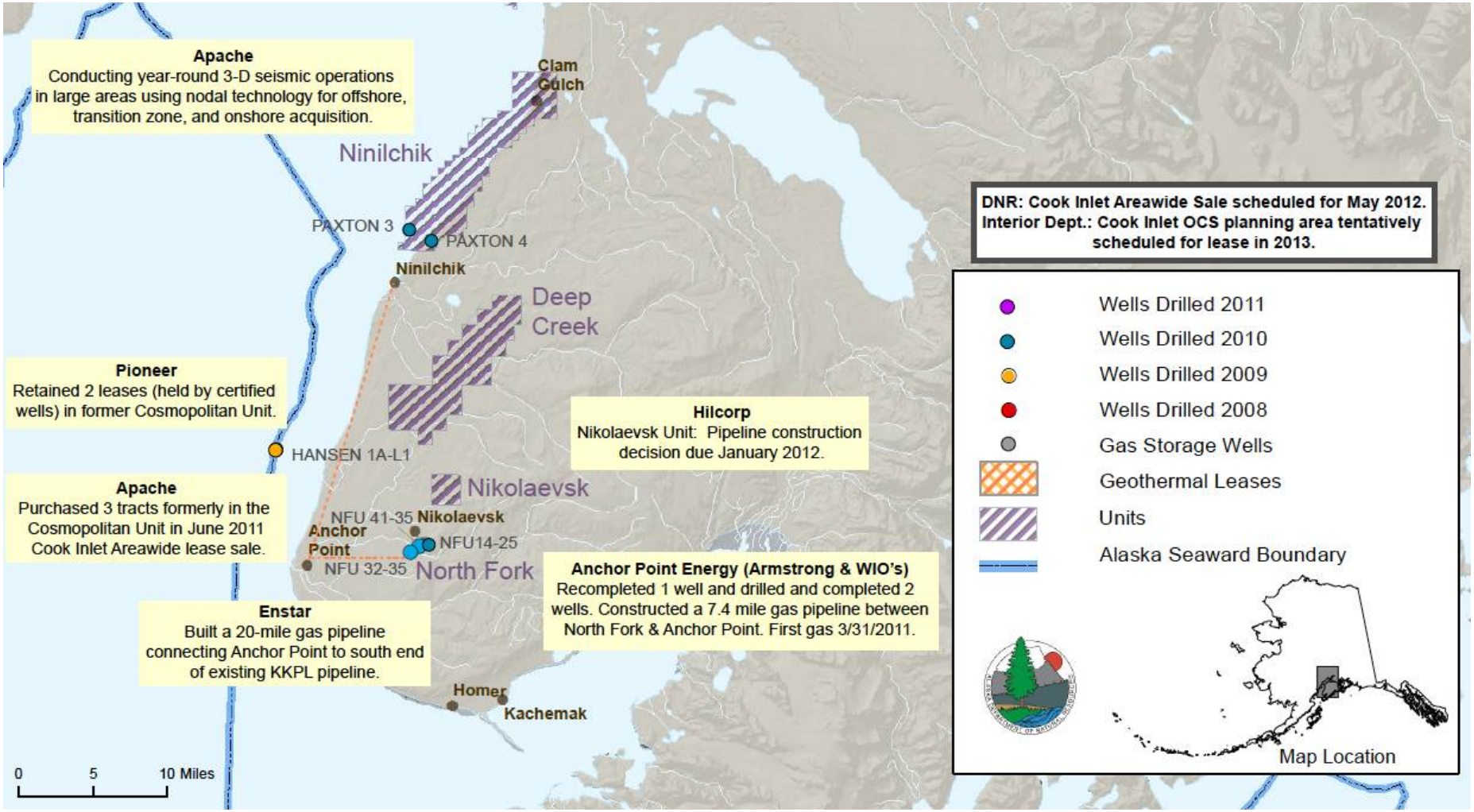
- Deep Creek Unit (http://dog.dnr.alaska.gov/Units/Documents/2001/deep_creek_decision.pdf)
- Nikolaevsk Unit (http://dog.dnr.alaska.gov/Units/Documents/2011/20110513_Approval_of_Ext_to_the_Term_of_the_Nikolaevsk_Unit_Agreement.pdf)
- Ninilchik Unit, (http://dog.dnr.alaska.gov/Units/Documents/2001/nk_final_decision_103001.pdf, first expansion of the unit http://dog.dnr.alaska.gov/Units/Documents/2003/UFirstEXP_3PAs_approval_finalD&F.pdf
- North Fork Unit (ADL 2095, Armstrong applied for North Fork draft unit expansion. Decision pending.



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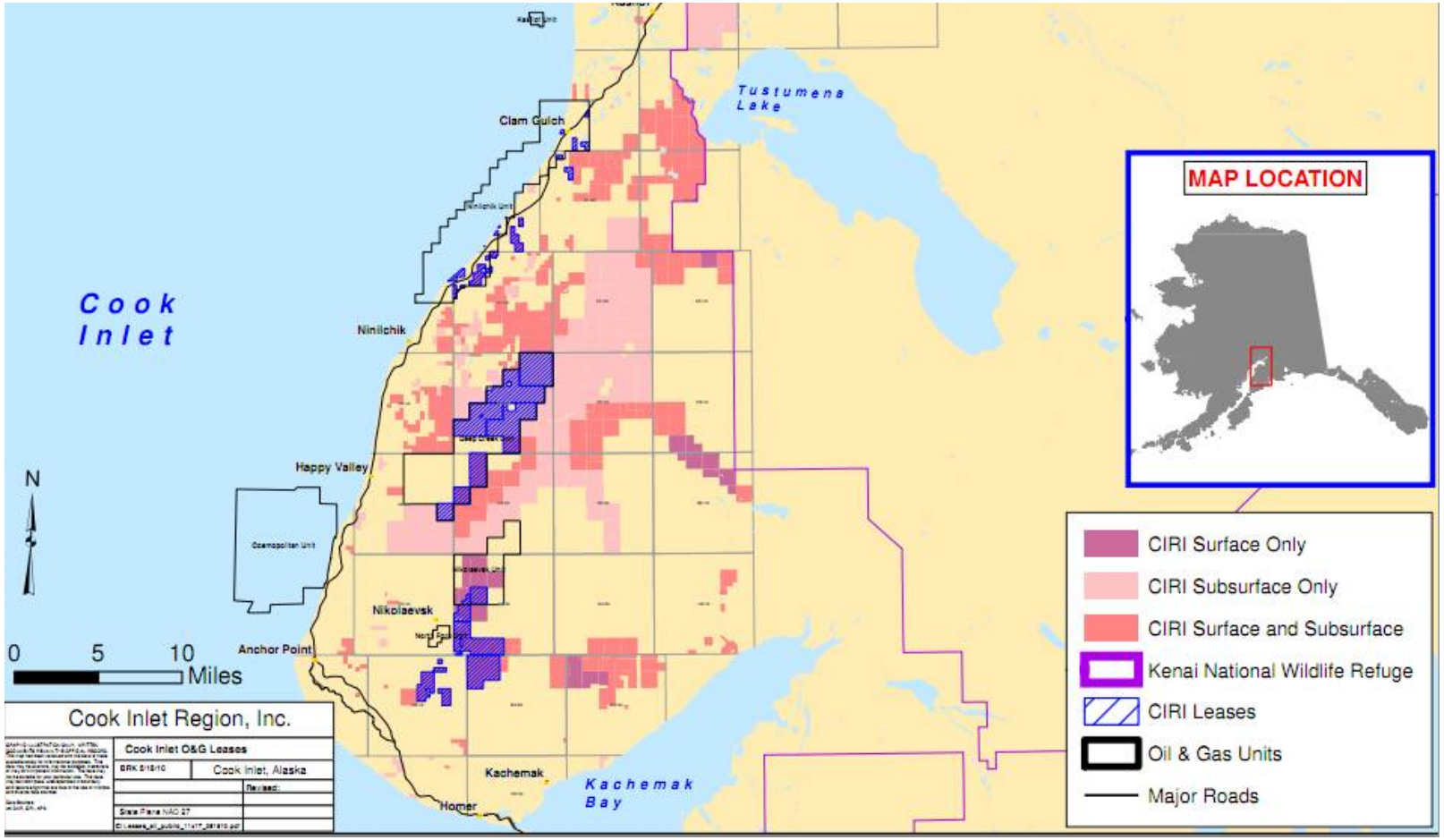
The map below shows Cook Inlet Region, Inc., oil and gas leases. This map and the following information is from CIRI's website (http://www.ciri.com/content/company/CookOilGas.aspx). CIRI is Southcentral Alaska's largest private landowner, with more than 750,000 acres of subsurface land in and around oil-producing regions on the Kenai Peninsula and the west side of Cook Inlet. CIRI is... is able to move more swiftly than larger public landowners and has the flexibility and financial strength to structure incentive options designed to encourage aggressive new oil and gas exploration. ...Cook Inlet gas has been considered "stranded" since its discovery in the 1950s, because global gas prices were not high enough to justify building a pipeline or other means of exporting the gas to external markets... Now, however, local demand will soon exceed known reserves, and Cook Inlet gas prices are increasing to match world energy prices. Higher prices will encourage gas exploration and production by making it more profitable for companies to find and develop new Cook Inlet area gas reserves. CIRI sees a window to encourage new Cook Inlet gas development before importation from outside the region becomes necessary, and is moving swiftly to attract new exploration entrants, including independent oil and gas companies.



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Ordinary high water (OHW)

(see also Agencies with responsibilities for watershed resources, Army Corps of Engineers, 404 permits , Wetland permits)

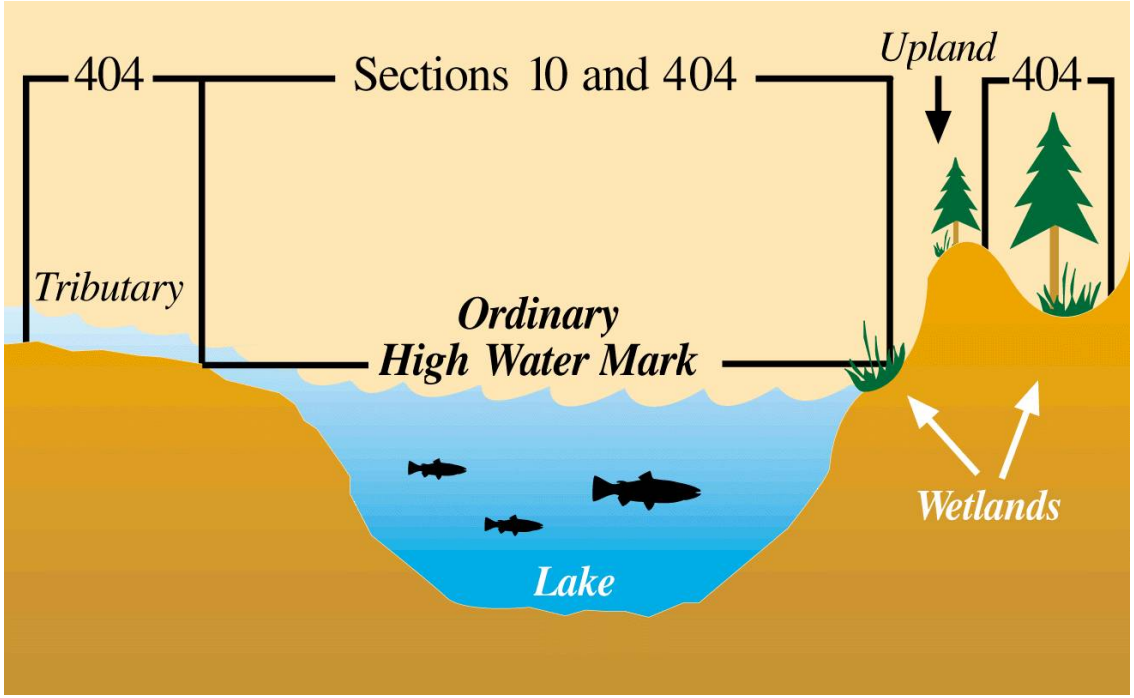
In order to protect anadromous fish and their habitats, ADF&G regulates activities that could affect conditions below ordinary high water (OHW). OHW is defined by state law as follows (see AS 41.17.950. Definitions, at: http://www.touchngo.com/lglcntr/akstats/Statutes/Title41/Chapter17/Section950.htm):

> "ordinary high water mark" means the mark along the bank or shore up to which the presence and action of the tidal or nontidal water are so common and usual, and so long continued in all ordinary years, as to leave a natural line impressed on the bank or shore and indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics.

The Army Corps of Engineers and the EPA also use the term ordinary high water, as the figure below shows. In the figure, 404 refers to Section 404 of the Clean Water Act, and Section 10 refers to Section 10 of the Rivers and Harbors Act. Here is a little more background and useful links to both of those sections:

- Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403) (links to Cornell University Law Library). Under this law a permit is required for any structure or work that takes place in, under, or over a navigable water, or wetlands adjacent to navigable waters of the United States.
- Section 404 of the Clean Water Act (33 U.S.C. 1344) (links to Cornell University Law Library). Under this law a permit is required for activities that involve a discharge of dredged or fill material into a water of the United States, including wetlands. Discharge activities that will drain or flood wetlands or significantly disturb the soils of a wetland also require a permit.

This link goes to a website where the Corps of Engineers permit program is explained in helpful detail: http://www.lrb.usace.army.mil/orgs/reg/reg-bro.htm.



A diagram showing an "ordinary high water" (OHW) mark (source: http://www.lrb.usace.army.mil/orgs/reg/reg-bro.htm).

Parr

(see also Fingerling, introductory article 1: Salmon species and life cycle)

This is the name of the salmon life stage between fry and smolt stages. This stage is generally reached by the end of the first summer. At this stage, the young salmon have distinctive parr marks—dark vertical bars on their sides that offer camouflage—and are actively feeding in fresh water.

This is a coho parr (photo from http://www.streamnet.org/SLCparr.html)

Partners for Fish and Wildlife Program

The National Partners for Fish and Wildlife Program (http://www.fws.gov/partners/) was established in 1987 to improve fish and wildlife habitat on non-federal lands. Beginning in 1995, the Partners for Fish and Wildlife Program has been active on the Kenai Peninsula, helping local landowners restore, enhance, and protect wetland, riparian, and instream habitats. Since 1995, US Fish and Wildlife has provided financial assistance and technical resources to install hundreds of projects benefiting peninsula rivers and streams and the salmon that use them.

Two programs are offered: Partners for Fish and Wildlife (see http://alaska.fws.gov/fisheries/fieldoffice/kenai/partners.htm and the Fish Passage Programs (http://alaska.fws.gov/fisheries/fieldoffice/kenai/fish_passage.htm). Through these, the Kenai Fish and Wildlife Field Office has developed partnerships with private landowners and the Cities of Kenai and Soldotna to restore and protect riverbanks and associated riparian habitat in Kenai, Kasilof, and Anchor River watersheds.

Peat

Peat is the partially decomposed remains of plants and animals that have accumulated in oxygen-poor, water-saturated, freshwater environments. In a water-logged environment that is poor in nutrients and oxygen, the organic debris is only partially broken down, resulting in peat rather than more fully decomposed humus. Peat is mainly composed of decaying sphagnum mosses and can be many feet deep.

Peatland

(Modified slightly from http://www.kenaiwetlands.net/EcosystemDescriptions/Intro.htm.) In terms of wetlands mapping on the Kenai Lowlands (see http://www.kenaiwetlands.net/), peatlands are defined as locations where peat has built up to a depth of 40 cm or more (about 18 inches). These wetlands are common and extensive on the Kenai Lowlands. Peatlands form where plant productivity is greater than decomposition. Productivity is moderate, but decomposition is low, due to interactions between a number of factors. The low oxygen content and pH of saturated soils combines with the sequestration of minerals and amino-nitrogen by spahgnan, to preserve dead plant remains (sphagnan is a chemical present in the cell walls of sphagnum moss). Plant remains accumulate as peat deposits, which may be many feet thick in places.

Peatlands can be classified into two categories: bogs and fens. Bogs are commonly defined as *ombrotrophic* systems, literally "fed by precipitation" or "cloud fed." Such ecosystems receive all of their water and nutrients from precipitation, rather than from streams, springs, or groundwater, and since rain is acidic and very low in nutrients, they are home to organisms tolerant of acidic, low-nutrient environments. The vegetation of ombrotrophic peatlands is often bog, dominated by sphagnum mosses. Bogs are rare on the Kenai, found locally within a few larger peatland systems. Bogs form when certain sphagnum mosses build up a layer of nearly undecomposed peat that holds a lens of groundwater above the local groundwater table. Because this sphagnum peat has very low hydraulic conductivity, nutrient poor precipitation stays nearly isolated from richer groundwater below. Bogs can build rapidly where precipitation is high and temperatures moderate—conditions that allow production to greatly exceed decomposition. These conditions are more common further south in Alaska.

Kenai peatlands are typically fens and poor fens, as the growing season is probably too short, and precipitation too low, for bog forming sphagnum mosses to thrive (not all sphagna are bog forming). Fen groundwater has had some recent contact with a mineral substrate, so is more nutrient rich than bog water, and fen peat is composed of sedges, shrubs, and forbs as well as mosses, including both bog-forming and non-bog forming sphagna. On the Kenai, tephra (volcanic ash) input is steady and this input along with marine aerosols, may create a more mineral rich precipitation, ameliorating bog conditions.

Permits

(see first: Agencies with responsibilities for watershed resources; then see Alaska Department of Fish and Game, Alaska Department of Environmental Conservation, and Corps of Engineers for specifics on obtaining permits from them; see also Anadromous Waters Catalog and Wetland permits)

(Formerly, the Alaska Coastal Management Program, or ACMP, coordinated all permit activities in the coastal zone—which in the KPB was all lands below 1000 ft in elevation. ACMP coordination enabled permit applicants to apply more efficiently to multiple agencies and enabled the public and other reviewers to track who was applying for what permits, and where. The Alaska legislature during the 2011 legislative session did not re-authorize funding for the ACMP, so this coordination no longer occurs.)

Getting permits may seem intimidating, but it is not as complicated as you may think. On the Kenai Peninsula, the Gilman River Center can help you determine what permits you need and from whom. Reviewing the watershedipedia entries suggested above and highlighted below will provide you with much of the background you need to make sense of the permitting process.

Permits generally serve one of two purposes. The first is to **protect places or resources of value**. For example, anadromous streams are valued because they provide habitats in which salmon reproduce and survive. As a result, they are are protected by several kinds of permits. For example, Title 16 permits from the Alaska Department of Fish and Game restrict what activities can be conducted below ordinary high water in anadromous streams, as well as when and how permitted activities can be conducted. Anadromous streams are also protected by permits from the Corps of Engineers and by ordinances passed by the Kenai Peninsula Borough. Water quality in anadromous streams (and other water bodies) is protected by permit programs of the Alaska Department of Environmental Conservation, Division of Water. Similarly, wetlands are valued because they provide functions such as storing floodwaters (see Flooding), filtering surface runoff, and supporting many kinds of fish and wildlife (see Wetland functions and values). As a result, they are protected by wetland permits from the Corps of Engineers; the Corps seeks input from EPA, other agencies, and the general public as it reviews applications for wetland permits. Critical Habitat Areas—such as the Anchor River-Fritz Creek CHA—provide examples of places protected because of their recognized values.

The other purpose served by permits is to **protect the environment—and society—from impacts** that are generally associated with particular kinds of activities. For example, large-scale construction activities that clear, disturb, and/or expose significant areas to erosion are likely to increase stormwater runoff

and related pollution, so the Alaska Department of Environmental Conservation regulates stormwater pollution from such activities (see Stormwater Pollution Prevention Plans). Similarly, DEC regulates other activities that can degrade water quality and, therefore, handles permits for wastewater systems and permits under the National Pollutant Discharge Elimination System (NPDES) (see Nonpoint source pollution). (For a list of current NPDES permits in Alaska, go to http://yosemite.epa.gov/r10/water.nsf/ NPDES+Permits/CurrentAK822.) Finally cities—such as Homer, Soldotna, and Kenai—regulate land uses within particular zoning districts to protect the environment, the public, and nearby landowners. The planning departments of these cities can help landowners identify what, if any, permits each city requires. (Go to the Wetland Who's Who for help in finding contact information: http://www.homerswcd.org/user-files/Wetland%20Whos%20Who%20July%202011.pdf).

Pink (humpy) salmon

(see introductory article 1: Salmon species and life cycle)

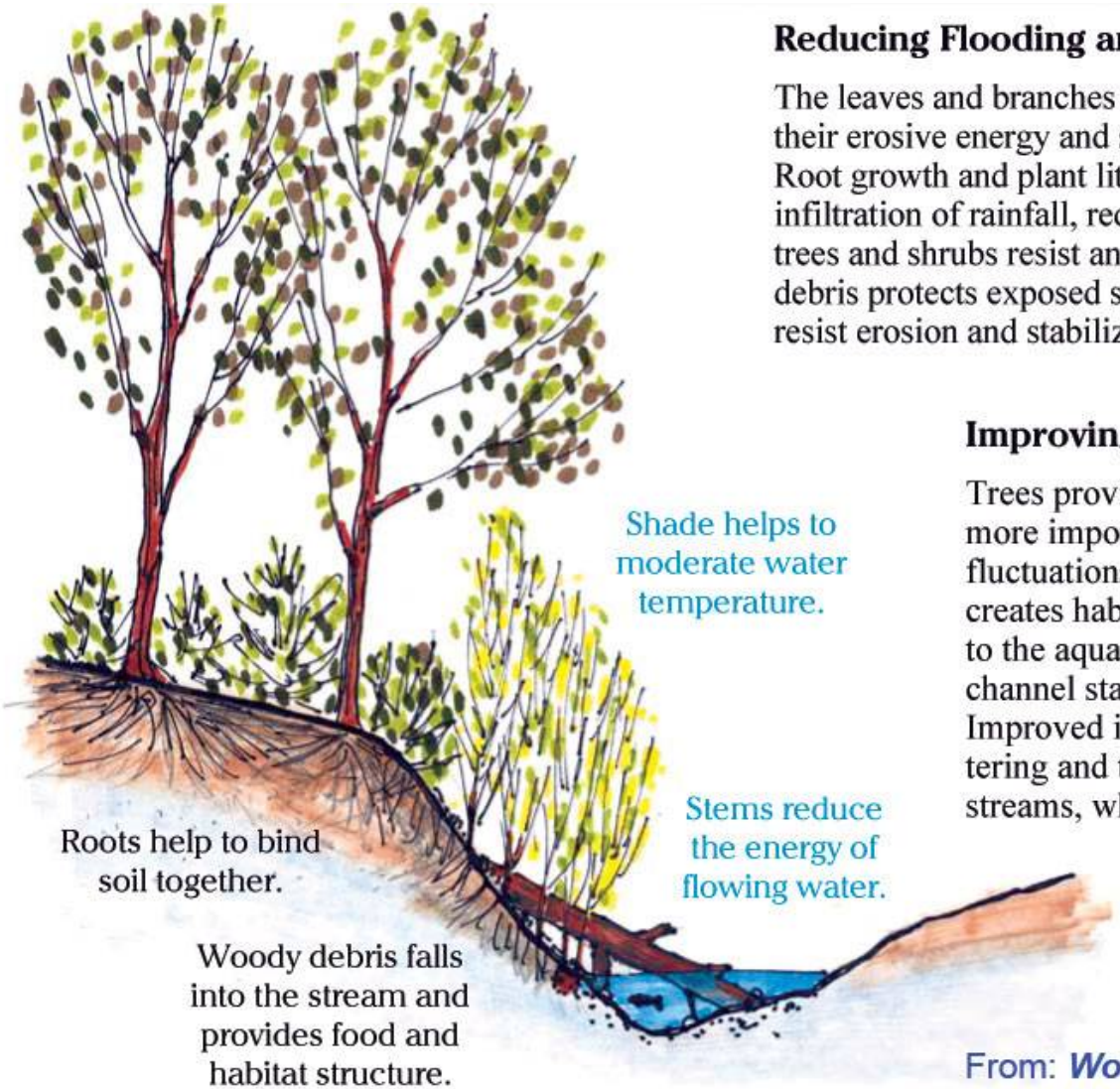
Plants

(see also Best Management Practices, Buffers, Infiltration, Interception, Soil bioengineering, Stormwater runoff, Stream temperature)

A salmon-friendly environment depends on healthy plant communities. Plants are Nature's way of doing many critical tasks, including:

- making the sun's energy available to other forms of life (by providing food for plant eaters and the creatures that eat them),
- building soils and preventing their erosion,
- minimizing flooding (see, for example, interception) and protecting water quality,
- stabilizing slopes—including streambanks,
- providing habitats for upland and aquatic organisms,
- storing carbon and releasing oxygen, and
- recycling many kinds of chemicals through ecosystems.

Some of the functions of plants are illustrated in the following drawings. These are from *Working Trees for Water Quality*, online at www.unl.edu/nac/brochures/wtwq/wtwq.pdf).



Reducing Flooding and Flood Damage

The leaves and branches of trees intercept rainfall, reducing their erosive energy and slowing the movement of rain water. Root growth and plant litter improve soil structure and enhance infiltration of rainfall, reducing surface runoff. Stiff stems of trees and shrubs resist and slow out-of-bank stream flow. Plant debris protects exposed soil and roots bind soil particles to resist erosion and stabilize slopes.

Improving Aquatic Habitat

Trees provide shade that reduces water temperature and, more importantly, prevents large and sudden temperature fluctuations. Trees supply debris to streams - large debris creates habitat structure and smaller detritus contributes to the aquatic food chain. Woody roots promote stream channel stability and permanence of habitat structure. Improved infiltration of runoff results in contaminant filtering and the gradual release of groundwater into streams, which helps maintain base flow.

From: ***Working Trees for Water Quality***
online at: www.unl.edu/nac/brochures/wtwq/wtwq.pdf

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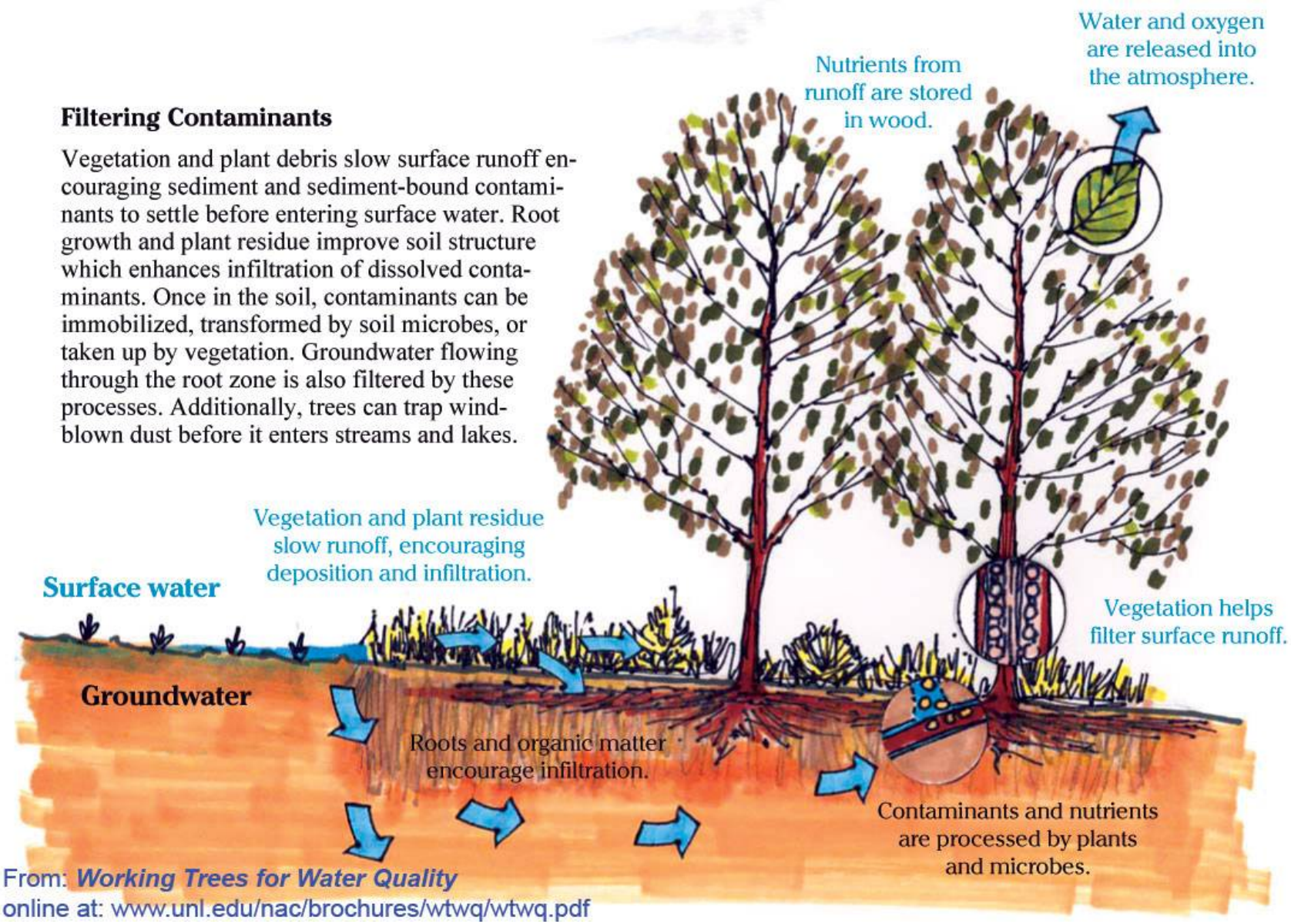
Filtering Contaminants

Vegetation and plant debris slow surface runoff encouraging sediment and sediment-bound contaminants to settle before entering surface water. Root growth and plant residue improve soil structure which enhances infiltration of dissolved contaminants. Once in the soil, contaminants can be immobilized, transformed by soil microbes, or taken up by vegetation. Groundwater flowing through the root zone is also filtered by these processes. Additionally, trees can trap windblown dust before it enters streams and lakes.



From: ***Working Trees for Water Quality***
online at: www.unl.edu/nac/brochures/wtwq/wtwq.pdf

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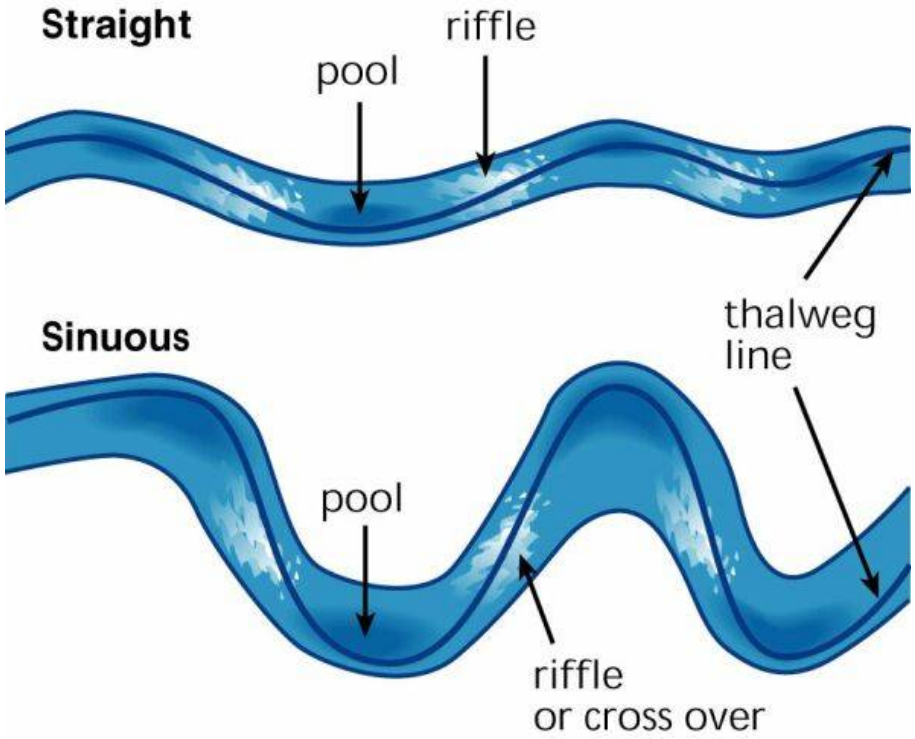
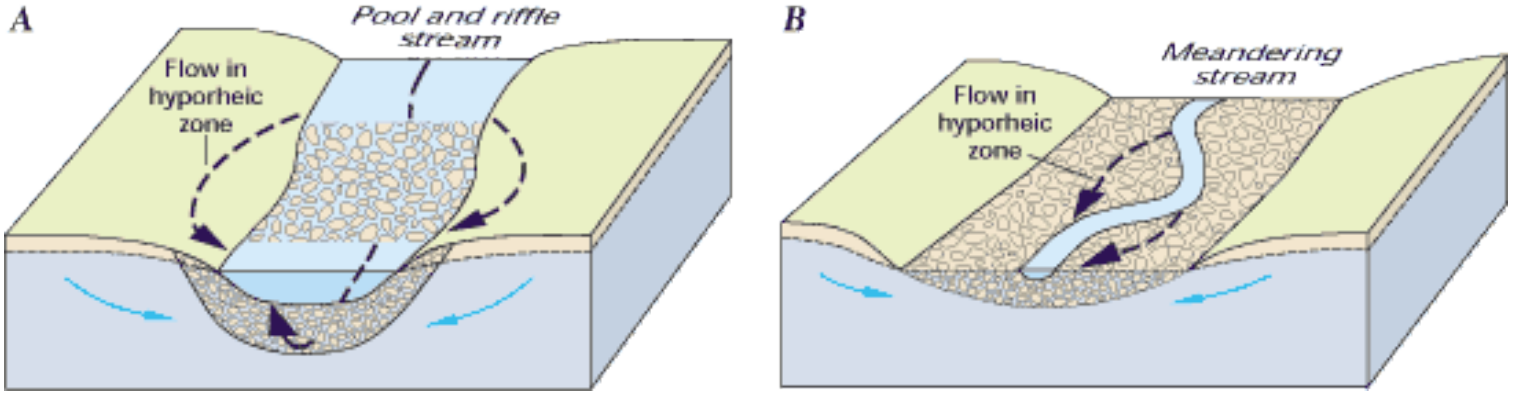
Pool and riffle channel pattern

(see also Hyporheic flow and zone, Meander, Sinuosity, Stream channel "anatomy," Stream channel processes)

As you read about salmon habitats, you'll run into references to *pool* and *riffle* streams or channel patterns. This describes stream channels in which shallow segments—riffles—alternate with deeper segments—pools. Riffles are shallow areas where water flows swiftly over completely or partially submerged obstructions to produce surface agitation (the *riffles*). Pools are areas with slower currents and often with water deeper than surrounding areas. Pools are typically formed behind dams (including large woody debris) and by scouring water that carves out a non-uniform depression in the channel bed. Because pools have slower currents and are less turbulent, finer sediments can settle onto the streambed in these areas. Other salmon habitat types include "runs," which are deep and fast areas with a defined thalweg and little surface agitation, and "plane-bed" areas, which are long stretches of a relatively featureless streambed without organized bedforms. Each of these channel habitat types can be associated with various stream-bank types—such as undercut banks or gravel banks—and with different kinds of vegetation. The **image at right** of pool and riffle patterns is from a fluvial geomorphology module at: http://www.fgmorph.com/fg_3_1.php.



Hyporheic zone in pool and riffle stream compared with in meandering stream; arrows show where streamflow tends to leave the stream channel and then return to it (from http://pubs.usgs.gov/circ/circ1139/htdocs/natural_processes_of_ground.htm).



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Raingarden

If you've ever watched water gurgling out of the downspout of a rain gutter, you begin to understand how much water comes off the roof during rainstorms or periods of snow melt. Rain and snow also run off driveways, walkways, and other impervious cover or compacted areas. Low-cut lawns are also a contributing problem. Stormwater will often carry pollutants collected from roads, driveways, and parking lots; and pollution is washed from industrial areas and just about any place harmful materials can collect. Along with whatever pollutants it brings, surface runoff will enter a city's storm ditches and drains, then flow downhill in ever increasing amounts as multiple sources combine, and eventually empty into local wetlands, streams, lakes and ponds—and finally—into Cook Inlet. Occasionally surface runoff will exceed the capacity of storm ditches and drains. Long-time residents of the Kenai Peninsula are likely to understand that this condition can increase flooding (like that seen in the Fall of 2002).

Image courtesy of Municipality of Anchorage

Procedures that reduce surface runoff will also reduce the risks of flooding and the offsite transport of pollutants. If the treatment promotes movement of rainwater and snow melt through the soil, it will also help filter surface runoff. Filtering will improve water quality, and contribute to the recharge of groundwater sources—which feed local drinking wells. Stormwater treatment processes can save money and provide significant benefits to the community, local wildlife, and environment.

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In order to help people take actions that will reduce and filter surface runoff, Homer Soil and Water has partnered with US Fish and Wildlife and the Natural Resources Conservation Service to establish a raingarden program in Homer. The program enables people to learn about raingardens and how to create them, as well as providing cost-sharing for landowners who establish raingardens. The program is modeled on the raingarden program in Anchorage, and many useful tips are available on their website http://www.anchorageraingardens.com.

So what exactly is a raingarden? A raingarden is simply a low area, or depression, in your landscape that's been altered so it will receive, hold, and filter rainwater and snowmelt running off your roof, driveway, lawn, or other impervious surfaces. Generally, a hole is excavated and bordered, then topsoil and sand are put back in, along with organic amendments. Usually, a lined channel or drain-pipe is placed to deliver runoff, then plants are added. Raingardens vary in size and scope, and can be anything from the simplest design to a true work of art. Several keys to installing a successful raingarden should be considered, so it's best to get informed and plan ahead. Properly locating and sizing your rain garden will ensure that bio-filtration occurs at an acceptable rate. Gardens that drain too quickly will leave plants thirsty, and those that don't drain well enough will create a perpetual pond. A good rule of thumb for sizing a raingarden in well-drained soils suggests that it be about 10 percent the size of the area that's delivering runoff. In soils that drain more slowly, raingardens should be closer to 20 percent of the area that contributes runoff. Recommended sizes for Kenai Peninsula rain gardens are larger than for Anchorage due to more precipitation and the likelihood of poorly drained soils. It's also important to locate your garden in an area that doesn't already pond with runoff. This indicates that the drainage will be inadequate even after amending the soil. For further design assistance and recommendations for a successful raingarden on the lower peninsula, consult the Anchorage Rain Gardens website, or contact the Homer Soil and Water Conservation District.

Modified bucket used to determine soil drainage properties.

Raingardens are a beautiful addition to any landscape!

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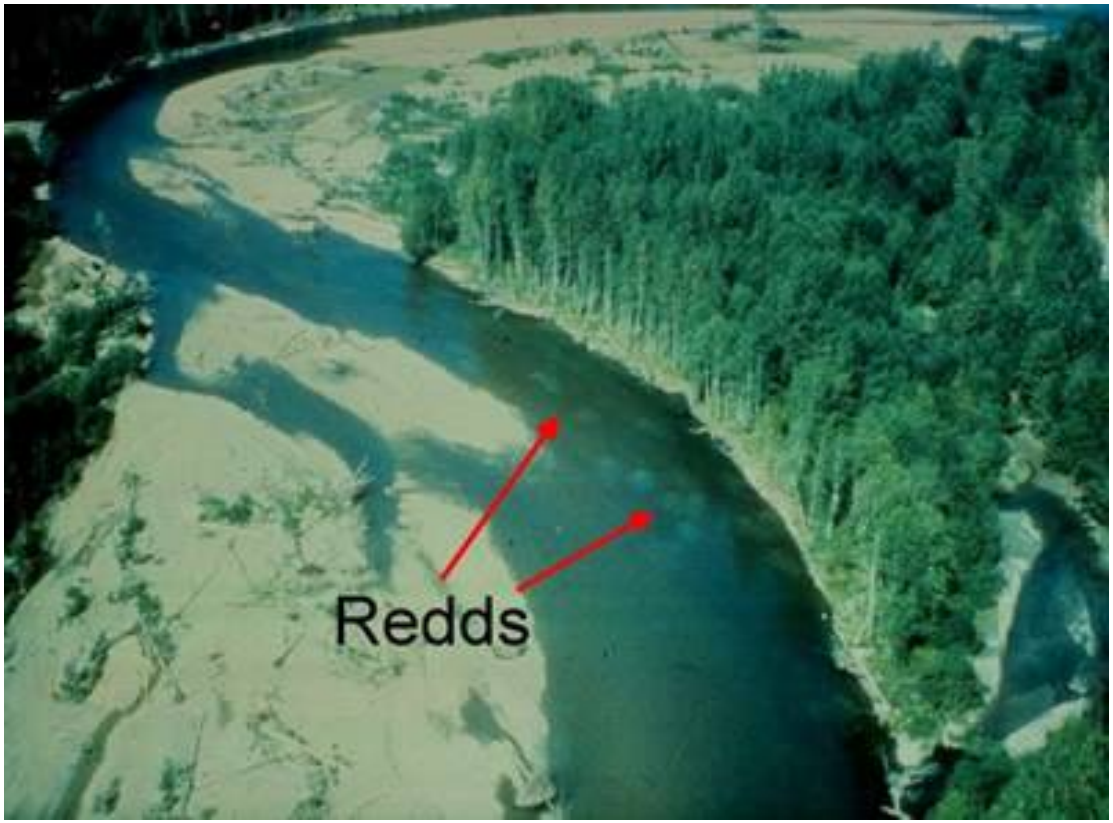
Redd

(see also Hyporheic flow and zone, introductory article 1: Salmon species and life cycle, Sediment, Stormwater runoff)

A redd is a nest (shallow depression) that the female salmon digs in the gravels of the stream channel and in which she lays her eggs. She digs out the depression by turning on her side and fanning her tail against the streambed. The currents created by her tail move streambed particles and scour out a shallow nest. After she digs one or more depressions, she releases her eggs, while a male simultaneously releases sperm, called milt. The size of a redd depends on the size of the fish making the nest, and different salmon species look for different size gravels for nest building.

Salmon eggs nestled in their gravel redd
(from: http://wdfw.wa.gov/wildwatch/salmoncam/hatchery.html)



After her fertilized eggs settle into the redd, the female then covers them with more streambed material, again by using her tail. This way the eggs can develop sheltered by gravel and oxygenated by water flowing through the nest. Different fish species choose different size sediments in which to build their redds. Chinook salmon dig their redds in streambeds with larger-sized gravels than do other salmon species. Dolly Varden and rainbow trout also dig redds.

(From http://wdfw.wa.gov/conservation/habitat/spawningbed_protection/redd.html.) In the **photo at left**, chinook redds can be seen in the riverbed along the curve next to the forested riparian area. They are the light colored areas in the water. Although they are apparent in this aerial photograph, they may be hard to see on the ground. Typically redds appear as lighter areas in the gravel, since the gravel has been cleaned by the female's tail during spawning activity, while the area around the redd appears darker due to the normal sediment and other biological material that remains on the undisturbed gravel.

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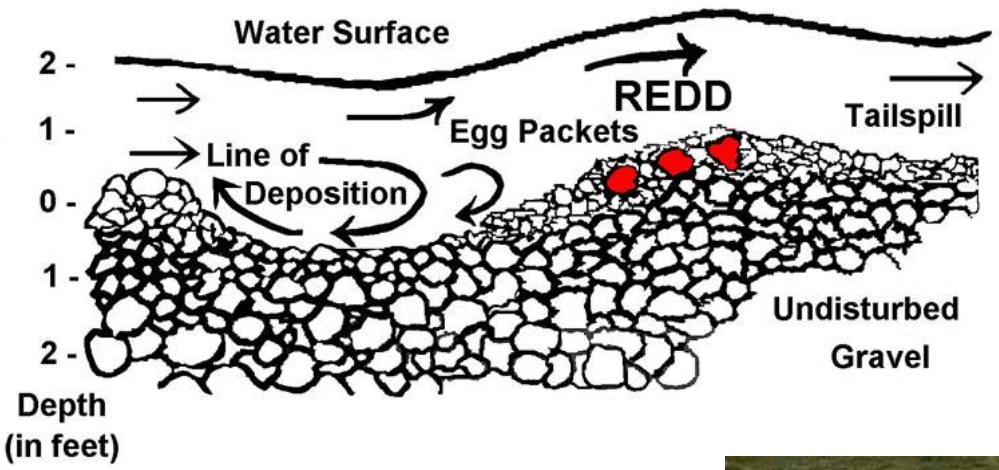

(From http://wdfw.wa.gov/conservation/habitat/spawningbed_protection/redd.html.) The drawing at left shows graphically what a typical redd looks like in profile. The downstream flow forces water through the gravel and across the buried eggs. This brings oxygen to the eggs and alevins, while moving waste products away. If the gravel becomes silted in, then this process cannot occur effectively. It can also be seen that the eggs and alevin are found relatively close to the surface. This places them in a situation where they can easily be dislodged from the nest and float downstream (see Stormwater runoff). If this happens, they are subject to predation or other mortality. The eggs or alevins are also vulnerable to crushing from humans or vehicular traffic. This can cause direct mortality.

The photo at right shows a redd
(source http://www.streamnet.org/SLCredd.html).

What landowner's can do: Be aware that redds may be located in streams you cross. As explained above, redds are fragile and can easily be destroyed by people, vehicles, or animals crossing on top of them or nearby. They can also be damaged by dislodged sediments settling into the redds, which can smother the eggs. Avoid walking across graveled areas that may contain redds. Gravel beds containing many redds will often show a distinctive pattern of depressions on their surface. Remember, gravels exposed during springtime low river flows may still have eggs safely incubating because of hyporheic flow.

Landowners can also help protect redds by taking steps to avoid causing erosion and to reduce stormwater runoff from their property (see Best Management Practices).

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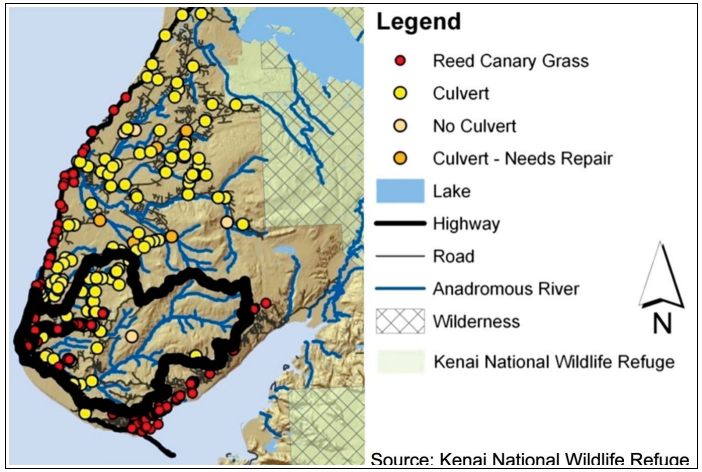
Reed canary grass
(see also Invasive plants)

Reed canary grass (RCG) has become a serious invader of salmon streams and wetlands on the Kenai Peninsula. It is particularly prevalent on the North Fork of the Anchor River (see **map at right** and under Invasive plants). In 2006, Homer Soil and Water identified 260 RCG populations, most of them associated with human disturbances such as boat launches, roads, bridges, culverts, and pastures; 51 infestations were in mapped wetlands. (Much of the information below is from a related HSWCD report, see http://www.homerswcd.org/invasives/FY07_RCGsummary.pdf.) Since then, RCG has spread along river corridors from many locations. Its invasive potential stems from its high capacity to set viable seed and to spread from rhizomes, as well as its rapid establishment following disturbance and ability to adapt to fluctuating water levels. Seeds can remain viable for 5-7 years in wetland sediments, and a dense network of rhizomes capable of excluding the growth of other species can form within a single growing season.



When RCG encroaches into stream channels, it can increase siltation of sand and gravel bars, reduce the active-channel area, and alter streamflow dynamics, all of which damage or eliminate salmon habitats. Infestations in narrow or slow stream channels can block salmon passage upstream or down. (A good article about RCG effects on salmon and an example of control efforts can be found at: http://www.kenaiwatershed.org/reedcanarygrass.html.) Habitats of many other species, including birds and small mammals, are also degraded or eliminated by dense stands of RCG. Control is difficult because RCG stands are so dense and must be mechanically controlled long enough to prevent new growth from seeds while other plants get established. Once desirable plants are dense enough, they shade out RCG seeds, which require adequate light to germinate. (Although RCG seeds can only get established in high-light gaps in plant canopies, rhizomes often extend into low-light areas.)

Photos from HSWCD report mentioned above.

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The following information about reed canary grass is modified from the species bio available at http://aknhp.uaa.alaska.edu/maps/akepic/.
Description: Reed canary grass is a robust, cool-season, sod-forming, perennial grass that produces culms from creeping rhizomes. Culms grow 15 to 152 ½ cm high. Leaf blades are flat, 5 to 15 cm long, and 6 to 12 ½ mm wide. Flowers are arranged in dense, branched panicles. Immature panicles are compact and resemble spikes, but open and become slightly spreading at anthesis. This species is morphologically variable, and more than ten varieties have been described.

Ecological impact: Reed canary grass forms dense, persistent, monotypic stands in wetlands and stream channels. These stands exclude and displace other plant species. Reed canary grass grows too densely to provide adequate cover for small mammals and waterfowl. Dense stands of reed canary grass promote silt deposition and the consequent constriction of waterways. Reed canary grass may alter soil hydrology. Reed canary grass is common in stream banks, spring margins, and wet meadows in southcentral Alaska (as well as many other parts of the state). It has ability to invade and dominate sedge meadows, wet marshes and other Kenai peninsula plant communities.

Reproduction and spread: Reed canary grass reproduces sexually by seeds and vegetatively from creeping rhizomes. Both rhizome fragments and seeds can be transported with the movement of water along streams and rivers.

Control recommendations: (from http://www.homerswcd.org/invasives/FY07 RCGsummary.pdf): Eradicating the smallest RCG populations (e.g., 1-5 plants) should be feasible by digging them out by their roots with a spade. The RCG root and rhizome network is dense but shallow (< 30 cm). Removing shoots without roots/rhizomes (by pulling or mowing) will not kill RCG. Somewhat larger patches (e.g., generally less than 100 sq m) may be treatable by covering with opaque tarps (or other covers) for several growing seasons. By eliminating light, the rhizome and root system will eventually be starved of needed carbohydrates from the leaves. This treatment will likely be most effective if the population is mowed first to aid in installing the tarp. Maintaining tarps over populations that are too large, or on sites that are too unstable (e.g., river channels), may not be feasible over multiple growing seasons. Combining careful herbicide treatment (using herbicides safe for aquatic systems) with burning or disking have been part of effective prescriptions for RCG reductions developed at the stand-scale in other states. Restoring invaded sites such as streambanks, floodplains, and wetland edges requires reducing the effects of the stressors (e.g., disturbances) that induced the invasion, eradicating RCG, and promoting revegetation of the desired plant community. Actions that will likely increase abnormal flood pulsing or increase nutrient runoff into riparian areas will likely increase the abundance of RCG and should be avoided. (This is another reason for landowners to use Best Management Practices and Low Impact Development techniques to maintain natural runoff patterns.) Areas with persistent nutrient inputs or abnormal hydrology should be considered poor candidates for restoration, since these conditions favor RCG. Sites with nearby RCG propagule sources (especially upstream) will be prone to reinvasion and are therefore also poor candidates for full restoration. To minimize the chance of RCG re-invasion, treated areas need to be revegetated (unless RCG removal was of just a few plants). Closing the canopy rapidly should be an initial aim. Infested riparian areas on the Kenai Peninsula could be planted with woody species such as alders or willows from adjacent stands. On potentially unstable streambanks, willows could be installed as brush mattresses and allowed to adventitiously root (see Soil bioengineering). Many sites, including streambanks, could be seeded with local native bluejoint grass (*Calamagrostis canadensis*). Bluejoint seeds could be collected from adjacent areas or bluejoint hay could be spread. For the first 3-5 years, revegetated areas should be scouted for RCG. Emerging plants are often best controlled by hand pulling.

Relict glacial drainageway wetland ecosystem
(see Drainageway wetland ecosystem, Peat, Peatlands, Fens)

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Relict glacial lakebed wetland ecosystem

(see also Glacial history of the western Kenai Peninsula, Landforms)

Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands and is represented on these maps by the code "LB" (for "lakebed"). Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia listing for wetland functions and values. For background on wetlands, including how wetlands are defined by the Army Corps of Engineers and other regulatory agencies, see the watershedipedia listing for wetlands.

(Slightly modified from http://www.kenaiwetlands.net/EcosystemDescriptions/Lakebed.htm.) **Relict Glacial Lakebed** wetlands are extensive peatlands occurring on expansive flat surfaces that were formerly occupied by large proglacial lakes. Peatlands develop on these surfaces through a process known as "primary peat formation," which is responsible for most of the peatlands on earth. Primary peat formation proceeds where a marshy area gradually fills with peat. A second, less common process of peat formation is lake infilling, which is a process typical of ice-block depression wetlands (Kettle, Depression, and Spring Fen wetlands). The third peat-forming process is paludification, where sphagnum peat invades upland surfaces.

Relict Lakebed peatlands are mostly fens, often with patterning. The patterns consist of low-lying pools, which can dry up seasonally to form mud-bottoms (flarks) and intervening strangs (low shrubby ridges). Tree islands often form. Tree islands are often areas where bog peat is forming on top of the fen peat. Bogs are almost completely absent from wetlands mapped on the Kenai Lowlands. This may be due to the nearly constant supply of tephra (volcanic ash) to the Kenai. The tephra contains some calcium, which may prohibit germination of sphagnum mosses that initiate bog formation.

Relict Glacial Lakebed peatlands are larger than Kettles, which also form on abandoned lakebeds. The centers of large Lakebed peatlands are far removed from uplands, so surface water runoff originating from mineral sources appears distant. However, the mineral soil is never more than several meters away, beneath the peatland. Some fens receive groundwater discharge from beneath, through sandy underlying sediments.

Photo at right: A Relict Lakebed peatland north of Beaver Lakes. Patterning is evident with low-lying pools and sedge-dominated areas, higher shrubby "strangs" and tree islands.

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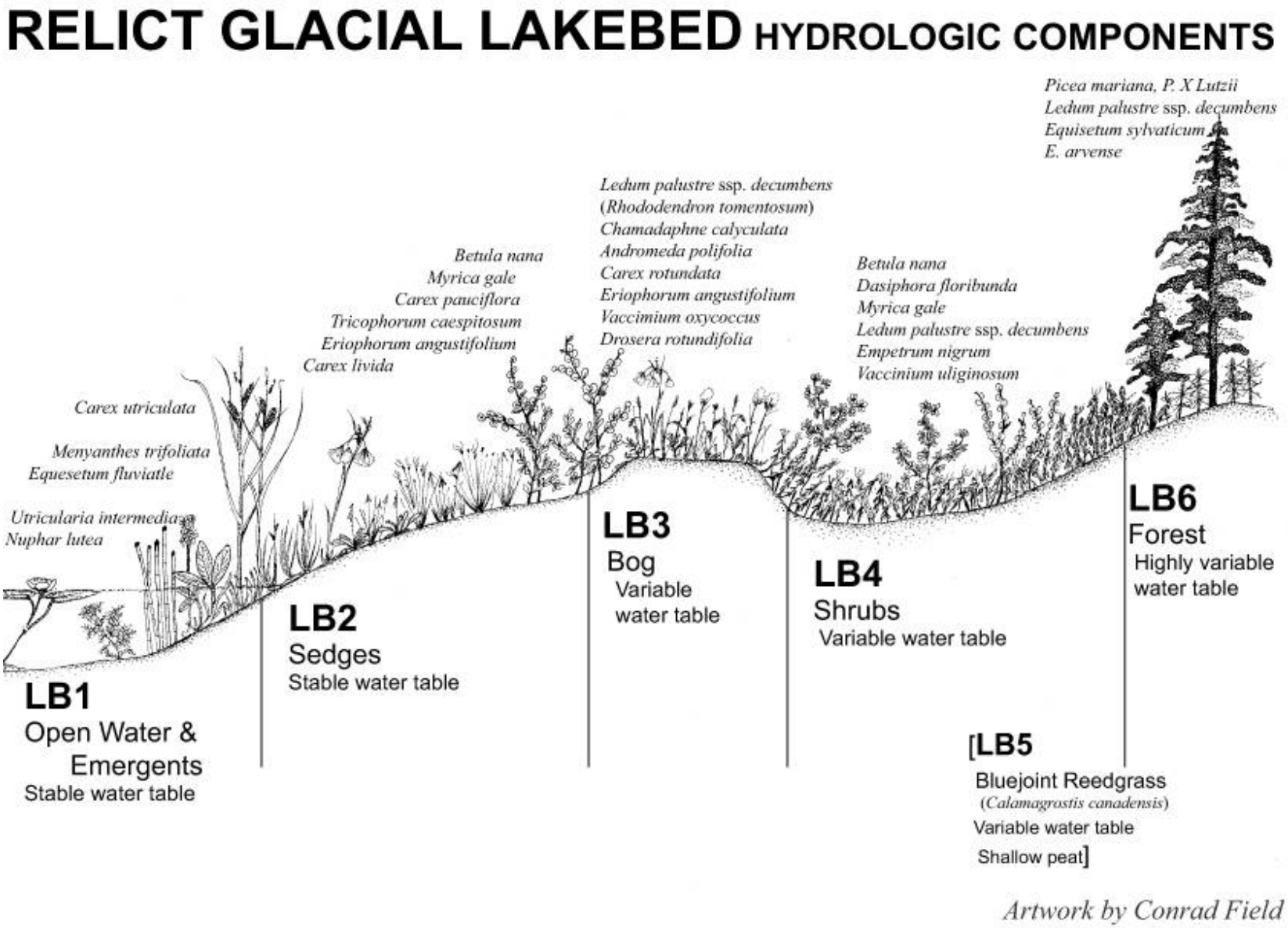
An idealized version of a Relict Glacial Lakebed wetland. Drawing by Conrad Field.



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Riparian

(See also Riparian ecosystem, Stream channel processes,)

Riparian means along a stream, river, or lake. There's no standard way of determining how wide a riparian area is, that's often a function of why you're looking at a particular riparian area. However, you'd certainly be justified in calling any area *riparian* that's within the zone where a stream's or lake's hyporheic flow affects plant species and/or growth.

(Slightly modified from http://www.nap.edu/openbook.php?record_id=10327&page=49 or Riparian Areas: Functions and Strategies for Management (2002).) Generally the interaction of many climatic, hydrologic, geomorphic, and biological factors shape riparian environments. For example, differences in climate dictate the seasonality of the hydrologic cycle and determine the timing and intensity of flooding. Watershed features such as the slope of the land, size of the watershed, storage capacity of the soil, and supplies of groundwater and sediment interact with climate to modulate or amplify these effects. Within the riparian area itself, further sources of variation can be found in channel morphology (see Stream channel "anatomy"), sediment dynamics, and floodplain structure. Ultimately, all these factors influence species composition and riparian biodiversity.

Photo at right: a willow-dominated riparian area along Beaver Creek. Beaver Creek is a tributary of the Anchor River (source HSWCD).

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Riparian ecosystem

Because of their effects on water flows, water quality, and plant and animal communities, wetlands play important roles in keeping watersheds salmon-friendly. This is one of ten main wetland ecosystem types identified and mapped on the Kenai Lowlands and is represented on these maps by the code "R" (for "riparian"). Each kind of wetland ecosystem is discussed in detail at http://www.kenaiwetlands.net, and information below is from that source. Functions of different kinds of wetlands are being identified and assessed now in a project funded by the EPA and coordinated by the Homer Soil and Water Conservation District. For more information on that project, go to: http://www.homerswcd.org/projects/wetlands.php or see the watershedipedia listing for wetland functions and values. For background on wetlands, including how wetlands are defined by the Army Corps of Engineers and other regulatory agencies, see the watershedipedia listing for wetlands.

(Slightly modified from http://www.kenaiwetlands.net/EcosystemDescriptions/Riparian.htm.) **Riparian ecosystem** wetlands are stream channels exhibiting a bed-and-bank morphology (that is, a discernible stream channel with streambanks on either side) and their associated valley bottoms. Valleys are various: some are carved by modern streams eroding their channels through either ancient glacial till or Tertiary bedrock sediments. Others were created by Pleistocene glaciofluvial processes (see Glacial history of the western Kenai Peninsula). Still others—like the Kenai and Kasilof River valleys—are carved by rivers still fed by glaciers.

Many Kenai Lowlands streams and rivers—including the Anchor and Ninilchik Rivers and Deep and Stariski Creeks—are fed by precipitation and groundwater and flow over a mantle of glacial till. Till overlies poorly lithified Tertiary bedrock sediments, and the upper reaches of many streams south of Clam Gulch have incised deep valleys into this easily eroded bedrock.

Whether still fed by existing glaciers or not, the drainage basins of all streams and rivers in the Kenai Lowlands have been profoundly affected by repeated glaciations (see Glacial history of the western Kenai Peninsula). Many streams follow circuitous courses from their headwaters to Cook Inlet. Stream courses often change direction suddenly when they encounter barriers, such as moraines or terraces. The Anchor River valley turns abruptly to the northwest just 2 miles before reaching Cook Inlet, continuing an additional 7 miles around a moraine before finally emptying into the inlet. The Ninilchik River follows a southwesterly course nearly parallel to the coast for over 15 miles before turning to the northwest at the edge of a terrace, and running its final 3 miles to the inlet. The highly underfit upper reaches of the Ninilchik River meander crazily through a river valley carved by much larger flows draining from melting glaciers.

Compared to much larger rivers throughout the state (the Yukon River being by far the longest and largest), rivers and streams on the southern Kenai Lowlands are relatively small and have short runs from their headwaters to their outlets in Cook Inlet. For example, the Anchor River watershed is just over 60 miles in length as the crow flies (not as the river meanders); Deep Creek watershed is only about 40 miles long, and both Ninilchik River and Stariski Creek have watersheds only about 26 miles long. Even the peninsula's longest and most impressive river, the Kenai, has a watershed not much over 80 miles from the outlet of Kenai Lake to the river's mouth at Cook Inlet. As a result, river basin features and processes act on a smaller scale than on larger river systems. Channels in these four streams exhibit relatively little braiding. (as compared to, for instance, Fox River and Sheep Creek at the head of Kachemak Bay).

Kenai Lowlands stream valleys are frequently underfit, cut by large braided Pleistocene glacier-fed rivers. Sluggish single-thread streams on Pleistocene river-deposited sediments were left far from steep valley walls after the ice retreated. A few valleys were cut during the late Wisconsin glaciation by possible catastrophic release of ice-dammed waters of glacially impounded lakes within what is now Cook Inlet. Many wide, underfit valley bottoms do flood and serve the storage and groundwater recharge function of floodplain wetlands, but they do not function as typical active floodplains which cut banks and create point

bars and terraces. Many are sluggish, linear, pool-dominated channels cut through peat.

Other streams are not underfit; they are entrenched in steeper Tertiary bedrock or thin discontinuous till, primarily south of Clam Gulch. These streams originate above the limits of late-Wisconsin glacial till: at headwater fen outflows; in till on high pre-Wisconsin plateaus; or as springs originating in Tertiary bedrock or thin early-Wisconsin till. When they reach lower-elevation late-Wisconsin till, they often alter course and character as they flow along terraces, across peatlands on relict glacial lakebeds, or into relict ice-marginal drainageways.

Stream Classification (see also Stream channel "anatomy")
We classify streams and their associated valley wetlands together as a wetland polygon feature; we don't delineate streams separately as waterbodies. We use Rosgen's river classification (Rosgen and Silvey, 1996) a basis to classify stream reaches and their associated valley bottom wetlands because it is well known, and provides more information then simple stream order. We use a modification of Level I, which has seven classes, three of which are common on the lowlands: Types B, C and E (Figure 1.):

- B reaches are moderately entrenched, riffle-dominated upper reaches with narrow fringe wetlands;
- C reaches possess riffle/pool morphology with point bars and broad fringe wetlands on floodplains; and
- E reaches (E for "evolutionary") are slightly entrenched, stable, pool-dominated channels within relict glacial channels (underfit) supporting wide stream fringe wetlands.

Summary of Riparian Ecosystem Map units:
AMT- Abandoned meander terraces and channels. Limited to a few reaches along the Kenai and Kasilof Rivers.
REl- Linear, low gradient, pool dominated, on glacial deposits.
REs- Sinuous, low gradient, pool dominated, on glacial deposits.
REb- Bank-full due to beaver dam, roads, logging debris or natural obstruction. Low gradient, on glacial deposits.
REa- Stream surface not discernible on 1:25,000 B&W aerial photography. Usually low gradient, pool dominated, but occasionally would fit the B reach type. On glacial deposits.
RB- Higher gradient (>2%); riffle dominated.
RC- Floodplain developed. Point bars. Riffle/pool morphology.
RDA- Multiple braided, low gradient, pool-dominated channels on glacial deposits.
Rt- Tidally influenced river or stream. Usually too small to map but extends about a mile on larger streams, and several miles on the Kasilof and Kenai Rivers.

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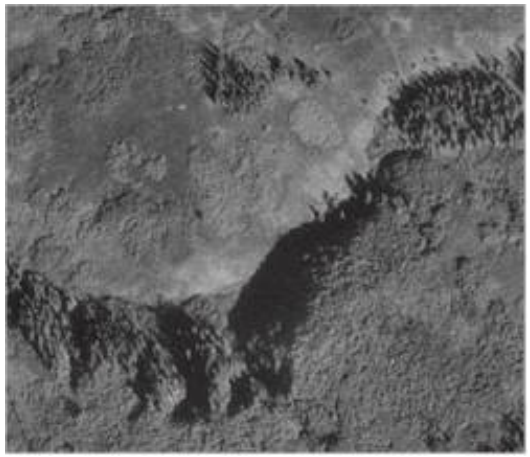
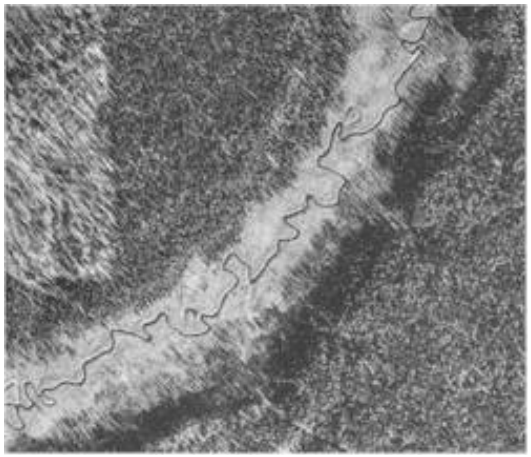
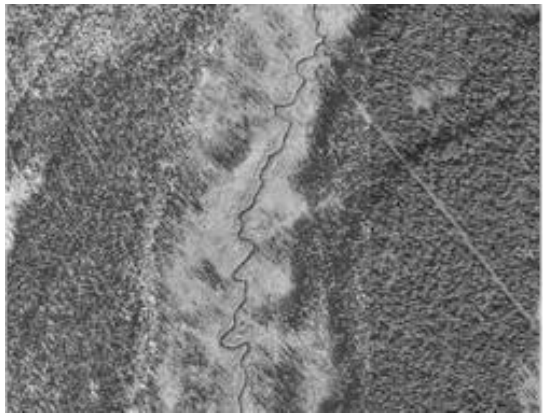
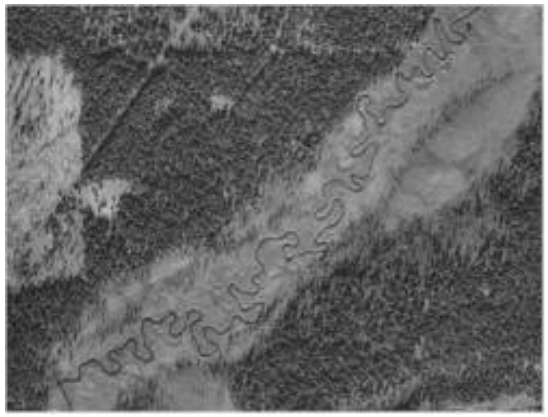
Type B stream draining the Epperson Knob area on the southern Lowlands.	**Type C** stream. Deep Creek, E of the Sterling Highway.	**Type E** stream. The middle Ninilchik River.
		

Sub-type El stream reach; middle Ninilchik River. Sinuosity = 1.23	**Sub-type Es** stream reach; middle Stariski Creek. Sinuosity = 2.52	**Sub-type Eb** stream reach; Soldotna Creek.
		

The images above show common stream types found in the Kenai Lowlands.

A fourth type, DA, is used to describe a small, multiple channel stream reach and associated wetlands as the reach fans out onto a glacial terrace, usually in a peatland. Steep, entrenched 'A' stream reaches, with rapids, waterfalls, and narrow associated wetland margins, occur along a few streams flowing into Kachemak Bay, such as McNeil and Falls Creek.

On the Kenai Lowlands many streams begin as B types, especially south of Clam Gulch. They are moderately entrenched, post-glacial features. At level II in Rosgen's classification, the dominant types are B4—with moderately steep valley walls and beds dominated by gravels—and B3—over cobbles.

On many upper B stream reaches, a steeper, more entrenched upper valley abruptly becomes narrower and less entrenched. This marked change in valley cross-section occurs where a glacial advance pushed material part way up the valley, sometimes changing the stream's course. This processes can easily be observed east of Homer, along the south slope of Bald Mountain where a late-Wisconsin (Killey) glacial advance stopped well below the summit (see glaciation section). The upper valleys are steep and their streams well entrenched. Downstream, the valleys abruptly flatten, and still further downstream, they change course abruptly to the west when they encounter the moraine that Hutler Road follows.

Type B reaches frequently flow into Type E reaches. E reaches on the Kenai are slightly entrenched, stable, low gradient pool-dominated reaches with low width/depth ratios, densely vegetated banks, and low sinuosity (though the typical Rosgen E reach has high sinuosity) and narrow active floodplains. Although many E reaches have narrow active floodplains and stable banks, occasional abandoned channels and oxbows are evident, and steep valley walls are distant from the channel.

Type E reaches occur on relict glacial deposits, within wide valley bottoms cut by large amounts of Pleistocene glacial meltwater, or on relict glacial lakebeds. A good example of a type E reach is the upper portion of the Ninilchik River, which flows along a terrace. The most common reach types are E3 and E4 at level II in Rosgen's classification, with cobble or gravel beds, respectively.

Type E reaches typically flow into C reaches, which are characterized by a broad floodplain with well-developed sinuosity, riffle-and-pool morphology, and point bars. C reaches can also flow in broad Pleistocene drainageways, but have point bars, floodplains and, on the Kenai Lowlands, greater sinuosity than typical E reaches. At Rosgen's level II, the dominant types are C3 (on cobbles) and C4 (on gravels). Stream type is independent of stream size; smaller C streams can flow into larger C steams.

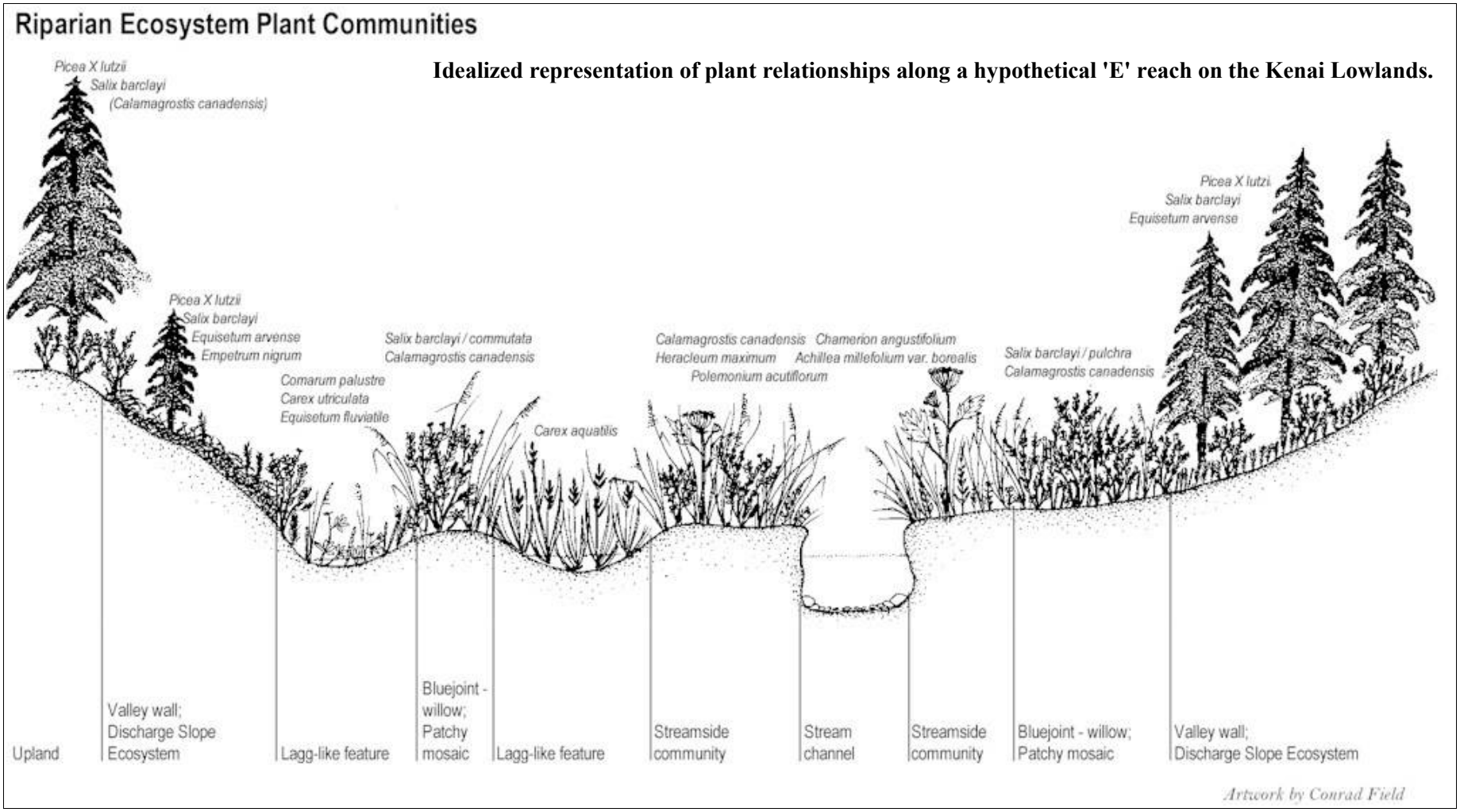
The lower reaches of the Anchor and Ninilchik Rivers, and Deep Creek are good examples of C reaches on the Kenai Lowlands, where terrace building and steep bank erosion on a broad floodplain is common. On smaller type C reaches, such as lower Stariski Creek, the floodplain is narrower, not as active, and the underfit nature of the stream is more evident.

Frequently, B reaches will flow directly into C reaches with no intermediate E reach. Short run B reaches are also common along the coastal bluffs. Streams are frequently heterogeneous. An E reach on a terrace tread will flow into a C or B reach across a riser then back to an E reach on a lower tread without a change in stream order.

Two Riparian ecosystem mapping components are not part of Rosgen's classification. These are tidally influenced river reaches (Tr) and abandoned meander terraces and channels (AMT). Tidally influenced reaches have a salinity of greater than about 0.5 parts per thousand on the highest spring tides. The exact spot on each western peninsula stream where this occurs has not been reported; we rely on local knowledge, especially Robert Begich and Larry Marsh of the

Alaska Department of Fish and Game, to map Tr units. Most streams are relatively small, steep and short run, and have a tidally influenced component too small to map at 1:25,000. On the large glacier-fed streams, the Kenai and Kasilof Rivers, the tidal influence extends for miles upstream.

The second mapping component that is not part of Rosgen's classification but is included in our Riparian Ecosystem are Abandoned Meander Terraces and Channels (AMT). These are relict features, created when the glacier-fed rivers were larger, or outburst floods more intense. These features, which are limited to a few lower reaches of the two glacier-fed streams, are now occupied by peatlands.



River Center
(see Gilman River Center)

Runoff
(see Stormwater runoff, Surface runoff)

Salmon fry
(see also introductory article 1: Salmon species and life cycle)
After salmon emerge from the gravels where they hatched, they are called fry. Fry that have just emerged from their nursery gravels are very small, smaller than a paper clip. This is the life stage between the alevin and fingerling stages.

Salmon habitat
(see introductory article 1: Salmon species and life cycle)

Salmon species and life cycle
(See introductory article 1: Salmon species and life cycle)
Three species of salmon are found in the Anchor River, Deep Creek, Ninilchik River, and Stariski Creek systems: king salmon (also called chinook), coho salmon (also called silvers), and pink salmon (sometimes called "humpies"). These rivers also support Dolly Varden and steelhead, as well as other fish species. For beautiful photographic explorations with the salmon, go to http://www.oneworldjourneys.com/expeditions/salmon/, click on "Join the Expedition Now," and choose "Saga of the Salmon" (http://www.oneworldjourneys.com/salmon/low/saga/index.html) or one of the other interesting choices).

Salmon-safe certification
Salmon-safe (http://www.salmonsafe.org/) is a program that provides an example of a collaborative way for many groups and individuals to work together to protect salmon throughout their watersheds. Founded by Pacific Rivers Council, Salmon-Safe is now an independent 501(c)3 nonprofit based in Portland. Their mission is to transform land management practices so Pacific salmon can thrive in West Coast watersheds.

Salmon-Safe works across the West Coast through a Partner Network. Established at the Salmon-Safe Summit in 2007, the Partner Network consists of place-based conservation organizations, as well as collaborating certification organizations. These partners have created certification programs that certify qualified businesses as "Salmon safe." Founding organizations—Stewardship Partners, Oregon Tilth, LIVE, Marin Organic, Applegate River Watershed Council, NBIS and National Fish & Wildlife Foundation—have been joined by Vinea and Trout Unlimited. Salmon-Safe seeks to extend the range of the Network in key agricultural and urban watersheds throughout the West Coast range of Pacific salmon. In 2010, Salmon-Safe joined with two leading Canadian conservation organizations, Pacific Salmon Foundation and Fraser Basin Council, to expand Salmon-Safe certification across British Columbia. You can watch a video about the Salmon Safe program called *Salmon Safe—Save Wild Salmon* at http://www.salmonsafe.org/blog/new-salmon-safe-video-save-wild-salmon.

Salmon stewardship
Salmon stewardship consists of learning about salmon populations and habitats and then acting in ways that contribute to their health and sustainability. The term has evolved to include the idea that humans have a responsibility to look after other species on the planet, now and for future generations.

Below are listed a few examples of organizations that promote salmon stewardship. These provide models that local landowners can use in coming up with salmon stewardship programs for Anchor River , Deep Creek, Ninilchik River, and Stariski Creek watersheds.

- The Quatse Salmon Stewardship Centre (http://www.thesalmoncentre.org/index.php), operated by the Northern Vancouver Island Salmonid Enhancement Association, is a non-profit organization dedicated to salmon conservation and education on northern Vancouver Island.
- Together, the Pacific Science Center (http://www.pacificsciencecenter.org/), Seattle, and the Mercer Slough Environmental Education Center, Bellevue (http://www.pacificsciencecenter.org/Mercer-Slough/slough) have developed a program to teach students in 4th to 6th grades to become salmon stewards, see: http://www.pacificsciencecenter.org/Mercer-Slough/salmon-stewards.html.
- The Stream Team (http://www.streamteam.info/) is an education-to-action program for people interested in protecting and enhancing Puget Sound and its streams, rivers, and lakes. The Stream Team trains volunteer salmon stewards (for example, see http://tumwater.komonews.com/news/environment/salmon-stewards-wanted-south-sound/655779.)
- The city of Olympia, WA, conducts a program to train salmon stewards (http://olympiawa.gov/events-and-activities/classes-and-activities/Sound-Stewards.aspx). Trained stewards are stationed at salmon-viewing locations so that they can interact one-on-one with visitors who have come to watch salmon.
- Whidby Watershed Stewards (http://www.whidbeywatersheds.org/salmon.html) promote the health and vitality of South Whidbey Island's watersheds and nearshores for the people and environment of Puget Sound by linking water, land, wildlife and people on Whidbey Island through education, research, and restoration (http://www.whidbeywatersheds.org/index.html).
- The Salmonid Restoration Federation (SRF) (http://www.calsalmon.org/) was formed in 1986 to help stream restoration practitioners advance the art and science of restoration. SRF promotes restoration, stewardship, and recovery of California native salmon, steelhead and trout populations through education, collaboration, and advocacy. They provide an excellent list of educational resources at http://www.calsalmon.org/resources/watershed-and-salmon-education.

Salmon watcher program (an example from Washington)

King and Snohomish Counties, Washington, operate a volunteer "salmon watcher" program that provides one model landowners can consider if interested in being more involved in helping learn about and understand local salmon populations and their needs. As explained at its website (http://www.kingcounty.gov/environment/animalsandplants/salmon-and-trout/salmon-watchers.aspx), Salmon Watcher is a multi-jurisdictional effort focused at protecting a Pacific Northwest treasure and educating the community in the process. The 16-year-old program involves volunteers watching streams for spawning salmon in King and Snohomish Counties. Dedicated salmon-watcher volunteers watch for fish on their assigned creeks two times a week during spawning. The information they collect helps identify where salmon are spawning and sometimes where barriers exist to salmon migration. Volunteers act as "eyes and ears" in the watersheds and give a heads up when things go awry in neighborhood creeks.

Sand

(see also Soil texture)

Sand particles are the largest of the three soil separates, ranging in size from 0.05 mm to 2.0 mm in diameter. Sand particles can be further divided into five categories, ranging from very fine sand to very coarse sand. Sand particles are visible to the naked eye, and you can feel the individual grains of sand with your fingers. They are often composed of the mineral quartz, SiO2, although other minerals may be present. The dominance of quartz means that sands contain little in the way of plant nutrients.

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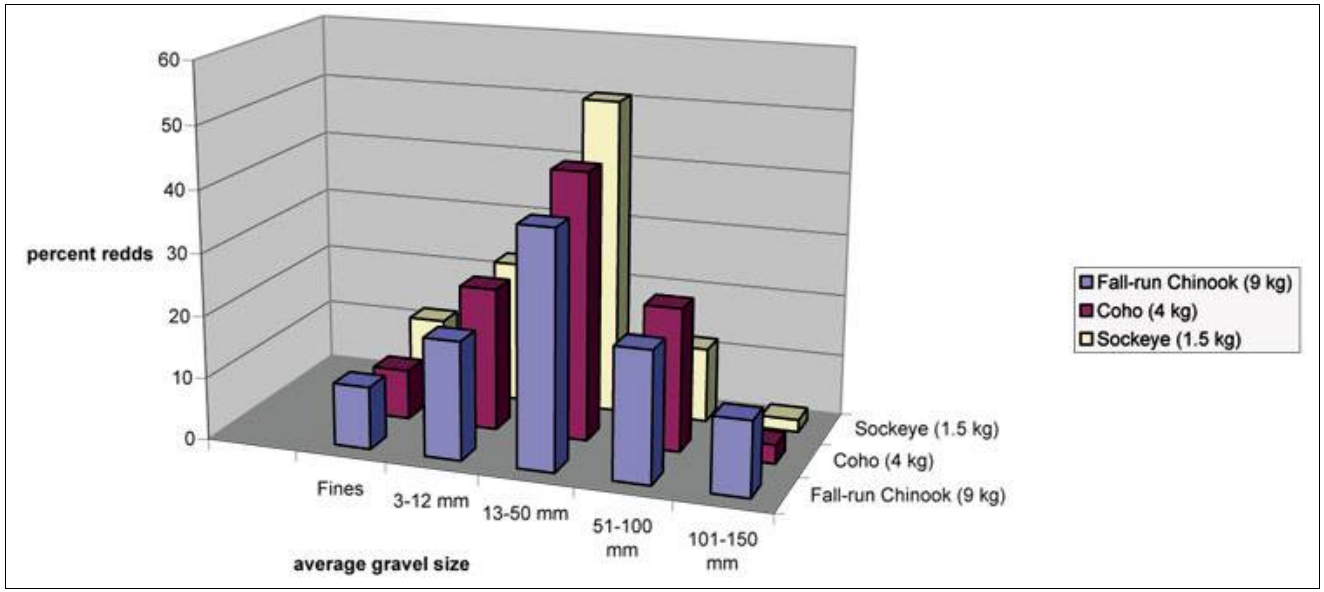
Sediment

(see also Erosion, Soils, Soil texture)

Sediment is naturally occurring material broken down by weathering and erosion, which is then transported by the action of wind, water, or ice, and/or by the force of gravity acting on particles.



Optimal sediment size distribution for Columbia River salmon
(source: http://pcnasa.ctc.edu/education/Sediment%20sizes%20for%20Salmon%20distribution%20graph.pdf).

Sediments are most often transported by water (alluvial or fluvial processes), wind (aeolian processes) and glaciers. Beach sands and river channel deposits are examples of water transport and deposition, sediments also often settle out of slow-moving or standing water in lakes and streams. Natural erosion moves sediments from locations where particles have been loosened by weathering. This process contributes to the shaping of landscapes and affects river dynamics (see Stream channel processes). When rates of erosion exceed natural levels, fine sediments washed into streams can increase turbidity and clog spawning gravels.

Streambed sediments of the right size distribution are critical in providing the gravel beds that salmon need for spawning (see Redds). The bar graph above shows that different salmon species prefer spawning gravels of different size distributions. The amount of fine sediment (silt and clay) in the streambed can be measured to determine suitability for salmon spawning and rearing. Long-term monitoring can help identify trends in sediment supply and movement through a stream system and can help ensure that salmon habitats remain productive (see http://www.krisweb.com/stream/sedmeas.html).

Setback

(see Buffers)

Silt

(see Erosion, Sediment, Soils, Soil texture, Stream load)

Silt particles are between sand and clay in size, and range between 0.002 mm and 0.05 mm. Although they are similar to sand particles in shape and in mineral composition, silt particles can't be seen with the naked eye. Unlike sand, which feels rough and gritty, silt particles feel smooth, like flour or powder. Silt is composed of weatherable minerals, and its smaller size (and increased surface area) allows weathering at rapid enough rates to release significant amounts of plant nutrients. Given slow currents, silt can settle into gravels redds and clog them, preventing oxygen from reaching buried salmon eggs.

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Silver (coho) salmon

(see introductory article 1: Salmon species and life cycle)

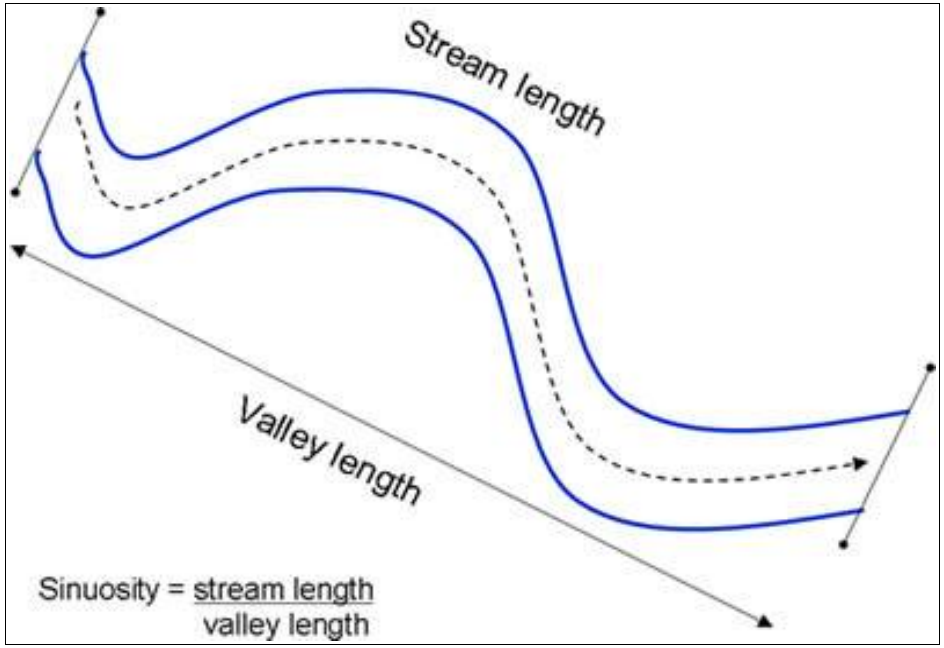
Sinuosity

(see also Meanders, Meander belt, Stream channel processes)

Sinuosity measures the "curviness" of a stream channel as viewed from above. It's calculated by dividing the actual "stream length" of a channel segment by the straight-line length of the same segment, typically called "valley length "(see diagram on right). A stream with a sinuosity of 1 is relatively straight, like the stream below left. As a stream meanders more, its sinuosity increases, like the stream below right, which has a sinuosity over 1.2.

Sinuosity tends to be inversely related to channel slope, meaning steep slopes with fast-moving streams generally have lower sinuosity values than flatter slopes with slower-moving streams, which tend to meander more.

Depending on their life cycle stage (from tiny juveniles to hefty adults), salmon use a variety of channel habitats; sinuosity is one of the features that's often used to describe different channel segments and related habitats. The watershedipedia entry on Riparian ecosystems gives examples of the sinuosity of some local stream segments.



Sinuosity is measured by dividing stream length by valley length (source: http://ag.arizona.edu/watershedsteward/resources/module/Stream/stream_proc_page5.htm).

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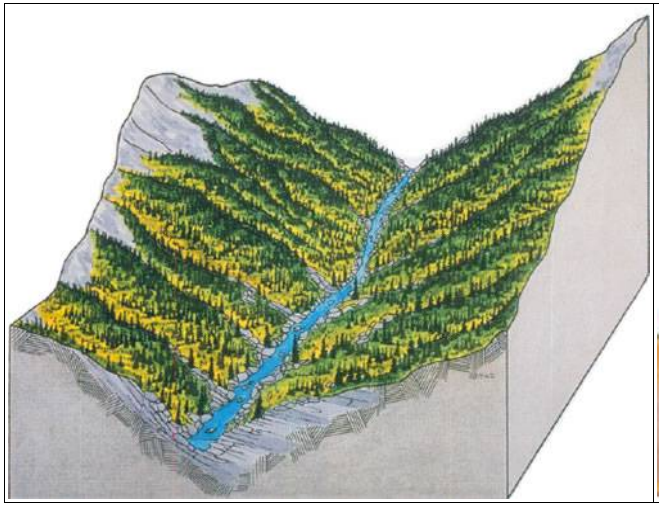
The stream below left would have a low sinuosity, the one below right would have a higher sinuosity value (source: http://www.fgmorph.com/fg_6_26.php).



Smolt

(see also Estuary, introductory article 1: Salmon species and life cycle)

A smolt is a young salmon (or trout) that has changed in color to silvery and has undergone a variety of changes (anatomical, physiological, and behavioral) to get ready for life at sea. It's something of a miracle that a fish born in freshwater can make all the changes it needs to make to face life in the vast saltwater currents of the ocean.

Smoltification

This term refers to the process during which salmon undergo changes that prepare them to leave the fresh-water streams where their lives began in order to head out to sea. In the ocean, salmon gain adult size and strength to make the journey back to their natal streams to spawn. Changes salmon undergo during smoltification include becoming more streamlined, losing dark vertical marks on their sides (parr marks), turning silvery in color, becoming tolerant of saltwater, and starting to school together in large groups. Once their bodies and behaviors have adjusted to saltwater, salmon head out into the Pacific Ocean to feed and grow to adult size.

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A handful of beautiful chinook salmon smolts (from http://fishbio.com/chinook-salmon/fish-whisperer).

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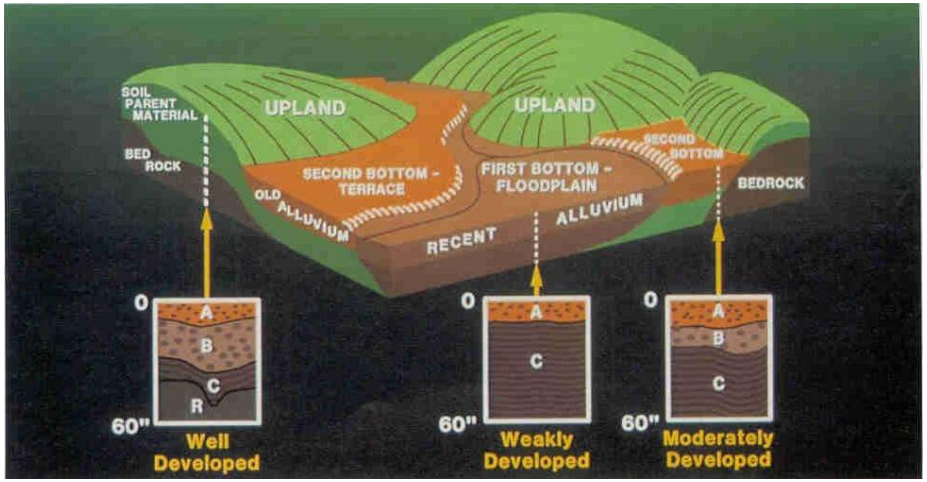
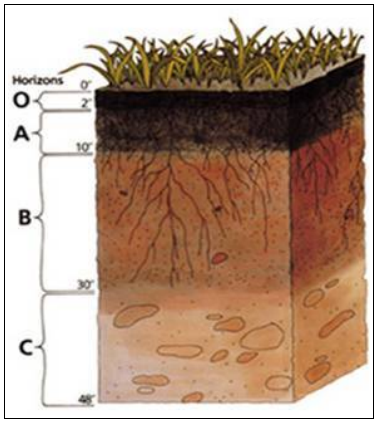
Soil

(see Soil survey, Soil texture, introductory article 3: the Five S's for landowners)



Soil is the layer on the earth's surface in which plants can grow. One Italian soil scientist called it "the excited skin of the earth." Which kinds of soils will develop where depends on five interacting factors: (1) parent material (the kinds of rocks and sediments making up local geology); (2) climate (particularly precipitation and temperatures); (3) topography or landscape position (see Landforms); (4) organisms (especially plants and microorganisms); and (5) time—the longer soils have been forming, the more developed they will be. (A soil that's had very little time to develop would be found, for example, on material recently exposed by a receding glacier.) The combined influence of soil-forming factors determines soil properties. The **image at right** shows landscape positions and related levels of soil development (from http://faculty.msmary.edu/envirothon/ current/guide/ factors_of_soil_formation.htm). In most soils, if you dig a hole, you'll see different soil layers, or *horizons*. Each horizon has its own physical and chemical characteristics. Horizons are formed by a variety of physical, biological, chemical, and geological processes, and vary by geographic location. The **image at right** shows a representation of typical soil horizons.



Typical soil **horizons as shown at right** (from USDA, http://soils.usda.gov/education/resources/lessons/profile/)

O Horizon: The surface layer in most soils, the O Horizon is composed of decaying plant matter.

A Horizon: Characterized by dark brown/black color, the A Horizon is at or near the surface and is generally rich in organic matter.

B Horizon: Commonly referred to as subsoil, the B Horizon consists of mineral layers and has very little, if any, organic matter. Minerals accumulate in this layer through leaching from the surface. Plant roots usually penetrate into this layer. The B Horizon also is commonly divided further into subtypes, depending on depth and mineral content.

C Horizon: The C Horizon consists of unweathered rock and parent material and is not usually affected by surface actions.

Land uses are more likely to be safe, successful, suitable, sustainable, and salmon friendly if landowners consider suitabilities of local soils. To learn about your soils, including their suitabilities and limitations and how these affect land uses, look in the Western Kenai Peninsula Soil Survey (see Soil survey). Here's a very brief summary of general soil conditions on your part of the peninsula: Coastal lowlands of the Lower Kenai Peninsula generally consist of low rolling glacial moraines, outwash plains, and depressions filled by lakes and muskeg. Soils range from gravels deposited by rivers to silts and clays deposited by glacial lakes (see Lakebed wetland ecosystems). Most local soils include bands of volcanic ash deposited by eruptions of volcanoes on the west side of Cook Inlet. Upland soils that are well- and moderately well-drained are best suited for buildings, septic systems, cultivation, or forestry. Many other soils have limitations, including high water tables, flooding, steep slopes, poor stability, or slow permeability. Some soils remain frozen until late summer, which also limits their use. Most hills, terraces, and better-drained outwash plains support forests of Lutz spruce (a cross between white and Sitka spruce) and paper birch, with some aspen and cottonwood. Black spruce is the principal tree on soils with poor drainage. Muskeg vegetation includes mosses, sedges, low shrubs, and forbs.

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Soil best management practices for salmon
(*see Soil for salmon*)

Soil bioengineering

Soil bioengineering is the name given to a group of techniques that use plant materials (live, dormant, and/or dead)—often in combination with geotextiles—to stabilize streambanks and other slopes. Plant materials increase the "roughness" of streambanks; streamflows are slowed by increased bank roughness, and slower flows mean less erosion. Juvenile salmon need areas of slower flows so they can rest and feed without fighting the current. They also find places to hide among nooks and crannies created by roots, stems, and branches that overhang or trail into the water. Hiding places are critical in protecting juvenile salmon from predators. Also, because plants increase the food available in streams (see Plants), soil bioengineering techniques contribute to local food webs, which promotes juvenile salmon survival. All in all, using soil bioengineering techniques on banks that you want to stabilize makes a lot of sense.

The photograph on the right shows a completed soil bionengineering installation, in this case, of "brush layering" or "hedge brush layering." The willow stems shown sticking out from geotextile-wrapped "soil burritos" will sprout and leaf out in the coming growing season. Land-owners can learn to successfully install this and other types of soil bionengineering practices. Because these practices are so beneficial to fish, the Alaska Department of Fish and Game regularly holds free training workshops for anyone who would like to learn the basics and practice what they've learned in an actual hands-on installation. Unless otherwise credited, all photos under this topic are from ADF&G and show projects being installed as part of a workshop. For more information on these workshops, go to http://www.adfg.alaska.gov/index.cfm?adfg=streambank protection.contacts or call (907) 267-2207. In addition, ADF&G has developed an excellent step-by-step, how-to guide for installing soil bioengineering projects. This guide, *Streambank Revegetation and Protection: A Guide for Alaska*, can be downloaded at http://www.adfg.alaska.gov/ index.cfm? adfg=streambankprotection.main, as can step-by-step fliers for individual techniques.

Some steps involved in creating the "brush layer" protected streambank in the **photo at right** are listed here:

- Bury a coir (coconut fiber) log in a shallow trench at the level of ordinary high water (OHW) and lay willow stems over this log, with buds facing towards the river;
- Cover willow stems with soil and water this heavily;
- Lay a geotextile fabric over the willow cuttings and fill this

with soil so that the fabric can be rolled back over the soil layer, creating what's sometimes called a "soil burrito;"

- Lay more willow cuttings over the geotextile "burrito" and bury the stems with soil, then water heavily;
- If necessary, create another soil wrap;
- Cover the final horizontal surface of your top brush layer with sod and vegetation collected from an appropriate location, as shown on the next page.

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A completed "brush layering" installation, covered with a vegetated mat.

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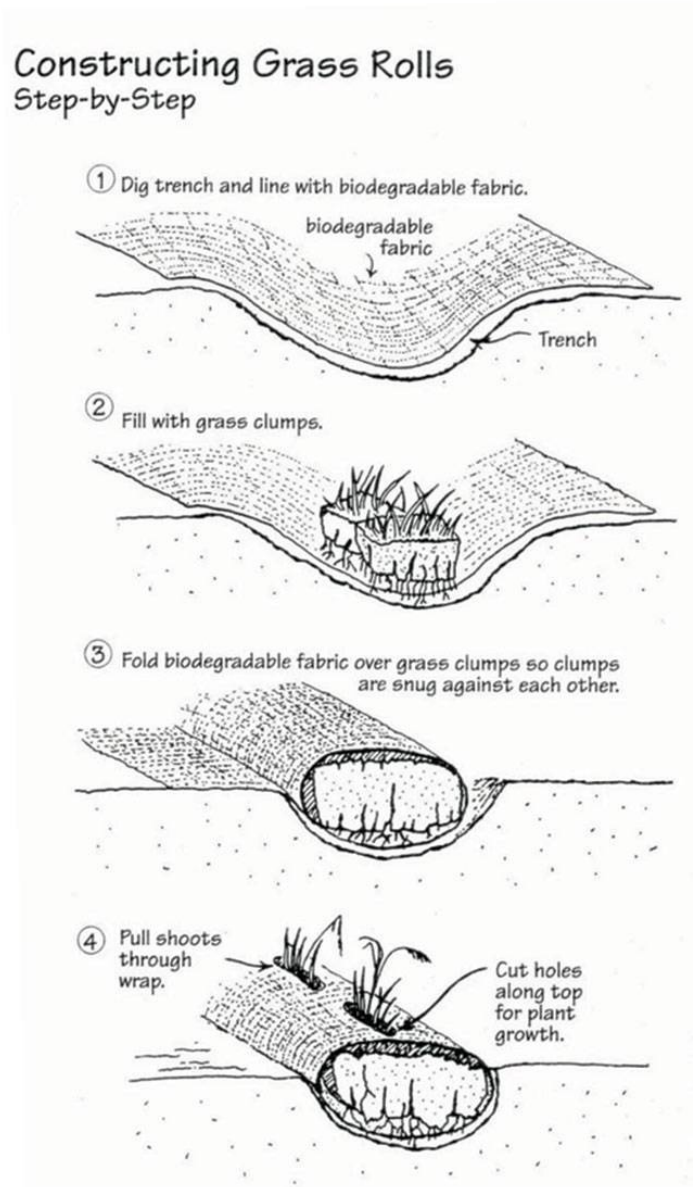
Another soil bioengineering technique is "grass rolls." These can immediately stabilize low banks where plant cover has been destroyed.

Steps for installing grass rolls:

- Dig a trench and line it with coconut fabric.
- Fill the trench with grass clumps and snug them against adjacent clumps.
- Fold fabric over clumps.
- Slit fabric and pull grass blades and stems through the fabric wrap.
- Water well.



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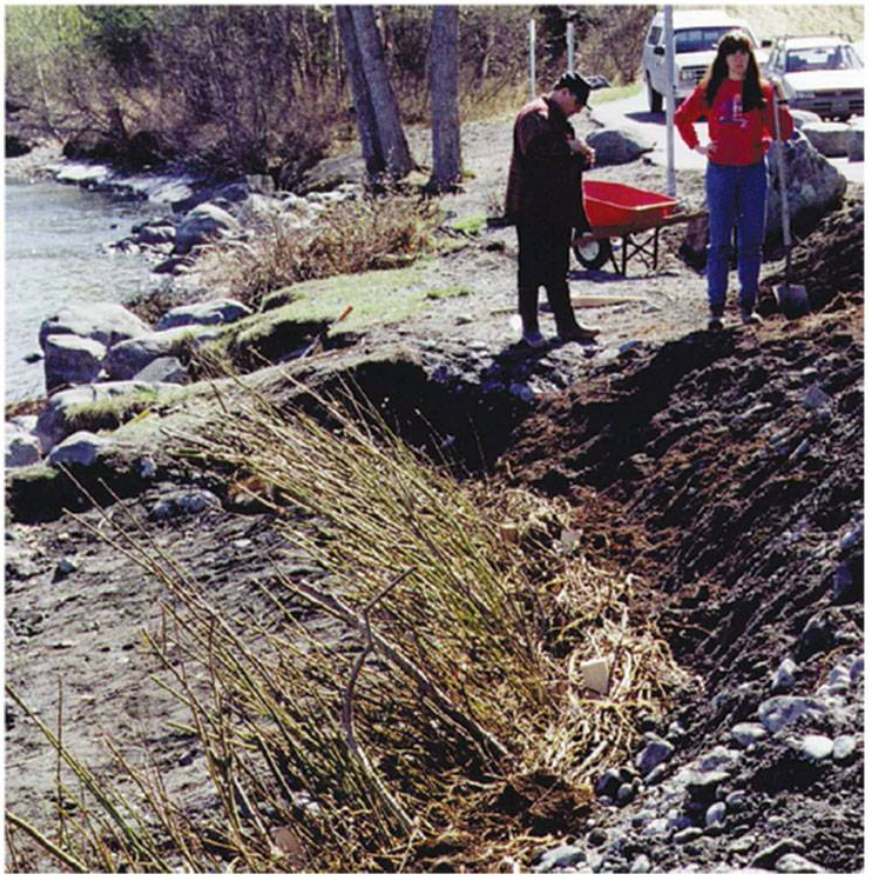
A third kind of soil bioengineering tecnique is called "live siltation plantings." Examples are shown below.



Two different areas of eroding streambank where live siltation plantings were installed, along with willow bundles (fascines) that were staked above. In the image below, along a stretch of Deep Creek, a live matting is shown installed above the willow bundles. If properly installed, soil bioengineering plantings like this can survive ice and inundation.

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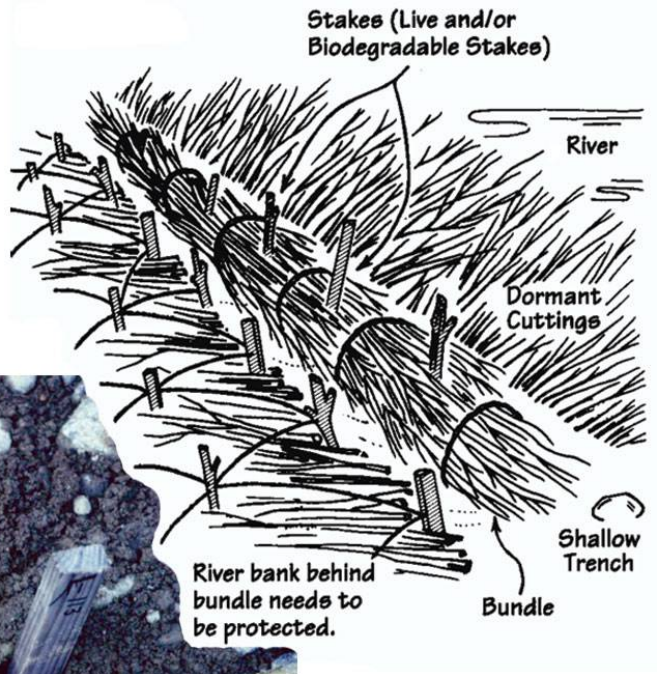
Finally, another common soil bioengineering technique is the installation of long bundles of live willows, also called "live fascines."

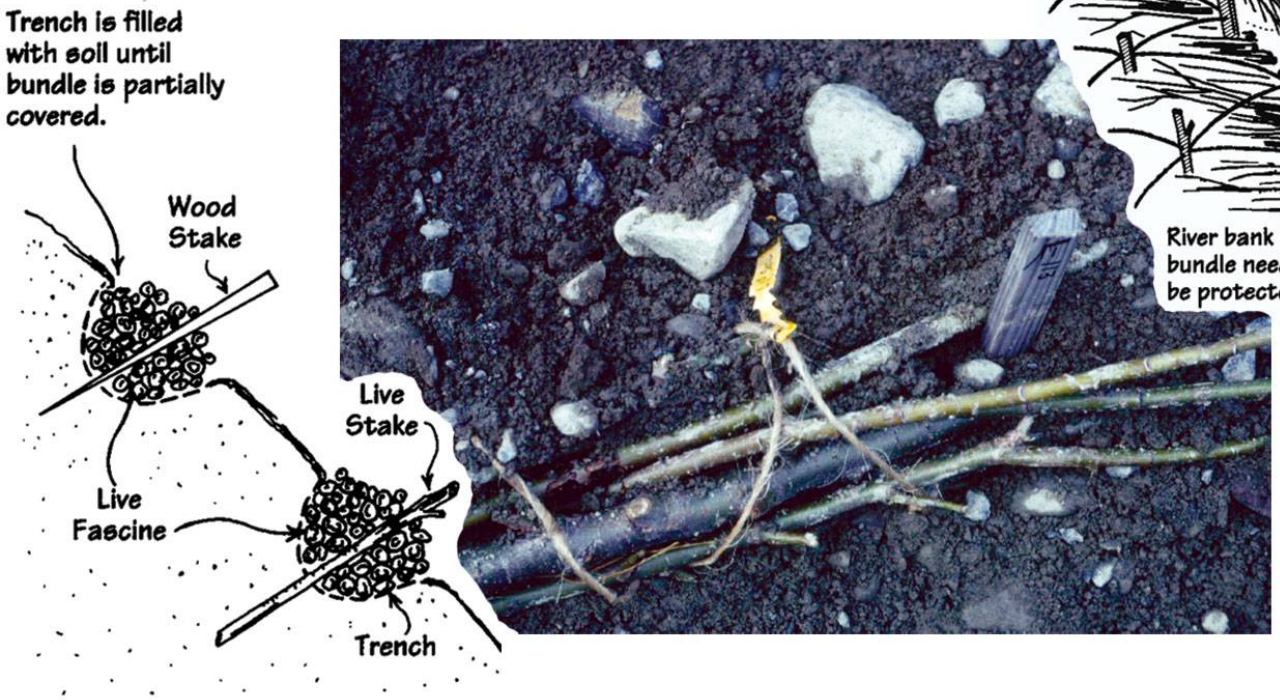
To install willow bundles (also called fascines):

- Dig a shallow trench across the slope or bank.
- Place willow bundles in the trench.
- Cover 2/3 of each bundle with soil, ensuring good soil/stem contact.
- Water well.

If the slope is steep and erosion potential high, drive additional stakes immediately downhill of and through the bundles.

In the image top right, a brush mat has been staked upslope of the willow bundle.





Side view of multiple live bundles in a bank. Live bundles are partially covered with soil. Slope of bank can vary.

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Soils for salmon

http://www.soilsforsalmon.org/how.htm

Soil best management practices (BMPs) include preserving native soil, and restoring soils disturbed during development with organic amendments like compost. This reduces stormwater runoff and pollution, reduces landscape maintenance needs for water, fertilizer, and pesticides, and makes healthier, more attractive landscapes.

New Construction

- Retain and protect native topsoil & vegetation where practical
- Restore disturbed soils by tilling 2-3" of compost into upper 8" of soil
- Loosen compacted subsoil, if needed, by ripping to 12" depth
- Mulch landscape beds after planting
- Existing Landscapes
- Till in compost when re-landscaping
- Mulch beds with organic mulches
- Topdress turf with compost

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The following is a useful publication prepared by Washington Organic Recycling Council (360) 556-3926, *info@compostwashington.org* www.compostwashington.org/, which is also available at www.soilsforsalmon.org.

SOILS for SALMON

Building the Soil for Healthier Landscapes and Healthier Streams

2005 Update

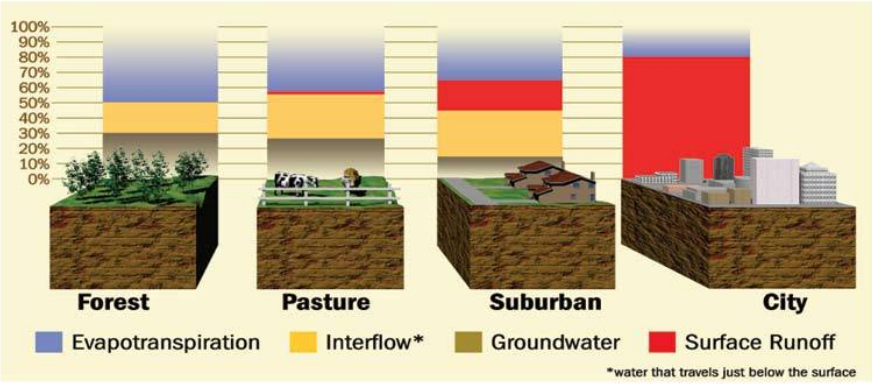
www.soilsforsalmon.org

Growing Recognition of the Benefits of Healthy Soil

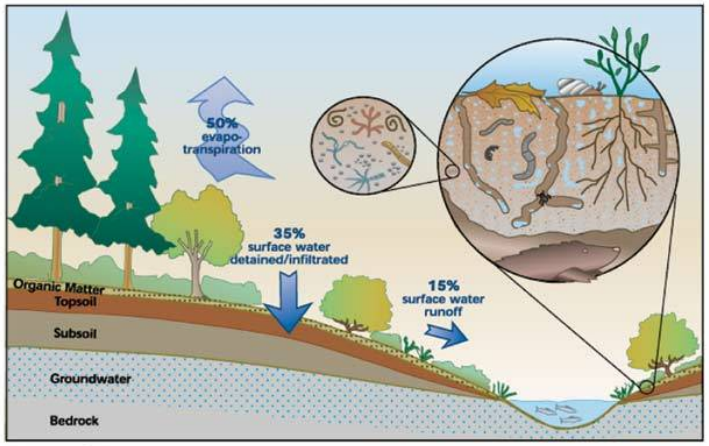
The "*Soils for Salmon*" initiative, begun by the Washington Organic Recycling Council (WORC) in March 1999, has become recognized both regionally and nationally as a practical approach to link the benefits of healthy functioning soils with clean, healthy water resources. The Pacific Northwest is engaged in significant debate and action around saving salmon, whose decline is an indicator of degraded aquatic resources. A widely supported direction for the protection of salmon and other species is the adoption of "Low Impact Development" practices, in order to restore more natural stream flows and protect water quality. The important function that soil quality plays in water issues had not been adequately recognized prior to the *Soils for Salmon* initiative.

Many local government and industry initiatives are underway in Washington and Oregon. A soil quality movement has developed, resulting in many successful projects using soil best practices. *Widespread recognition of the environmental functions of soils, and adoption of soil "best management practices" (BMPs) will have multiple benefits, including expanding recycling of organic waste and reducing irrigation water demand, as well as managing stormwater quantity and quality. For builders and homeowners the benefits include easier planting and better plant survival, as well as lower maintenance requirements for water, fertilizer, pesticides.*

What happens to rainwater as we develop land?
Surface runoff increases, impacting water quality. The soil is not performing its functions.



What is the value of native soil?
Numerous environmental functions:



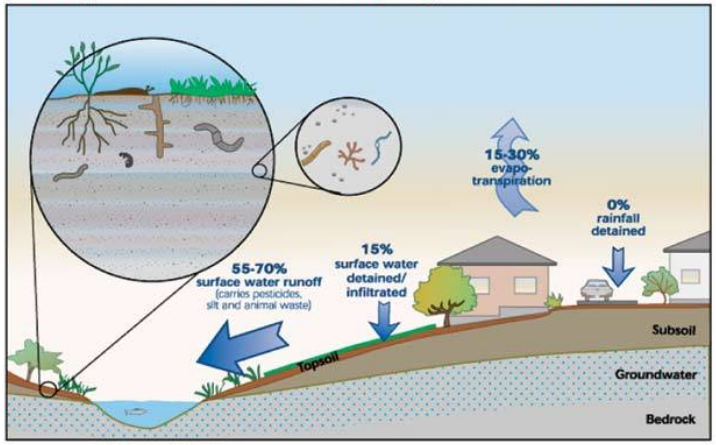
Native Soil

A healthy, vigorous soil and vegetation structure provides valuable plant nutrients, holds and retains water and oxygen, and binds and breaks down pollutants.

Characteristics of healthy soils:

- *Many air and water spaces*
- *Numerous micro and macro organisms*
- *Deep plant root growth*
- *High evapotranspiration, surface water infiltration, and stormwater detention*
- *Low water runoff, minimal erosion*

What is the human impact on soils?
Development limits soils' ability to provide environmental functions:



Disturbed Soil

A soil structure impacted by human activity, compaction and development, has limited organic life. This soil cannot perform its natural functions, resulting in negative impacts throughout the watershed.

Characteristics of disturbed soils:

- *Few air and water pockets*
- *Limited beneficial soil organisms – more pests*
- *Shallow root growth*
- *Low evapotranspiration; low surface water detention and infiltration*
- *High runoff and erosion*

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Soil Biology and Soil Functions: Why Soil Life Matters

US Dept. of Agriculture, NRCS Soil Quality Institute http://soils.usda.gov/sqi/. Download the excellent *Soil Biology Primer*, and other soil quality and erosion prevention resources, or order print copies from 1-800-THE SOIL Washington State University's Soil Management research site http://www.puyallup.wsu.edu/soilmgmt/.

Soil Restoration and Compost Use

Washington Organic Recycling Council / Soils for Salmon

www.SoilsforSalmon.org. Background and up to date information on Soils for Salmon initiative, a soil BMP manual, and useful links on compost use and soil restoration.

U.S. Composting Council http://compostingcouncil.org/. The most authoritative source for information on compost specifications.

Stormwater Management with Soil and Low Impact Development BMPs

Washington State Department of Ecology *Stormwater Management Manual*, used by local jurisdictions for stormwater design, contains soil improvement as a Best Management Practice (Volume V, Chapter 5, BMP T5.13) at www.ecy.wa.gov/programs/wq/stormwater/manual.html, and see the Soils for Salmon website above for a useful manual for implementing that BMP.

Puget Sound Action Team (PSAT) plan update includes a soil improvement policy as a water quality tool. PSAT's Low Impact Development website contains a wide array of useful site planning tools, including a soil BMP in the new *Low Impact Development Manual* http://www.psat.wa.gov/Programs/LID.htm.

Master Builders Association's "Built Green" sustainable building program, developed with King and Snohomish Counties, includes soil strategies for home building. www.builtgreen.net.

Soil BMP Specifications and Design Guidelines

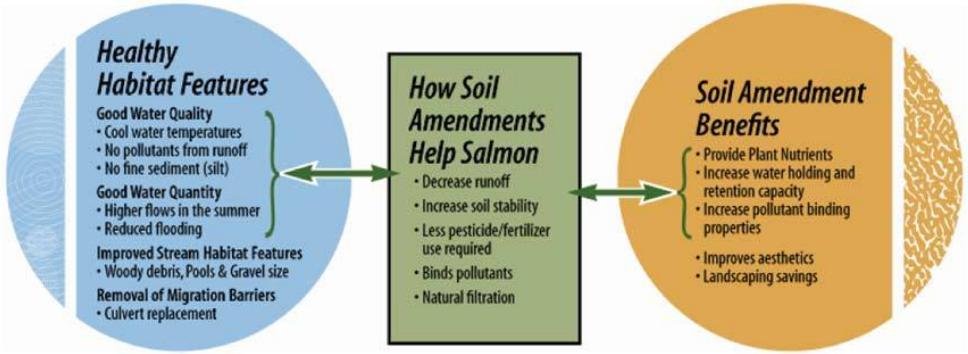
WA Dept. of Transportation soil bio-engineering page http://www.wsdot.wa.gov/eesc/design/roadside/sb.htm.

See also the EPA's "Model Compost Spec for Highways" http://www.epa.gov/epaoswer/non-hw/compost/highway/.

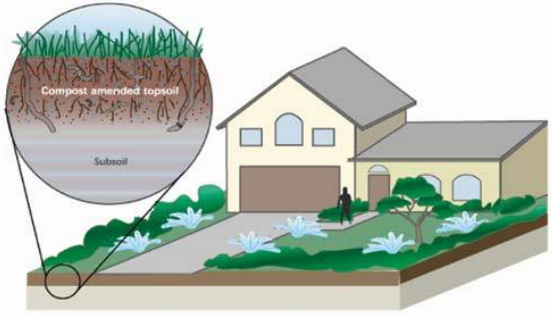
Seattle Public Utilities, SEA Street project soil specifications and other Natural Drainage design information at

Soil Amendment improves water, aquatic habitat, and landscape success:

Soil and water are linked. Soil amendment has a role in salmon recovery.



Compost and other organics can improve soil health and environmental functions:



Utilization of best management practices for soils

Amending soils with compost or other decomposed organics will help restore many of the native soil functions.

Characteristics of amended soils:

- *Increased evapotranspiration, natural stormwater detention and infiltration*
- *Decreased surface water runoff, erosion and pollutants*
- *Improvements in plant nutrient availability, plant appearance, and savings in water, fertilizer and pesticide usage*

Soil Best Management Practices – for healthy streams and healthy landscapes

New Construction BMP's (best management practices)

- Retain and protect native topsoil & vegetation (especially trees) where practical
- Minimize construction footprint and unnecessary soil compaction
- Store and reuse topsoil from site
- Retain "buffer" vegetation along waterways
- Restore disturbed soils by tilling 2-4" of compost into upper 8-12" of soil (or deeper) before planting. (Use a tractor-mounted ripper to loosen compacted layers within 12" of surface.)

Existing Landscape BMP's

- Retrofit soils by tilling in compost when re-landscaping
- Mulch beds with organic mulches (leaves, wood chips, compost), and topdress turf with compost
- Avoid over-use of soluble chemical fertilizers and pesticides, which may damage soil life

Washington Organic Recycling Council *www.compostwashington.org*

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http://www.seattle.gov/util/NaturalSystems/default.htm; best landscape practices (including soil) information at http://www.seattle.gov/util/rescons/plantNaturally. Puget Sound Action Team, LID Technical Manual http://www.psat.wa.gov/Programs/LID.htm. Low Impact Development Center http://www.lowimpactdevelopment.org/.
For More Information Contact: www.soilsforsalmon.org.

[add suitable illustration]

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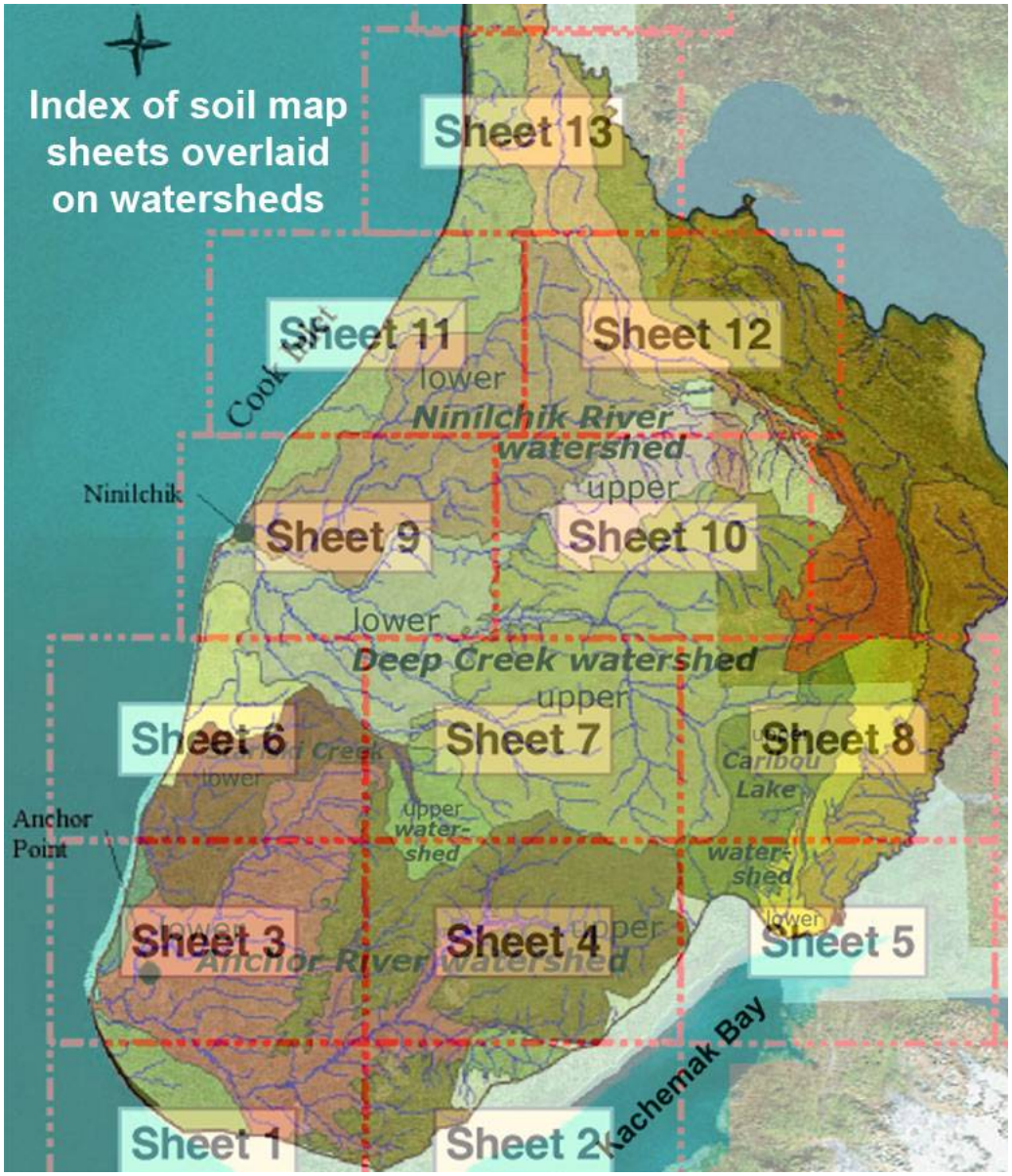
Soil Survey

(see also Soil, Soil texture)

Your local soil survey is generally the best source of information about soils on your property and how they can be used (their suitabilities and limitations; see *introductory article 2: Five S's for landowners*.). Soil surveys are prepared by the Natural Resources Conservation Service. Our local soil survey is *Soil Survey of Western Kenai Peninsula Area, Alaska*, published online in 2005. The manuscript (pdf) of this survey, along with accompanying maps, can be downloaded at http://soildatamart.nrcs.usda.gov/Manuscripts/AK652/0/. The **map at right** shows how numbered soil survey map sheets line up with lower Kenai Peninsula watersheds. A portion of Map Sheet 3 is shown below as an example.



Additional information about soils and the uses for which they're suited is available at an interactive online Web site called Web Soil Survey (WSS). Web Soil Survey is reached at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm or by searching online for "web soil survey."

The objective of soil mapping is to separate the landscape into landforms or landform segments that have similar use and management

A soil is defined as a natural, three-dimensional body at the earth's surface that is capable of supporting plants. Each kind of soil has properties resulting from the integrated effects of climate and organisms acting on earthy parent material, as shaped by topography, over time. The upper limit of a soil is the boundary between the soil and air, shallow water, live plants, or plant materials that have not begun to decompose.

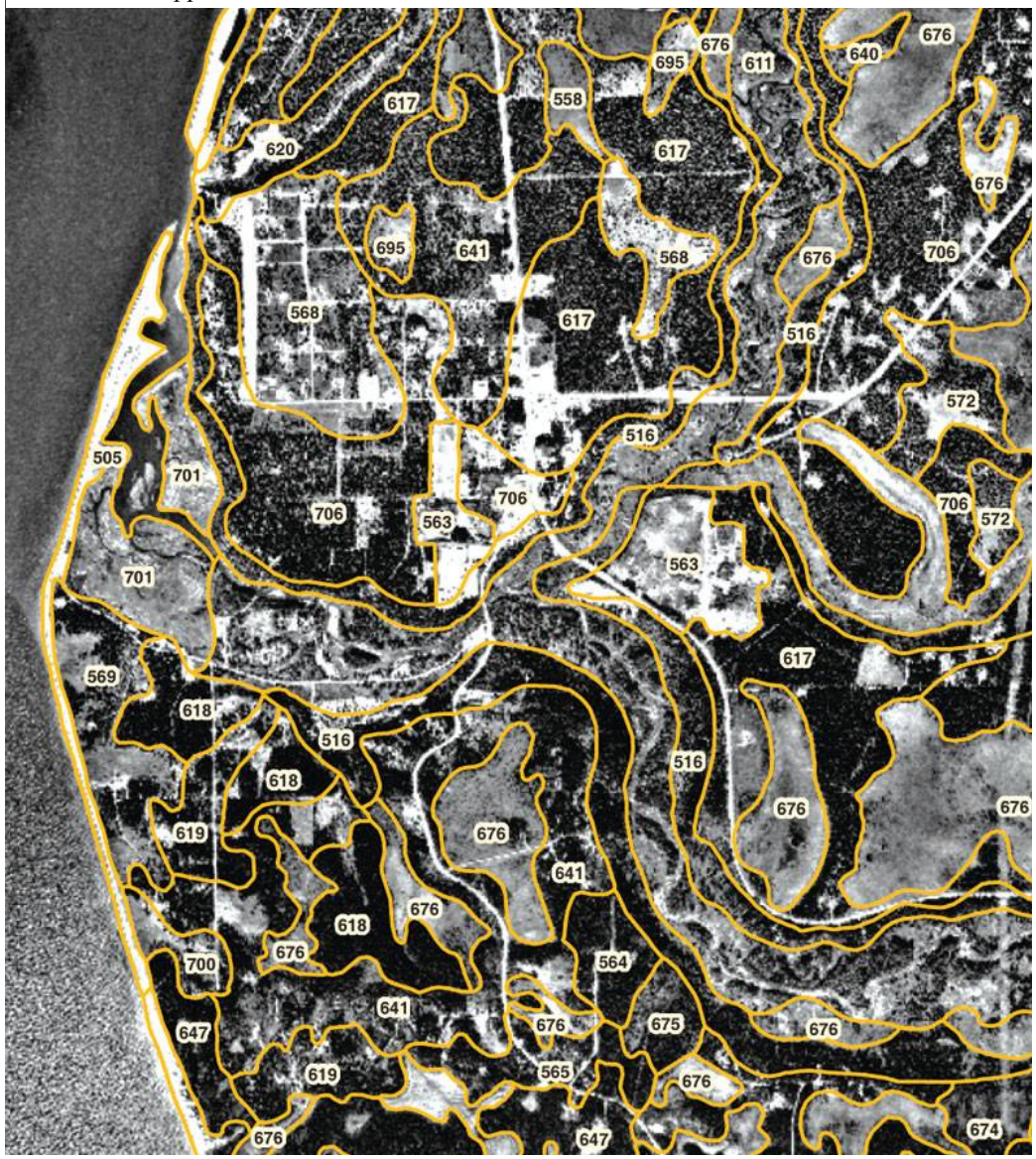
Basic terminology—soil surveys and soil maps (modified from *Soil Survey of Western Kenai Peninsula Area, Alaska*, and "From the Surface Down," at Web Soil Survey): A soil survey is an inventory and evaluation of soils in the survey area. In preparing a soil survey, soil scientists and other professionals collect

extensive field data about the nature and behavioral characteristics of soils in the survey area. Field experience and collected data on soil properties and performance are used as a basis for predicting soil behavior during different land uses.

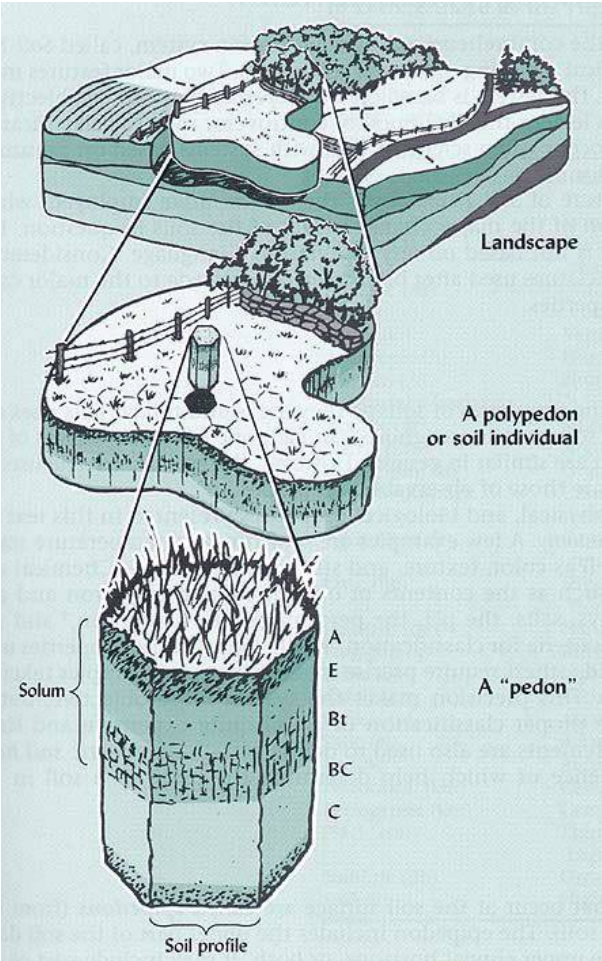
During soil survey fieldwork, soil scientist —often accompanied by botanists or ecologists—walk across the landscape looking for features that suggest a possible change in underlying soils (a slope break, for example, or change in vegetation or surface wetness). When they find a probable boundary between different kinds of soils, they dig holes (usually with an augur) to confirm that the landscape change reflects a change in soil conditions. As needed, they dig larger soil pits to expose soil "profiles" or "horizons" (see Soil). These layers extend from ground surface down to the soil's "parent material" (underlying rocks and sediments not affected by soil-forming processes or organisms). Information about these layers is recorded at each soil pit. By examining soil profiles, soil scientists determine various properties of the soil, such as soil texture, color, structure, and reaction of the soil, as well as the relationship and thickness of different soil horizons. Each soil survey shows locations of identified kinds of soils on detailed maps. On the **map at right**, each different kind of soil ("mapunit") has received a different identifying number. These maps provide enough information to identify areas generally best suited for particular kinds of land uses. However, if intensive use of specific areas is planned, more detailed investigations may be needed. An example would be performing a percolation test to determine that a particular spot has soils suitable for a septic system leachfield.

Soils in the Western Kenai Peninsula soil survey area were mapped at a scale of 1:25,000. As mentioned above, each outlined soil *map unit* or polygon was given a number, which corresponds to a particular kind of soil series and phase. "Miscellaneous areas" were also mapped; these are areas that have little or no soil material and support little or no vegetation. For example, gravel pits are mapped as miscellaneous areas. In the Western Kenai Peninsula soil survey area, soils were

The map below is from Map Sheet 3 in the Western Kenai Peninsula soil survey. It shows soils mapped near the mouth of the Anchor River and the confluence with North Fork.



mapped in terms of "soil series." A *soil series* is group of soils having profiles that are almost alike, except for differences in surface layer texture. Series are given names like "Beluga silt loam." All the soils of a series have horizons that are similar in composition, thickness, and arrangement. Despite their basic similarities, soils within a given series can differ somewhat in slope, stoniness, surface texture, or other characteristics that may affect their use. Based on such differences, soil series are subdivided into *soil phases*. Slope, in particular, is used in distinguishing different soil phases from each other, such as *Kachemak silt loam, nearly level*, from *Kachemak silt loam, strongly sloping*. Soils within a single series and phase have similar suitabilities and limitations for particular land uses. (The most fundamental unit of a soil is the *pedon*, which is the smallest unit or volume of soil that contains all the horizons typical of a particular type of soil.) The **drawing bottom left** illustrates how soils fit onto the landscape (source: http://urbanext.illinois.edu/soil/concepts/concepts.pdf).



Depending on map scale and the complexity of land surface features, some soil phases will be too small to outline. As a result, mapped areas showing a single soil series almost always include small areas of other series or phases that were too small to be drawn separately at the map scale being used. These areas are called "inclusions." Because of inclusions and other necessary generalizations made during mapping, soil maps can be thought of as "probability" maps—they are very good at showing the *probability* or *likelihood* that a particular kind of soil will be found at a specific location. For the Western Kenai Peninsula survey, chances are generally 85% or better that if you dig a hole in an area mapped as *Kachemak silt loam, gently sloping*, that's what you'll find. That means there's a 15% chance that you'll find something different, for example, because you dug in a small depression that collects and holds water differently from surrounding areas. Such inclusions, or areas of contrasting conditions, are too small to identify and outline unless every square foot is mapped at a very enlarged scale—which is what happens in project-specific onsite mapping.

> Encouraging proper use and management of soils is what soil surveys are all about.

In addition to unmapped inclusions, some map units consist of more than one major soil. A ***complex*** consists of two or more soils in such an intricate pattern or in such small areas that they can't be shown separately on the maps. "Tutka-Portgraham complex, hilly to steep" is an example. An *association* is made up of two or more geographically associated soils that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map these soils separately. The pattern and relative proportion of the soils are somewhat similar. An *undifferentiated group* is made up of two or more soils that could be mapped individually but are mapped as one unit because similar interpretations can be made for their use and management.

Encouraging proper use and management of soils is what soil surveys are all about. (Look at the Dust Bowl photos under Natural Resources Conservation Service to see what can happen when soils are not used in accordance with their suitabilities and limitations.) As a result, soil surveys identify which land uses (building with foundations, septic system leach fields, recreation trails, etc.) a soil is well suited for. If a soil is poorly suited for a particular land use, the soil survey identifies "limitations" that affect that soil for that use. Landowners can help keep their lands salmon friendly by using them in suitable ways.

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Soil texture

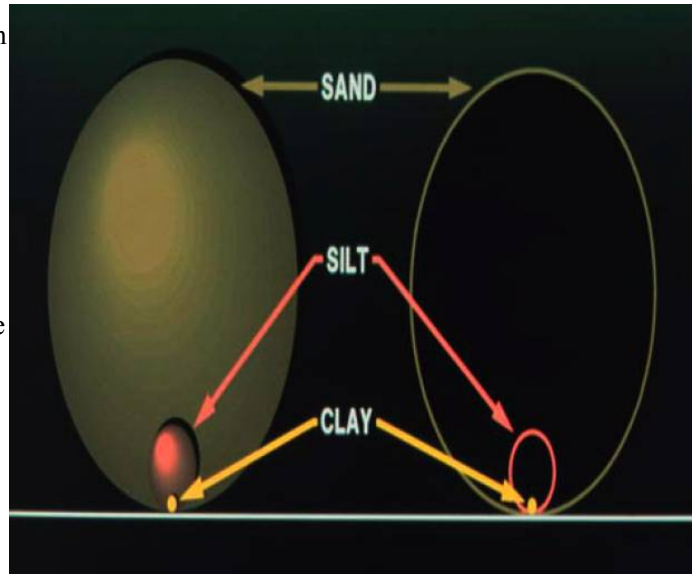
(see also Soils, introductory article 3: Five S's for landowners)

(Modified from http://www.clu-in.org/ecotools/soilsci.cfm#subhead3.) The texture or "feel" of a soil is very important and affects how water and nutrients are retained, the type of plant life the soil can sustain, the soil's susceptibility to erosion, and how well the soil is suited for many land uses, from buildings with foundations to septic system leach fields, to recreational trails. Using soils in accordance with their suitabilities can save time and money and prevent many kinds of environmental damage potentially harmful to salmon (e.g., erosion, surface runoff, sedimentation, etc.)

Texture is defined by the relative proportions of the three primary soil particles present in soil: sand, silt, and clay. Since each particle size has different physical characteristics, the nature of a soil is commonly defined by the most abundant particles. Thus, a soil containing a large amount of clay has different physical properties from one that consists mostly of sand and/or silt. Soils that are made up of relatively equal amounts of each size type are known as "loams."

Soil textural triangles such as the one below are used to classify soil texture. The number scale on the outside of the triangle represents the percentage of sand, silt, and clay, and the intersection of each line gives the texture classification. For example, a soil that has 30 percent clay, 40 percent silt, and 20 percent sand falls into the "silt loam" texture class. For a detailed guide that includes step-by-step instructions on determining soil texture, visit United States Department of Agriculture's (USDA) Guide to Texture and Feel. Soil texture may be determined in a laboratory by particle size analysis or in the field with a "texture by feel" estimate.

(Modified from http://soils.missouri.edu/tutorial/page8.asp.) As mentioned above, texture affects many soil properties, among them water movement in the soil, chemical reactivity, availability of nutrients for plants, and erosion potential. Many of these properties are related to the surface area that a soil particle provides, and the smaller the particle, the more surface area it has relative to its size. Other soil properties stem from packing ratios and pore size. By providing more surface area, finer textures result in a soil having a higher capacity to hold water, a higher chemical reactivity (the ability to store more nutrients and supply them to plants, called Cation Exchange Capacity), and usually a greater resistance to erosion. On the other hand, a clayey soil is poorer in aeration (due to stagnation of water), which reduced plant vigor and growth. A soil with sandy texture has difficulty retaining water, and thus nutrients are not made available to the plants growing in such a soil. Loamy soil (a mixture of clay and sand) is the best textured soil for crop cultivation since it has all the beneficial aspects not found in the sandy and clayey soil. Thus we can see how texture affects the plant growth.



Sand particles are too large to be able to fit close together. As a result, coarser textured (sandy) soils will have larger "packing voids" between particles and, therefore, larger pore spaces; water can move and drain rapidly through coarse-textured soils. Large enough voids between sand particles can be occupied by smaller silts and clays.

To picture relative size of sand, silt, and clay, imagine standing outside a large sports stadium and someone parks a car next to you. Place a postage stamp on the car window. The stadium represents a sand-sized particle, the car represents a silt-sized particle, and the stamp, a clay-sized particle. The **image at right** tells a similar story (http://urbanext.illinois.edu/soil/concepts/concepts.pdf).

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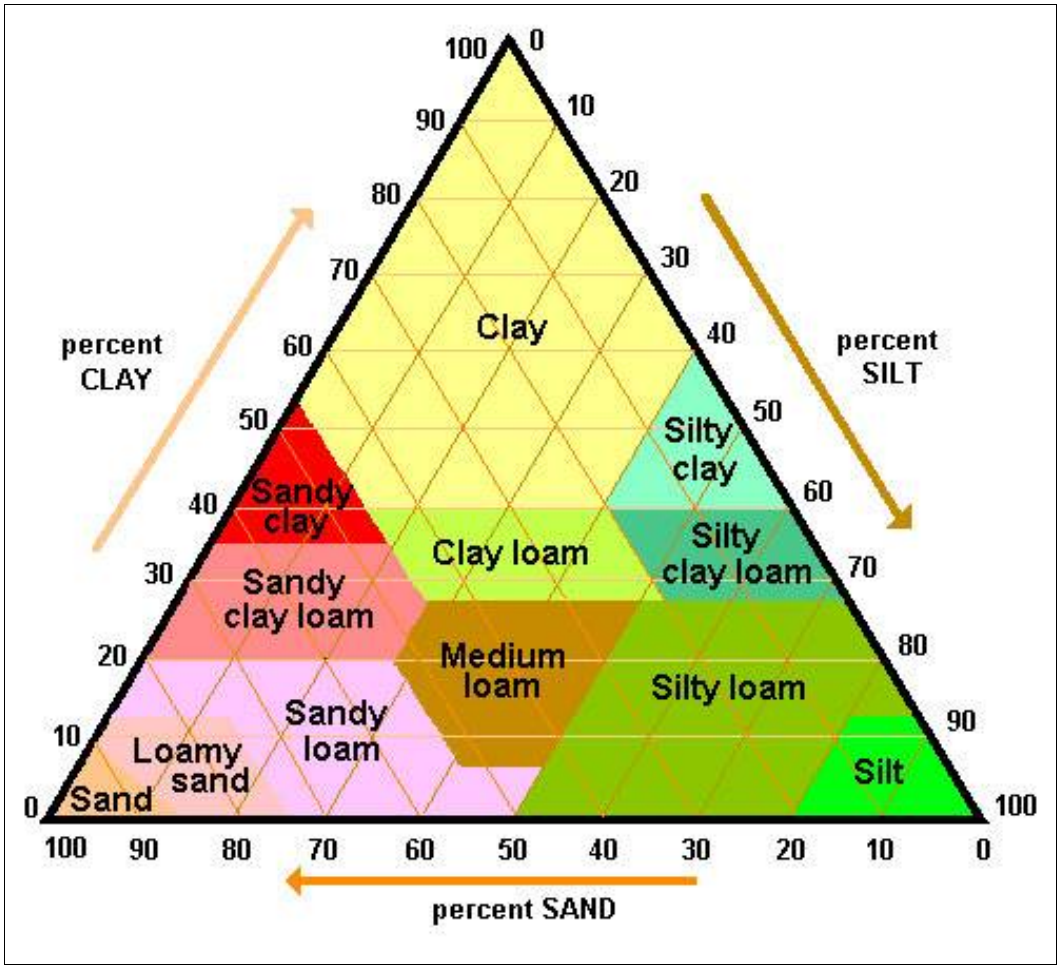
Many soils have particles larger than sand, called coarse fragments. Size classes range from pebbles (or gravel, 2 mm to 75 mm), cobbles (75 mm to 250 mm), stones (250 mm to 600 mm), and finally boulders (≥600 mm). Coarse fragments can affect water movement in the soil or prevent root penetration, and they also occupy volume in the soil that could otherwise be occupied by soil-sized particles.

As mentioned above, the soil textural triangle is used to name soil textures that have specified percentages of sand, silt, and clay particles. Textural class names can be defined as a grouping of various ranges of textural separates such that each grouping possesses unique management properties.

To use the Textural Triangle, first find the appropriate clay percentage on the left-hand side of the graph; draw a line across parallel to the base of the triangle. Next, find the sand percentage along the base of the triangle; draw a line upward parallel to the right side of the triangle (the one labeled "percent silt"). The area where these two lines intersect will be the textural class of the soil. You need to know only two of the three percentages (sand, silt and clay) to find the textural class because all three percentages must total 100%.

Look at each side of the Textural Triangle. Notice how much sand is required to get the word "sand" in the textural class name. Now look at the side labeled "percent silt." How much silt is needed to get the word silt in the textural class name? Look at the third side of the triangle, for percent clay. You need a much smaller amount of clay to get the word clay in the textural class name. You should now understand that the smaller the particle size (sand to silt to clay), the greater the influence the particle has on texture.



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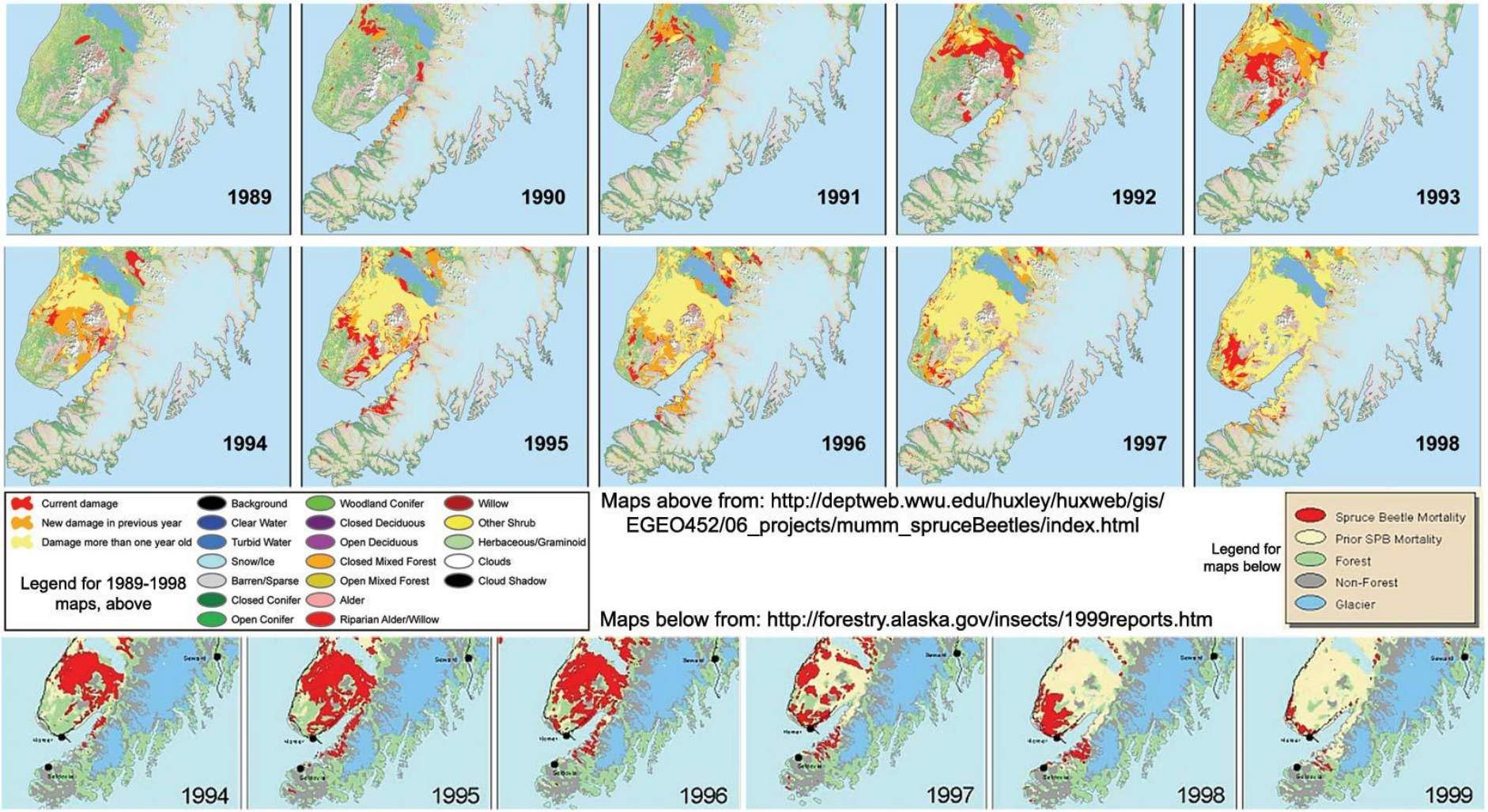
Spruce bark beetle spread 1989-1999

(see also Forests and spruce bark beetle)

The spruce bark beetle has had profound effects on our watersheds by killing large areas of mature spruce trees. As discussed under Forests, these effects may be part of long-term, natural cycles, maybe amplified by warming temperatures (see Climate change). The map below shows the spread of spruce bark beetles across the lower Kenai Peninsula from 1989 to 1999.



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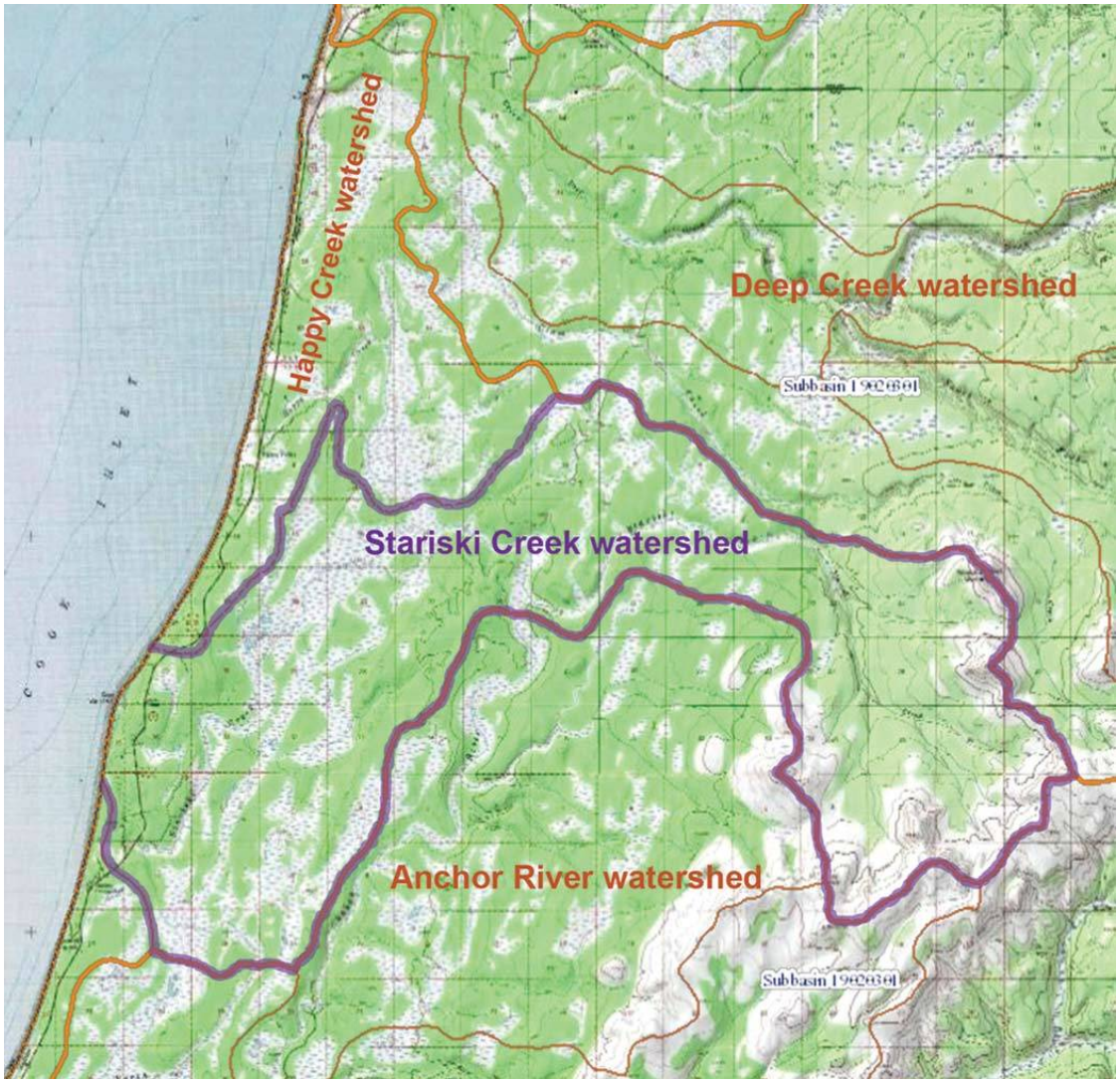
Stariski Creek and watershed

Stariski Creek has a mainstem length of roughly 26 miles (as the boat floats) and is supplied by a watershed of about 52 sq mi in size (about 33,280 acres). The creek headwaters on the northwestern flanks of the Caribou Hills and the combined length of all its mapped and measured tributaries equals just over 67 miles. As shown in *introductory article 3*, however, many tributaries will have been too small to map.

As discussed in *introductory article 1: Salmon species and life cycle*, Stariski Creek, like its neighboring watersheds—Deep Creek to the north and Anchor River to the south—supports chinook, pink, and coho salmon, as well as steelhead and Dolly Varden.

Stariski Creek is explored at some length in *introductory article 3: Exploring your watershed with online tools*.



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Stormwater Pollution Prevention Plan (SWPPP)

If you plan to undertake a development project that disturbs 1 acre or more, or if you are disturbing an area of less than an acre that is part of the planned disturbance of a larger development, you need to learn a bit about the "Alaska Construction General Permit (ACGP) for discharges from large and small construction activities." In October 2008 the Environmental Protection Agency (EPA) approved Alaska's application to administer the National Pollutant Discharge Elimination System (NPDES) Program. The state's program is the Alaska Pollutant Discharge Elimination System (APDES) Program. EPA's approval of the state's application included the phased transfer of authority to administer the APDES Program. Authority to administer the stormwater program transferred to the Alaska Department of Environmental Conservation (DEC) on October 31, 2009. EPA has no authority to issue a permit to a facility where jurisdiction over that facility or activity has transferred to the state. (EPA, however, retains authority under the Clean Water Act to review all DEC-drafted permits and to conduct inspections and pursue an enforcement action on any discharges in Alaska.) For a factsheet about the Alaskan Construction General Permit, go to http://dec.alaska.gov/water/wnpspc/stormwater/docs/Final_2011_ACGP_Fact_Sheet_(20110519).pdf.

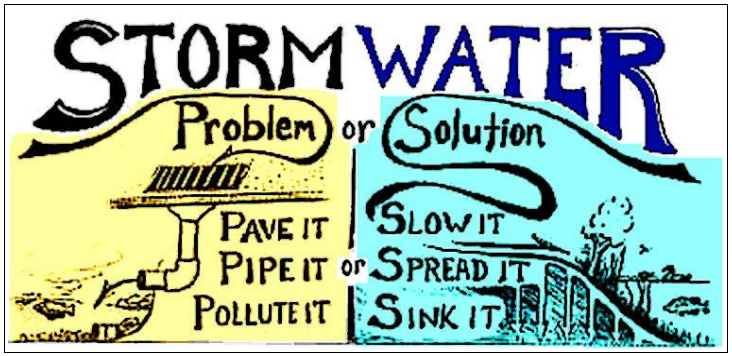
The Alaska Construction General Permit (AGCP) sets conditions on the discharge of pollutants from construction projects into "waters of the United States" (including certain wetlands). Making sure that your project meets the conditions of the ACGP involves developing and following a project-specific Stormwater Pollution Prevention Plan (SWPPP). The SWPPP should describe your activities and lay out how you will manage materials, equipment, and runoff from your construction site so as to prevent stormwater pollution from washing off the site. The DEC is the state agency with the authority to review SWPPPs to make sure that they are adequate and are being followed, see: http://dec.alaska.gov/water/wnpspc/stormwater/sw_construction.htm.

Don't worry, developing a SWPPP is mostly common sense; clear, helpful instructions are available online. You can get guidance at http://cfpub.epa.gov/npdes/stormwater/swppp.cfm or look at a SWPPP template at http://dec.alaska.gov/water/wnpspc/stormwater/docs/2011_ACGP_SWPPP_Template_June_Final_w97.doc. You can also get guidance from staff at the Gilman River Center in Soldotna or from the DEC.

Stormwater runoff

(see also Best Management Practices, Flooding, Hydrograph, Impervious surfaces, Low Impact Development, Nonpoint source pollution, Raingardens, Stream channel processes, Surface runoff)

Stormwater runoff is rain or other precipitation that flows across land and buildings—including, roads, parking areas, and rooftops—into nearby waterbodies, wetlands, and coastal waters. Impervious surfaces like buildings and roads increase stormwater runoff by preventing water from soaking into the ground. Clearing plants for construction, logging, lawns, or other activities also increases stormwater runoff by reducing plant-related infiltration and interception.



Stormwater runoff causes two major problems. First, it picks up and carries pollutants, including oil and gas from roads and parking areas, animal wastes from livestock pens and pet yards, sediments from construction sites and cleared areas, and other kinds of trash and debris from far and wide. Stormwater runoff is a leading contributor to water pollution. Secondly, and especially during heavy fall rainstorms, stormwater runoff can cause flooding, damage property, and damage or destroy fish and wildlife habitats. Streamflows swollen by runoff harm salmon habitats by eroding streambanks, scouring streambed materials (including gravels where salmon eggs incubate in redds), altering stream channels, increasing deposits of sediments, and washing away insects and other food that juvenile salmon rely on. Runoff also carries away animals unable to fight higher streamflows and stronger currents—including salmon fry and fingerlings.

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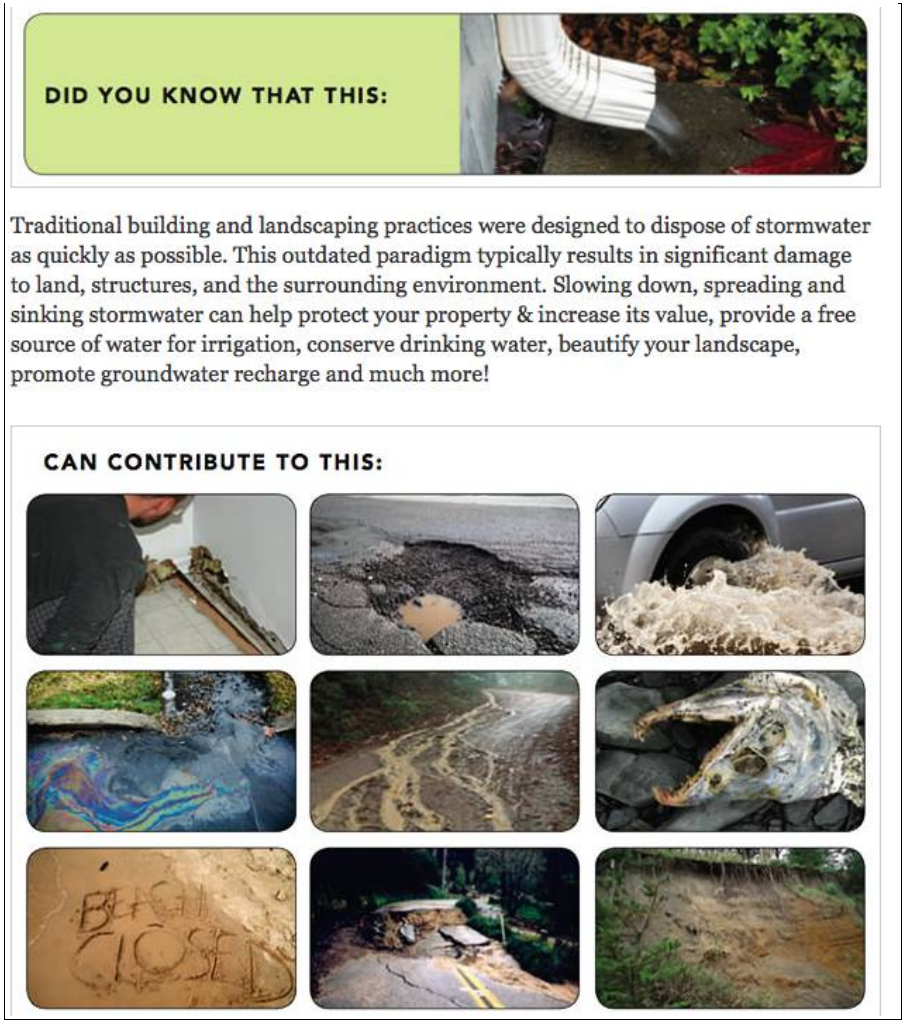
EPA provides a good overview of problems associated with stormwater runoff at http://cfpub.epa.gov/npdes/stormwater/menuofbmps/bmp_background.cfm. Except for the last paragraph, the rest of this entry is modified from that website.

The page below is from *A Homeowner's & Landowner's Guide to Beneficial Stormwater Management*, available at http://www.sscrcd.org/pdf/Slowit.Spreadit.Sinkit.vfinal.pdf.



DID YOU KNOW THAT THIS:

Traditional building and landscaping practices were designed to dispose of stormwater as quickly as possible. This outdated paradigm typically results in significant damage to land, structures, and the surrounding environment. Slowing down, spreading and sinking stormwater can help protect your property & increase its value, provide a free source of water for irrigation, conserve drinking water, beautify your landscape, promote groundwater recharge and much more!

CAN CONTRIBUTE TO THIS:

The stormwater pollution problem has two main components: increased volumes and rates of runoff from impervious surfaces and increased concentrations of pollutants in the runoff. Both components are directly related to development in urban and urbanizing areas. Together, these components cause changes in hydrology and water quality that result in a variety of problems, including habitat modification and loss, increased flooding, decreased aquatic biological diversity (biodiversity), and increased sedimentation and erosion. Effective management of stormwater runoff offers a multitude of possible benefits, including protection of wetlands and aquatic ecosystems, improved quality of receiving waterbodies, conservation of water resources, protection of public health, and flood control.

In addition to chemical pollutants in stormwater, the physical aspects related to urban runoff, such as erosion and scour, can significantly affect a receiving water's fish populations and associated habitats. Alterations in hydraulic characteristics of streams receiving runoff include higher peak flow rates, increased frequency and duration of bankfull and subbankfull flows, increased occurrences of downstream flooding, and reduced baseflow levels. Traditional flood control measures that rely on the detention (storage) of the peak flow (referred to as peak shaving) have been characteristic of many stormwater management approaches. These have generally not targeted pollutant reduction, and in many cases have exacerbated problems associated with changes in hydrology and hydraulics. EPA recommends an approach that integrates control of stormwater peak flows and protection of natural channels to sustain the physical and chemical properties of aquatic habitats.

Polluted stormwater runoff can have many adverse effects on plants, fish, animals and people.

- Sediment can cloud the water (increase turbidity) and make it difficult or impossible for salmon (and other fish that feed by site) to find food. Turbidity can also impair the growth of aquatic plants. Sediments can destroy aquatic habitats, for example, by plugging up gravels in which salmon build their nests (redds) and lay their eggs..
- Excess nutrients can cause algae blooms. When algae die, they sink to the bottom and decompose in a process that removes oxygen from the water. Fish and many other aquatic organisms can't exist in water with low dissolved oxygen levels.

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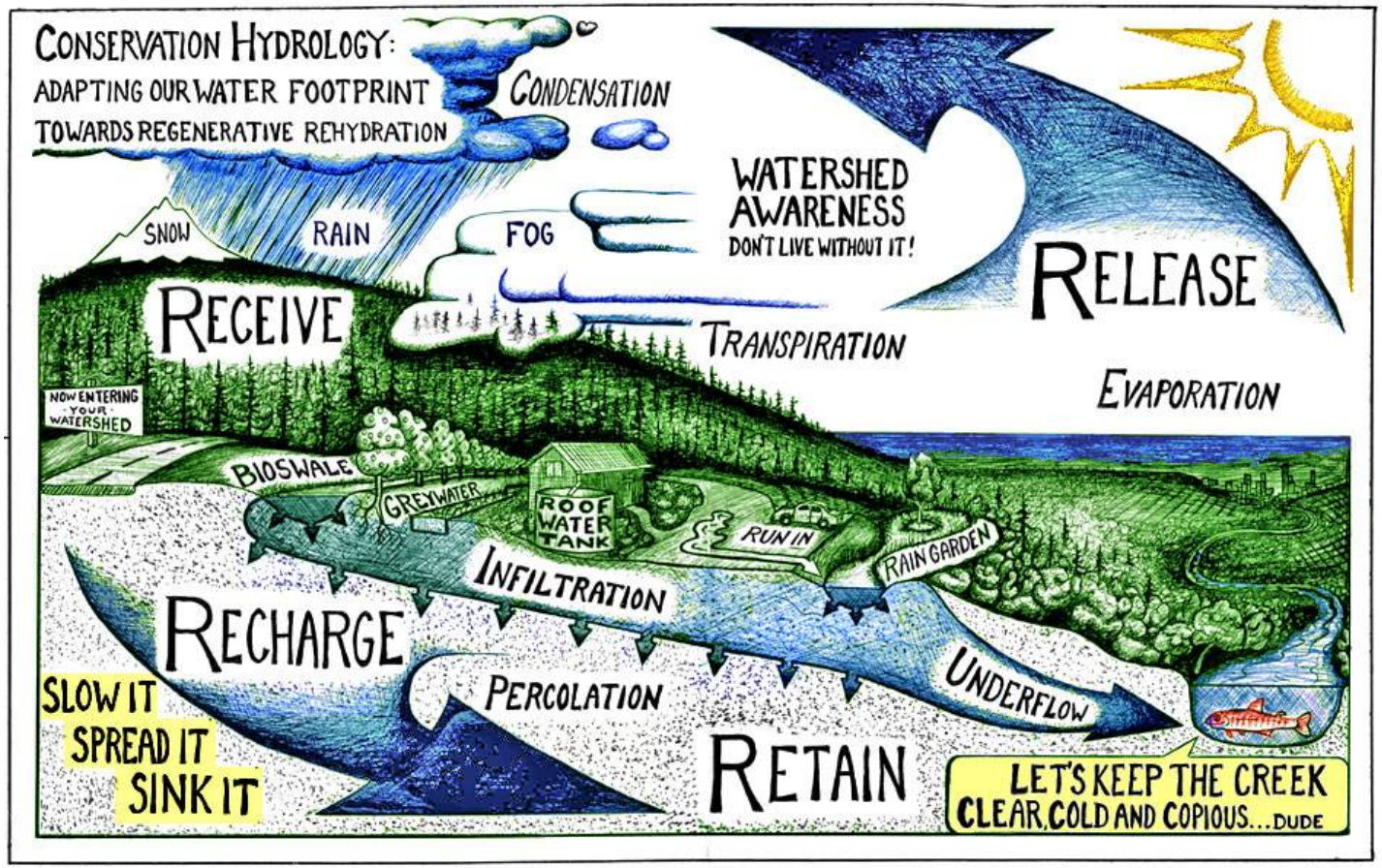
- Bacteria and other pathogens can wash into streams, causing diseases in aquatic organisms.
- Debris—plastic bags, six-pack rings, bottles, and cigarette butts—washed into waterbodies can choke, suffocate, or disable aquatic life, including fish, waterfowl, other birds, and mammals like river otter, beaver, and muskrat.
- Household hazardous wastes like insecticides, pesticides, paint, solvents, used motor oil, and other auto fluids can poison aquatic life. Land animals and people can become sick from eating diseased fish and shellfish or ingesting polluted water.

Because of how damaging increased stormwater runoff can be, many websites and publications provide information about what landowners can do to reduce runoff (e.g., see weblink with illustration on the previous page). Many recommendations boil down to: "Slow it. Spread it. Sink it." The **drawing below** illustrates this principle, showing ways landowners can **slow** runoff flowing across their property—which gives it more time to **sink** into the soil. Helping runoff **spread** out is one way to slow it down. Landowners can also help stormwater sink into the ground by maintaining dense, healthy groundcover plants (see Best Management Practices) and by including features such as raingardens and vegetated swales in landscaping.



As the drawing at left suggests, to reduce stormwater, think: *Slow it, Spread it, Sink it*. (This drawing and the one on the first page of this entry are from: http://www.calsalmon.org/news/biannual-newsletters/winter-2008-newsletter/basins-relations-protecting-and-restoring-our-water; original black & white drawing colored by HSWCD. For lots more information, check out the Salmonid Restoration Federation website: http://www.calsalmon.org/.)

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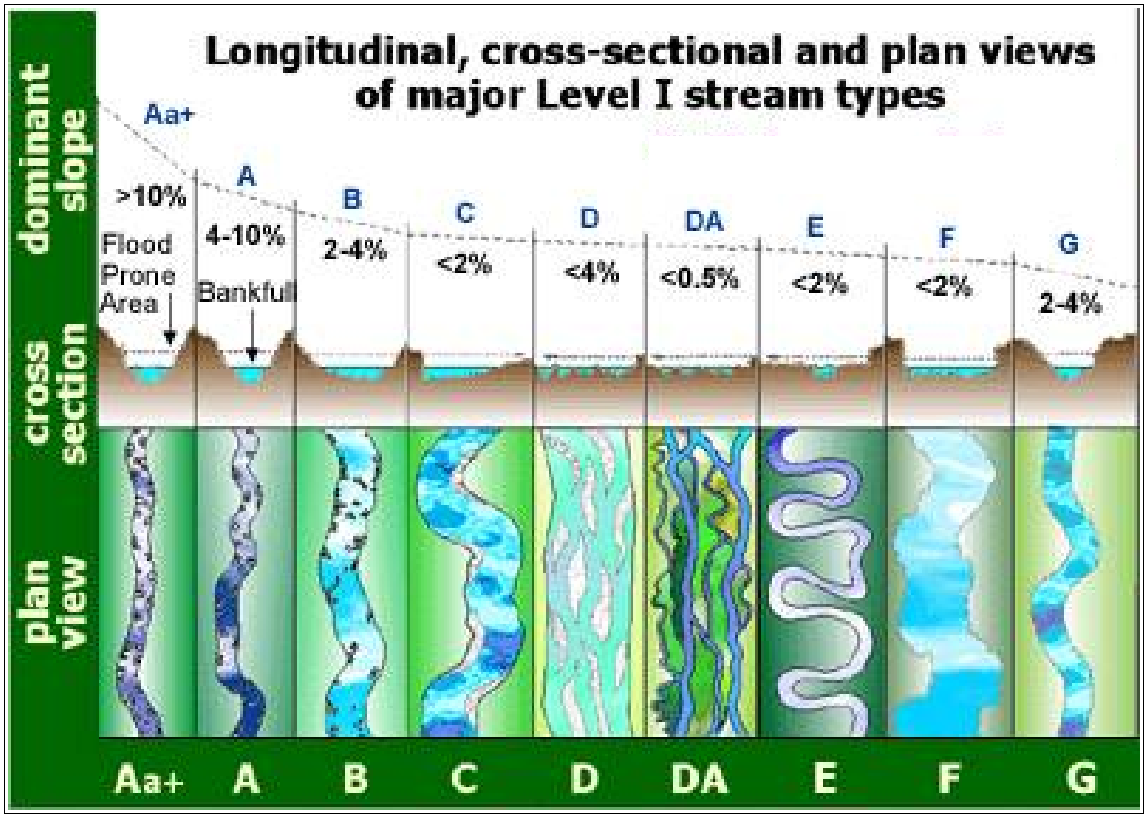
Stream channel "anatomy" and classification
(see also Stream channel processes)

(Modified from http://www.epa.gov/owow/watershed/wacademy/acad2000/stream_class/03set.htm.) When you look at a stream, what you notice is its "anatomy," or more formally, its *morphology*. You notice whether the stream is straight or meandering, whether there's a single channel or multiple channels that interweave like the segments of a braid (braided channel), whether the stream is free to weave across a wide, flat valley or is trapped between confining valley walls or bluffs. Noticing these kinds of patterns has led many scientists who study river systems to develop ways to classify stream and river systems. One of the classifications most commonly used was developed by David L. Rosgen (see, for example, A Classification of Natural Rivers at http://www.alpine-eco.com/files/Rosgen_ClassificationNaturalRivers.pdf.) Rosgen's system is the one you'll encounter as you read about Kenai Peninsula riparian ecosystems. It's important to understand that different segments of a river can fall into different classification categories; small headwaters (first order streams) will tend to be Aa+ or A, whereas towards their mouths, many rivers will be C or E. You can see illustrations of local examples of these different categories under Riparian ecosystems, or by going to the source material for that entry.

This diagram compares the longitudinal (as seen from the side), cross-sectional (bank to bank), and plan (as seen from above) views of each of the nine major stream types in Rosgen's Level I stream classification. At the EPA website from which this diagram was copied, you can bring up a brief description of each stream type by clicking on its letter in the diagram. To do that, go to: http://www.epa.gov/owow/watershed/wacademy/acad2000/stream_class/03set.htm.



Because of how commonly Rosgen's system for classifying rivers is used, we are providing a VERY brief introduction to it here. This introduction is based on a module that EPA has developed, and which can be viewed at http://www.epa.gov/owow/watershed/wacademy/acad2000/stream_class/index.htm. The EPA module provides a fuller introduction to Rosgen's system without giving the average landowner TOO much information: We recommend that you check out the EPA website if you're interested in more background. Many of the illustrations included here are from the EPA website.

The most general level in Rosgen's system for classifying streams and rivers is Level I, shown in the chart at right. Stream types are labeled from Aa to G. Level I is based on stream characteristics that result from relief, landform, and valley morphology.

As explained in the EPA module on Rosgen's system,

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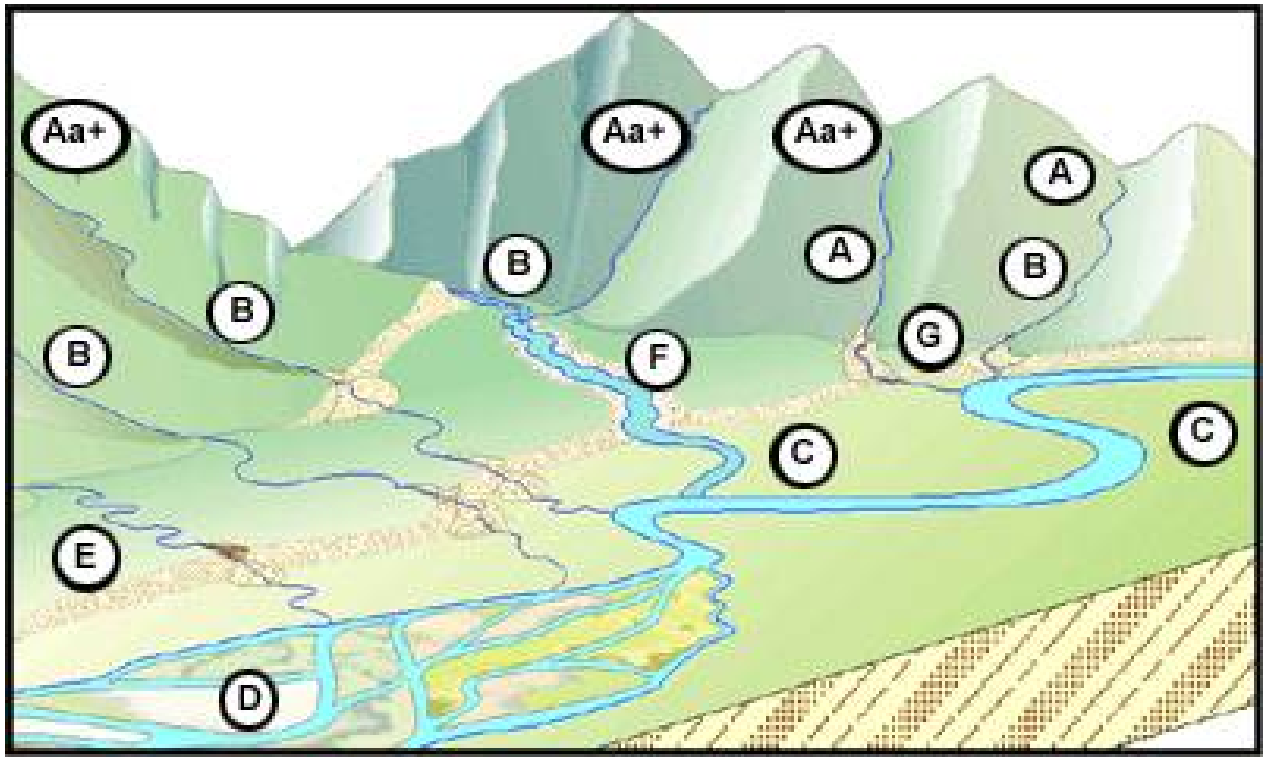
Level I stream classification serves four primary functions. It:

1. provides for the initial integration of basin characteristics, valley types, and landforms with stream system morphology.
2. provides a consistent initial framework for organizing river information and communicating the aspects of river morphology. Mapping of physiographic attributes at Level I can quickly determine location and approximate percentage of river types within a watershed and/or valley type.
3. assists in setting priorities for conducting more detailed assessments and/or companion inventories.
4. correlates similar general level inventories—such as inventories of fisheries habitats, river boating categories, and riparian habitats—with companion river inventories.

The advantage of a broad, general classification is that it allows for a rapid initial delineation of stream types and illustrates the distribution of these types that would be encountered within a given study area. The Level I classification and delineation process provides a general characterization of valley types (addressed in the second part of the EPA module) and identifies the corresponding major stream types, A through G.

The next category in the Rosgen system is Valley Type. Eleven kinds of valleys are identified. Some of these are illustrated at right.

Different Level I stream types tend to occur in different landscape settings, as shown here (from http://www.epa.gov/owow/watershed/wacademy/acad2000/stream_class/04set.htm).



The third category in Rosgen's system is Level II. Whereas Level I stream types are distinguished primarily on the basis of valley landforms and channel dimensions observable on aerial photos and maps, Level II stream types are determined with field measurements from specific channel reaches and fluvial features within the river's valley. The Level II classification process employs more finely resolved criteria in order to address questions of sediment supply, stream sensitivity to disturbance, potential for natural recovery, channel response to changes in flow regime, and fish habitat potential.

Level II stream type delineation criteria are based on characteristics of channel cross-section, longitudinal profile, and planform features as measured and computed from collected field data.

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Streambank stabilization and restoration

(see also Best Management Practices, Buffers, Soil bioengineering)

Vegetation is nature's way of stabilizing and protecting a streambank. Streambanks that are well vegetated greatly improve salmon habitats in adjacent stream channels, particularly if plants grow in and overhang the water. In particular, where plants overhang the water or grow partially submerged, small salmon (juveniles) that haven't yet headed out to sea can find areas to rest out of the current and to hide from predators. Leaf litter and insects falling or washed off plants and into the stream provide food sources critical to growing salmon, as well as to other kinds of fish and wildlife.

Making sure that streambanks are well vegetated is the best way to keep them stable and salmon friendly. If you want to restore a streambank, you'll want to revegetate it, and an excellent way to do that is by using techniques called "soil bioengineering."

If you have well-vegetated streambanks and want to keep them that way, protect existing plants by using buffers.

The photo to the right shows a streambank along Beaver Creek stabilized with soil bioengineering techniques, including brush layering and cabled spruce trees (source: Homer Soil and Water Conservation District). Beaver Creek is a tributary of the Anchor River.

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Stream channel processes

Streams are incredibly dynamic systems characterized by many complex processes. Many stream processes are interconnected so that a change in one alters others, and then those changes feed back into the system and change something else. But very basically, streams do three things—and these determine what kinds of salmon habitats will be found where.

- Most obviously, **streams carry water**, which is delivered from both surface and subsurface sources. The water that's delivered can be clean and cold or warm and polluted, depending on what's going on in the watershed—including what the humans in the watershed are doing (see water quality). Terms like discharge, flooding, bankfull, and ordinary high water, and tools like hydrographs relate to how quickly surface and groundwater are pouring or seeping into the stream channel, how much water is flowing within the channel, and how fast that water is moving.
- **Streams carry a load**, which consists of all the "stuff"—organic or inorganic, alive or dead—that washes or blows, slumps, slides, slips, rolls, falls, or gets dumped into the stream channel. Most of this stuff is sediment of some kind—sand, silt, clay, or larger materials like gravels and cobbles—but a lot of it is plant parts that have fallen or been washed in, and some of it is chemicals dissolved in the water. Terms like suspended load, bed load, dissolved load, and turbidity refer to stream load.
- **Streams sculpt and shape their channels**, by washing sections of it away or by dropping some of their load. Terms like meanders, downcutting, outside meander bend, braided channel, aggrading and degrading, and pools and riffles refer to how a stream sculpts its channel. Some of the categories into which stream and river channels can be divided are described under Stream channel "anatomy" (which would more accurately be called *fluvial*—having to do with water flowing in channels—*geomorphology*—having to do with how land gets shaped).

The Anchor River, looking downstream from the bridge on the Old Sterling Highway. Notice the different flow patterns on the right and left of the partially submerged gravel bar in the middle of the channel. Which side of the river is flowing faster? Is the water in the middle of the channel flowing right or left over the gravel bar? How will flow patterns change at higher flows? (Source: National Weather Service, see Anchor River.)

Clearly, a great variety of stream processes and interactions are possible when: varying volumes of water flow down different and changing slopes at varying speeds, over and through different kinds of surface and subsurface materials, which are covered by different and changing plant communities (not to mention shifting human land uses), over days, weeks, centuries, or millenia—with a few earthquakes, glaciers, and volcanic eruptions thrown in.

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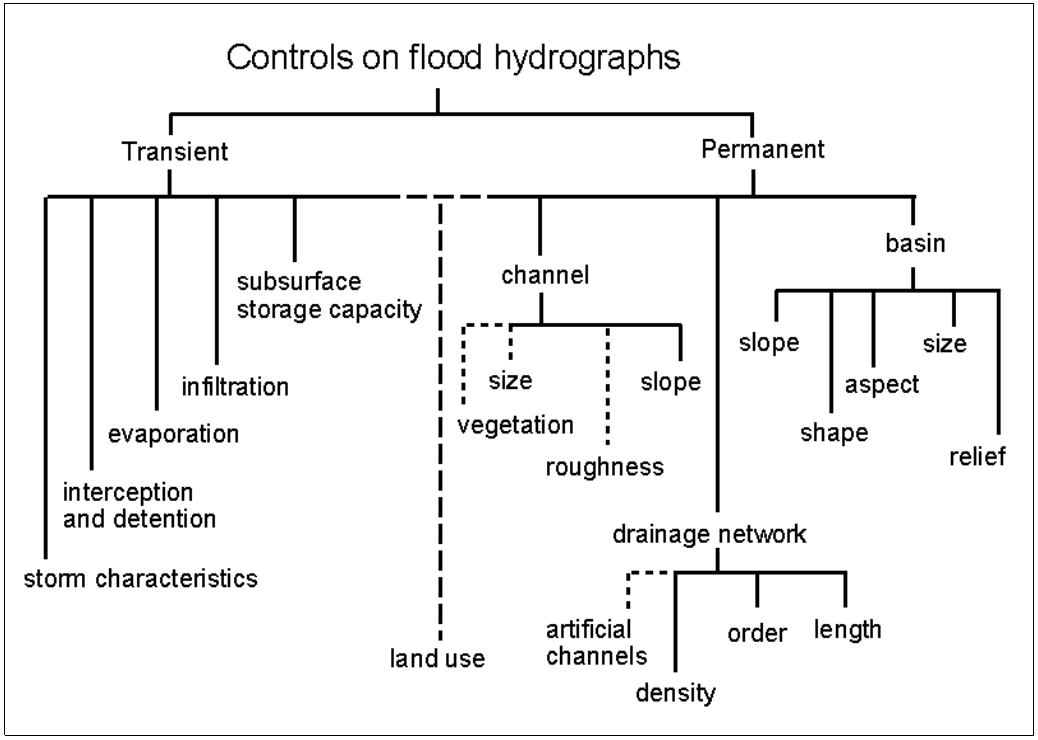
The variety of components (and time frames) that come into play in stream channel processes is suggested in **the diagram at right** (from http://uregina.ca/~sauchyn/geog327/controls.gif). The diagram identifies key variables that "control" flood patterns (see also Hydrograph). These range from short-term and transient—like the characteristics of a particular storm event—to essentially permanent—like the size a a watershed (or basin).



Below we summarize many concepts related to stream channel processes. Most of this summary was derived from a write up on channel processes by the Klamath Resource Information Service (KRIS), see http://www.krisweb.com/hydrol/channel.htm; references have been deleted.) At the KRIS website, many other stream and watershed processes are explained in terms easy for landowners to understand. To see the list of KRIS topics, go to: http://www.krisweb.com/backintr.htm.

Basic concepts related to channel processes
(Modified from http://www.krisweb.com/hydrol/ channel.htm.)
The velocity of a stream, as much as any single factor, is responsible for determining the size of particles a stream can transport, as well as the way in which it carries the particles, or load (see Stream load). Stream velocity is dependent on several factors:

Gradient: In general, the higher the gradient of a stream channel, the faster the flow velocity. Streams often begin in steep mountainous areas and fall precipitously in headwater tributaries (see Headwaters). Channels steeper than 12% gradient are considered by geologists to be *source reaches*, since any material falling into a channel of that steepness in a storm event will immediately move downstream. Streams tend to flow down into reaches of lesser gradient (4-12%) as they drop in elevation, but often remain in fairly incised canyons. These are known as *transport reaches* because materials still tend to move through these areas because of high hydraulic energy. When streams drop below 4% gradient and their channels are unconfined by high banks, the energy of the stream drops and sediment tends to remain in residence for longer periods. These areas are classified as *response reaches*.

Valley width and confinement: Wide, shallow rivers have more contact with streambed material and therefore more friction, which slows flow velocity. Entrenched rivers have less friction because they have a relatively low area in contact with bank and streambed materials. (In streams and rivers, the *wetted perimeter* is the surface of the channel bottom and sides in direct contact with water. Friction losses typically increase with increasing wetted perimeter,) Streams will increase in width when sediment supply exceeds transport capacity. As the channel widens in response to sediment over-supply it may become braided and lose a defined riparian zone.

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Roughness of sides and bottom of channel: A smooth stream bottom allows a higher velocity, while boulders or cobbles slow water flow. The size of particles on the stream bed is also a function of channel gradient and confinement.

Discharge: Increasing flows means less contact with the perimeter of the streambed as the water gets deeper and, therefore, greater velocity. Peak flood flows drive high sediment transport, and often sediment in transit on the stream bottom may be many feet deep. The **photo at right** is of the Salmon River during the 1964 flood (from http://www.krisweb.com/hydrol/64flood4.jpg). (For photos of 2002 flooding in our watersheds, see Flooding.)

Dominant discharge: The streamflow responsible for transporting the majority of the sediment and for creating or maintaining the characteristic size and shape of the channel is known as the *channel forming flow* or the *dominant discharge*. Most sediment transport occurs at relatively moderate flow events rather than large flow events, because moderate flows occur much more frequently than larger events (see Bankfull discharge). In channels at or near dynamic equilibrium, the dominant discharge is approximately equal to the bankfull discharge, which is the flow that fills the channel from bank to bank before spilling over the banks and out onto the floodplain. In streams that have been significantly incised, like portions of rivers on the Lower Kenai Peninsula, the dominant discharge is less than the bankfull discharge.

Amount of sediment: Increased sediment transport is associated with increased flows. The velocity of water required to mobilize tiny clay particles is approximately equal to the amount needed to mobilize sand, but once in motion clay will tend to stay suspended longer. Stream c*apacity* is the potential load a stream can carry, which is a function of gradient and flow; while stream load is the actual amount of material being moved. A stream in equilibrium is said to be "at grade" but will respond to any changes in flow or sediment supply. A stream loaded in excess of its capacity will deposit as much of its load as needed to achieve a new equilibrium between discharge (volume and velocity of water flow) and load (amount of material delivered to the stream). When a streambed is building up by sediment deposition as a result of bedload exceeding capacity, it is said to be *aggrading*. Increases in bedload may make a channel much shallower and wider, which in turn reduces the ability to hold high stream flows and thus increases flood frequency. Conversely, a stream with reduced bedload supply may have a capacity greater than its load and will downcut into its channel to increase its bedload, this is called downcutting or *degrading*.

Greater sediment transport slows the velocity of a stream, and in extreme cases makes it a slurry of debris. (When Kenai Peninsula glaciers were melting and receding, debris flows were common channel-shaping processes, see Glacial history of the western Kenai Peninsula and Landforms.) During debris flows, stream channels may be buried in sediments and plant material many feet deep. Large wood entrained in these flows may form temporary check dams that back up flows and slow the downstream movement of debris.

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If a stream bed is narrowed or confined to allow development in its riparian zone, this changes the equilibrium of the stream (see the photo of washed-out levees at Meanders). The faster velocity caused by the confinement increases the stream's capacity, and the stream begins to downcut. This downcutting may move upstream in what is known as headward erosion, causing banks to fail upstream and gullies to form in headwater areas or tributaries. Urbanization also increases stream runoff because water is no longer absorbed by soil or intercepted by vegetation (see Interception) where areas have been paved or otherwise made impervious. Flood peaks in streams with a high amount of total impervious surfaces are larger and higher than flood peaks in streams without urbanization (see also Hydrographs).

Rivers that form meanders in lowland areas, with alternating sequences of corner pools, crossings, and point bars, have bank material that is cohesive, like silt or clay. Cutbanks form at pools in meandering reaches, and this type of stream consequently has a naturally higher suspended load. Low gradient reaches where bank materials lack cohesion will generally form braided channels and carry coarser bed load (such as Fox River and Sheep Creek, at the head of Kachemak Bay).

An excellent online reference that discusses stream processes in more detail is Riparian Areas: Functions and Strategies for Management (2002) (go to http://www.nap.edu/catalog.php?record_id=10327#toc to begin looking through the book). Chapter 2, Structure and Functioning of Riparian Areas Across the United States, may be of particular interest (go to http://www.nap.edu/openbook.php?record_id=10327&page=49).

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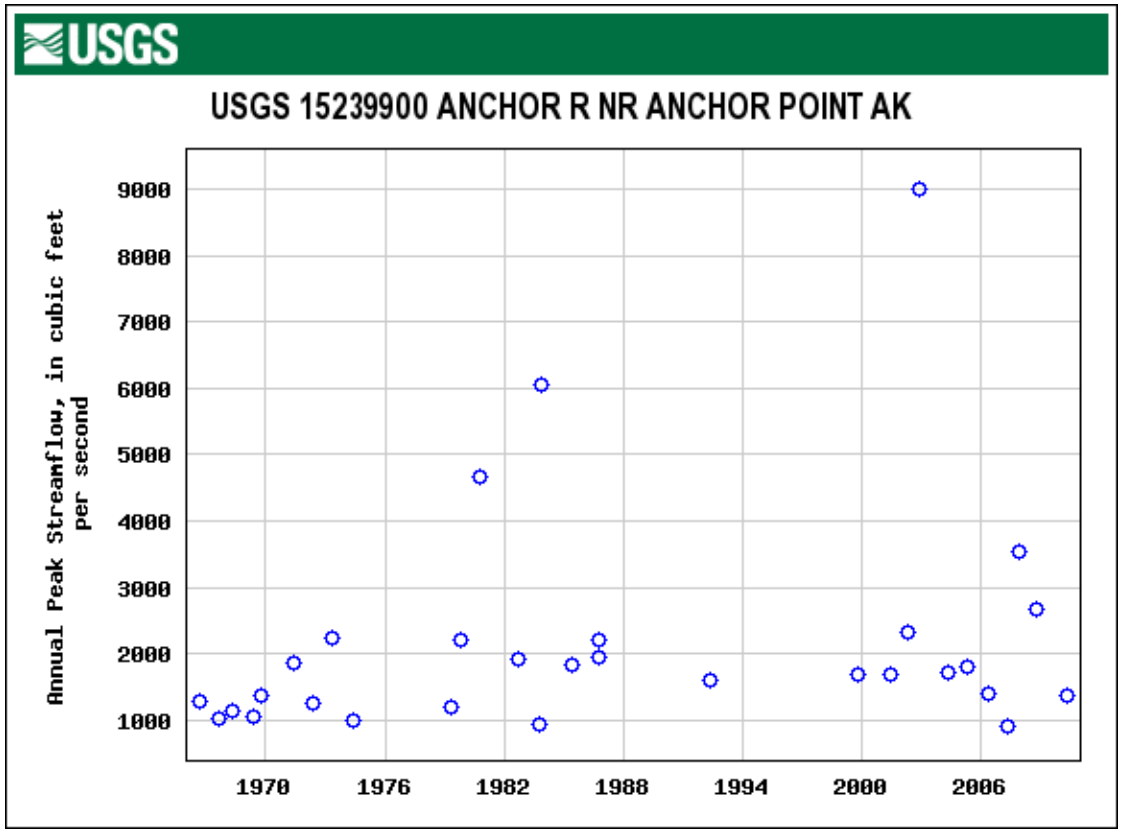
Stream discharge

The discharge of a stream or river is the amount of water that flows past a given point in a given length of time. Stream discharge is expressed as volume of flow past a point per unit time, i.e. cubic feet per second, (cfs) or gallons per minute (gpm). Obviously, discharge will vary depending where along the length of a stream or river it's measured; the closer to the mouth, the larger the discharge will be.

On the Kenai Peninsula, stream discharge is usually highest in September or October, and that's when flooding is most likely. Low flows usually occur June-July, when many salmon are heading upstream to spawn. (This is one reason why base flow is so important.)

You can see annual peak discharges in the Anchor River at the Sterling Highway bridge by clicking on this link: http://nwis.waterdata.usgs.gov/ak/nwis/ peak/?site_no=15239900, which brings up a graph like the one at right. Notice the dot up at 9000 cubic feet per second in 2002. That was during major flooding in October-November. Annual *peak* discharges in the Anchor River are usually less than 3000 cfs.



Stream discharge and stream stage can be linked, as shown in this graph from the National Weather Service: [copy from Anchor River]

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Streamflow

(*see also Flooding, Hydrograph, Hyporheic flow and zone, Stream channel processes, Stream discharge*)

The flow of water in streams and rivers is measured in a number of ways. Most commonly, this flow is measured as the volume of water (gallon, cubic feet) moving past a point in a specified period of time (minute, second). That measurement is called "discharge" (see Stream discharge). Another way streamflow is measured is in terms of the height of the water surface at a particular location. Water surface height is called "stage" and is measured by a stream gage (see Stream stage).

Streamflow is strongly correlated with many critical physical and biological characteristics of rivers, including stream temperature, sediment transport, stream channel "anatomy," stream channel processes, and habitats within and along the stream. Streamflow can be looked at in a number of ways, briefly described below. Changes in any of these flow parameters affect salmon habitats and salmon survival.

Flow magnitude is another term for discharge and represents the amount of water moving past a given location per unit time. It determines how much stream load a stream can carry (its capacity), and thus is a critical variable with regard to the creation of stream channel "anatomy" and alluvial landforms (e.g., meanders, point bars, floodplains streambanks, and channel sinuosity).

Flow frequency refers to how often a flow of a given magnitude is equaled or exceeded over some time interval. Flow frequency, in combination with flow magnitude, indicates the amount of energy a stream has to do work (e.g., sediment transport and channel shaping, etc., see Stream channel processes).

Flow duration represents the period of time associated with a specific flow magnitude. From the perspective of riparian plant communities and floodplain functions, flow duration represents the length of time that overbank flows occur or that soils remain saturated from high flows.

Flow timing generally refers to the seasonality of a given flow. For example, the timing of most snowmelt runoff in Anchor River, Deep Creek, Ninilchik River, and Stariski Creek is late spring and early summer. High flows generally occur during fall rainstorms. In contrast, the highest flows on glacier-fed streams (such as Fox River and Sheep Creek at the head of Kachemak Bay) generally occur during the warmest days of summer, when glacial melt is most rapid. Fish and other organisms have adapted their life history strategies to the timing of these flow periods.

The ***rate of change*** in streamflow or water levels represents how quickly a flow changes from one magnitude to another. Rate of change can influence sediment transport rates and riparian plant communities.

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Stream load

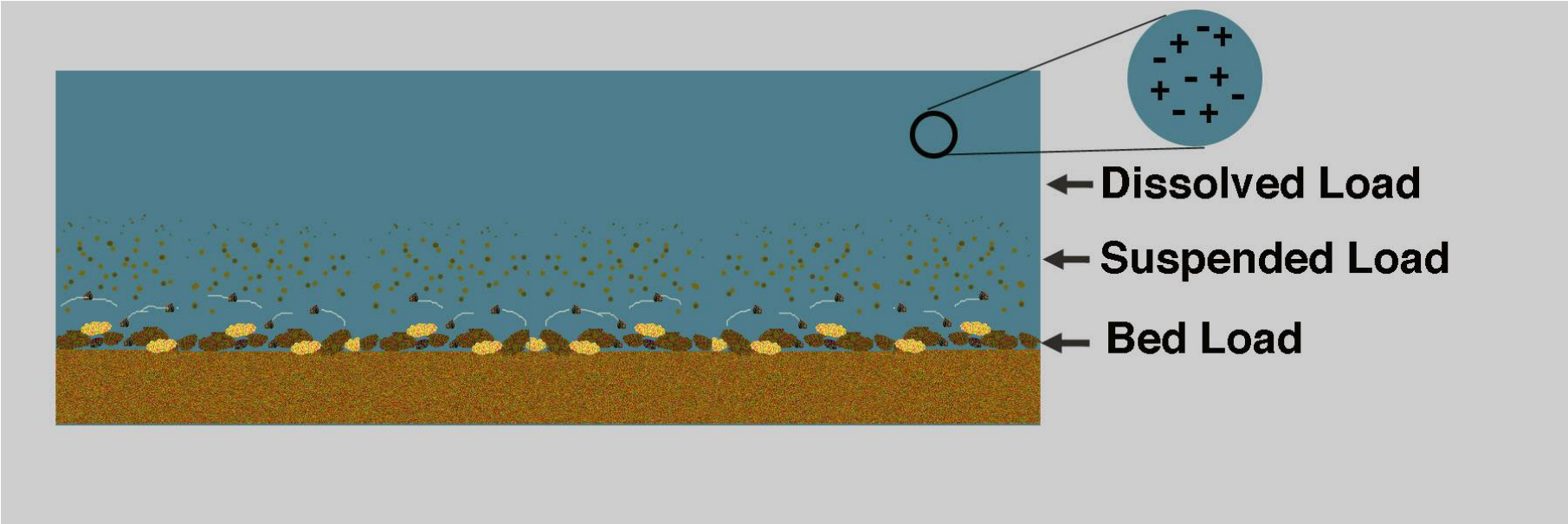
(see also Flooding, Sediment, Stream channel processes)

Stream load refers to all the the solid matter carried or moved by a stream. Erosion continually removes material from the streambanks and bed of a stream, and the stream's flow of water moves this material along. A stream's capacity to carry solid material is measured in tons per day passing a given location. This capacity is basically a function of the stream's discharge. Flood flows can move much more and much larger (heavier) material than more typical within-bank flows. During strong floods, huge boulders (and even buildings) can be moved by river currents (see Flooding).

A stream has three ways of moving solid material:, as *dissolved* load, *suspended* load, and *bed* load. The mass of the material (how heavy and/or buoyant it is) will determine how it gets carried by the streamflow. (The following descriptions are slightly modified from http://en.wikipedia.org/wiki/Stream_load and http://www.indiana.edu/~geol116/week9/load.jpg, the **image below** is from the latter source):

Dissolved load: Dissolved matter is invisible and is transported in the form of chemical ions (positively or negatively charged particles). All streams carry some type of dissolved load. This type of load can result from mineral alteration, from chemical erosion, or may be the result of groundwater seepage into the stream. Materials comprising the dissolved load have the smallest particle size of the three load types.

Suspended load: Suspended load is composed of fine sediment particles that are suspended in the water and transported by the current. These materials are too large to be dissolved but too small or light to stay on the bed of the stream. Streamflow keeps these suspended materials, such as clay and silt, from settling on the stream bed. Suspended load is the result of material eroded by hydraulic action at the stream surface bordering the channel, as well as erosion of the channel itself. Suspended load accounts for the largest portion of stream load. Rivers become muddy during floods because of the large increase in their



suspended load.

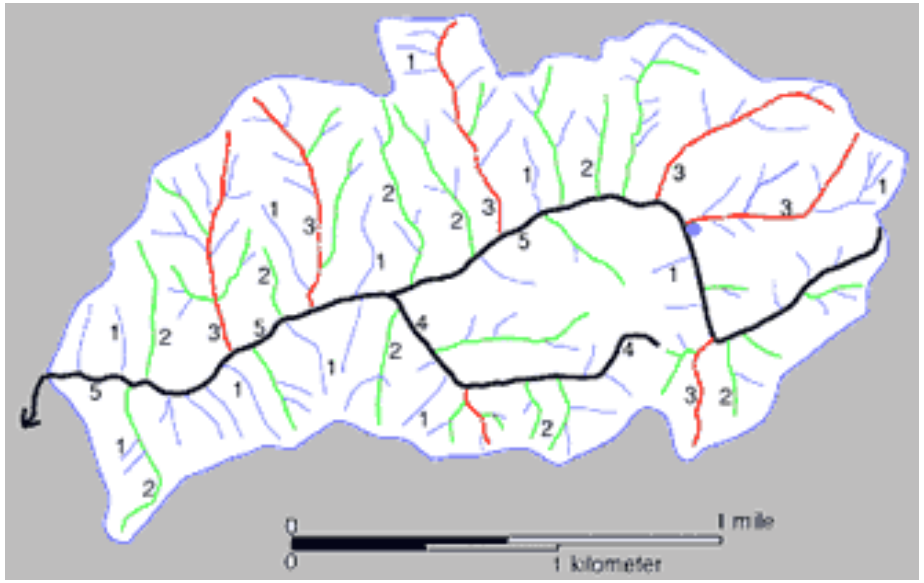
Bed load: Bed load rolls slowly or bounces along the floor of the stream. Bed load includes the largest and heaviest materials in the stream, ranging from sand and gravel to cobbles and boulders. There are two main ways to transport bed load: traction and saltation. Traction describes the "scooting and rolling" of particles along the bed. Saltation describes a bouncing movement, which occurs when large particles are lifted and momentarily suspended in the stream, get carried a short distance, and then fall back onto the bed, often dislodging other particles from the bed that may then also bounce a short distance downstream.

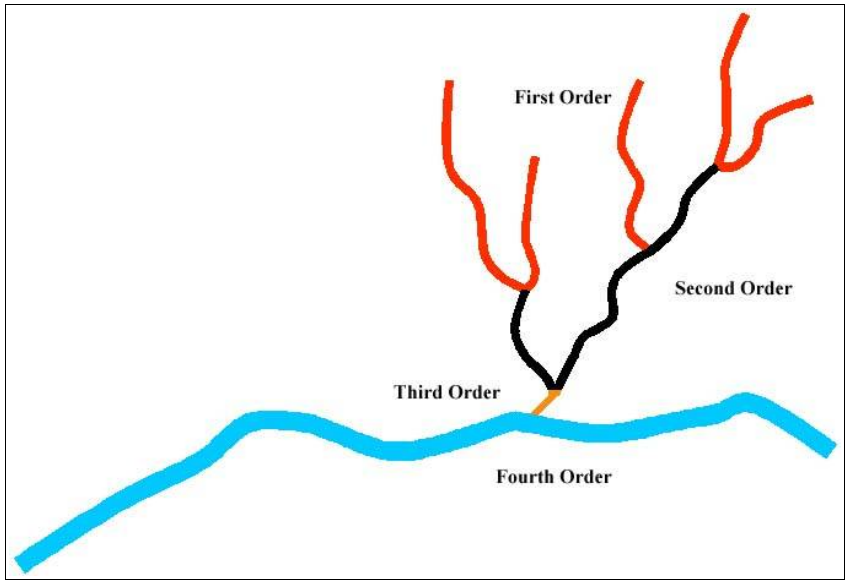
Stream order

(see also Stream channel "anatomy")

Throughout this guide, you'll run into the term "stream order" or "first order stream." Stream systems within a watershed can be ordered by numbering their channels from the smallest headwater tributaries to the largest mainstem channel entering the sea. The tiniest identifiable stream channels or reaches, which have no identifiable tributaries, are called "first order streams or reaches" and are numbered 1. A second order stream or stream segment is numbered 2 and has at least two first-order tributaries. A third order stream has at least two second-order tributaries, and so on, until you number the mainstem channel, which flows into the ocean, or for our rivers, into Cook Inlet. The calculation of stream order provides a rough indication of stream size and discharge (the amount of water passing a given point per unit time). The numbers of different orders characterizing a stream system will be a function of how many "layers" of streams exist in that watershed, which reflects watershed size and complexity. Some watersheds have only a few layers (orders) before you reach the mouth of the main channel; others, like the Yukon River system, will have numerous levels. The diagrams below illustrate stream order.

Examples of stream order (sources, on left, from: http://msnucleus.org/membership/html/jh/earth/water/lesson5/water5b.html, on right, from: http://www.epa.gov/esd/land-sci/lcb/nrb/VFRDB/glossary.htm).



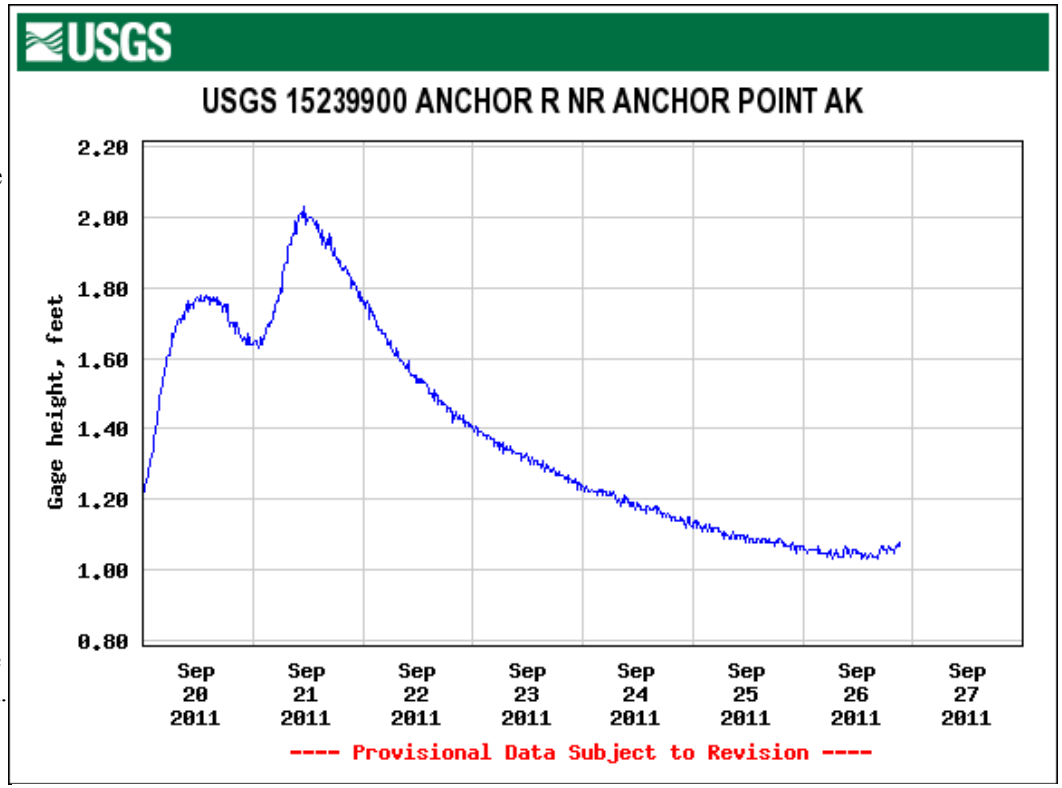


Stream stage

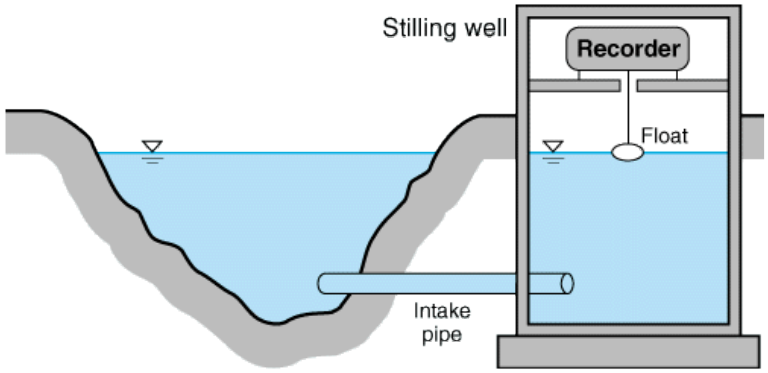
(see also Hydrograph, Stream discharge)

(Slightly modified from http://www.geology.sdsu.edu/classes/geol351/streamstage1.htm.)
The height or elevation of a stream's water surface above a reference elevation (such as sea level or a gage level) is called the stream stage. Stream stage can be measured manually or by instrumentation installed in the field. Floating gages use a buoyant ball that rises with rising water levels (that is, with increasing water surface elevation) and falls with falling water. Pressure transducers can be installed below the water surface to monitor increasing pressure as the water level rises and decreasing pressure as the water level falls. Such devices can be connected to data loggers to record changing water levels over time, as shown in the graph on the right.

Locations along streams that are monitored for stage over time are called gaging stations. Many gaging stations are monitored and maintained by the National Weather Service (NWS) and the US Geological Survey (USGS), including gaging stations on the Anchor River near Anchor Point and on the Ninilchik River. The diagram below shows how a stream gaging station is set up (from. http://hercules.gcsu.edu/~sdatta/home/teaching/hydro/slides/eph_images/fig5_2.gif).



The graph above shows the height of the Anchor River, in feet, September 20 through the 26; the river was highest on September 21, after a rainstorm, water surface reached 2 ft on the gage (source: http://waterdata.usgs.gov/usa/nwis/uv?site_no=15239900).



You can see the current stage of the Anchor River by clicking on http://waterdata.usgs.gov/usa/nwis/uv?site_no=15239900, or http://water.weather.gov/ahps2/hydrograph.phpwfo=pafc&gage =apba2. You can also find out the Anchor River stage on various dates at: http://waterdata.usgs.gov/usa/nwis/uv?site_no=15239900. If you choose to view a graph of stream discharge for 7 days, you'll get a graph that looks something like those shown above and on the next page.

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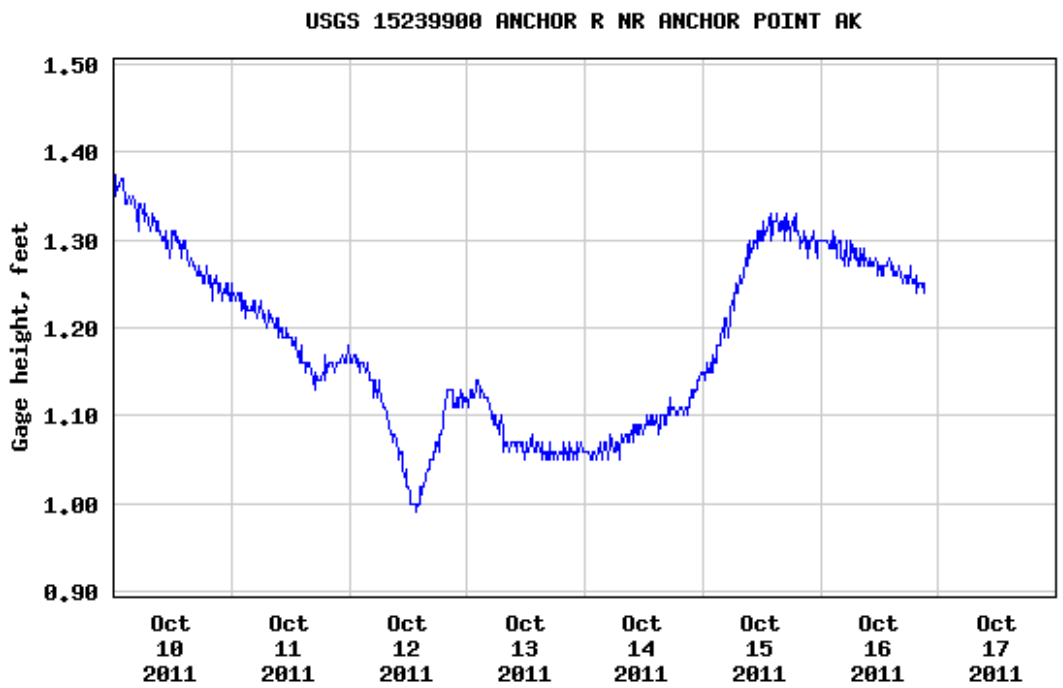
(From the National Weather Service, Alaska-Pacific River Forecast Center: http://aprfc.arh.noaa.gov/resources/docs/floodterms.php.) Since gages are few and far between in Alaska, the stage measured at each gage is used as an index of water level characteristics upstream and downstream of the gage, in addition to the status at the gage. In many cases, there is only one gage on a stream system and thus the gage represents the water level characteristics in the entire stream basin. The gage is also often used to indicate the water level status of other streams or lakes in the general area that have similar characteristics to the gaged stream.

People living or recreating near a stream or lake can use the closest gaged stream as a rough index for expected water level changes at their location (although storms can be localized, which reduces correlations between a gaged stream and ungaged streams nearby). For example, by checking stage height on the Anchor River at http://waterdata.usgs.gov/usa/nwis/uv?site_no=15239900 or http://water.weather.gov/ahps2/hydrograph.php?wfo=pafc&gage=apba2, landowners along an ungaged tributary can track how stream levels on their property generally correlate with stage heights reported for the Anchor River at gaged locations.



The graph above shows river stage on the Anchor River from October 10 through 16 (source: http://waterdata.usgs.gov/usa/nwis/uv?site_no=15239900).

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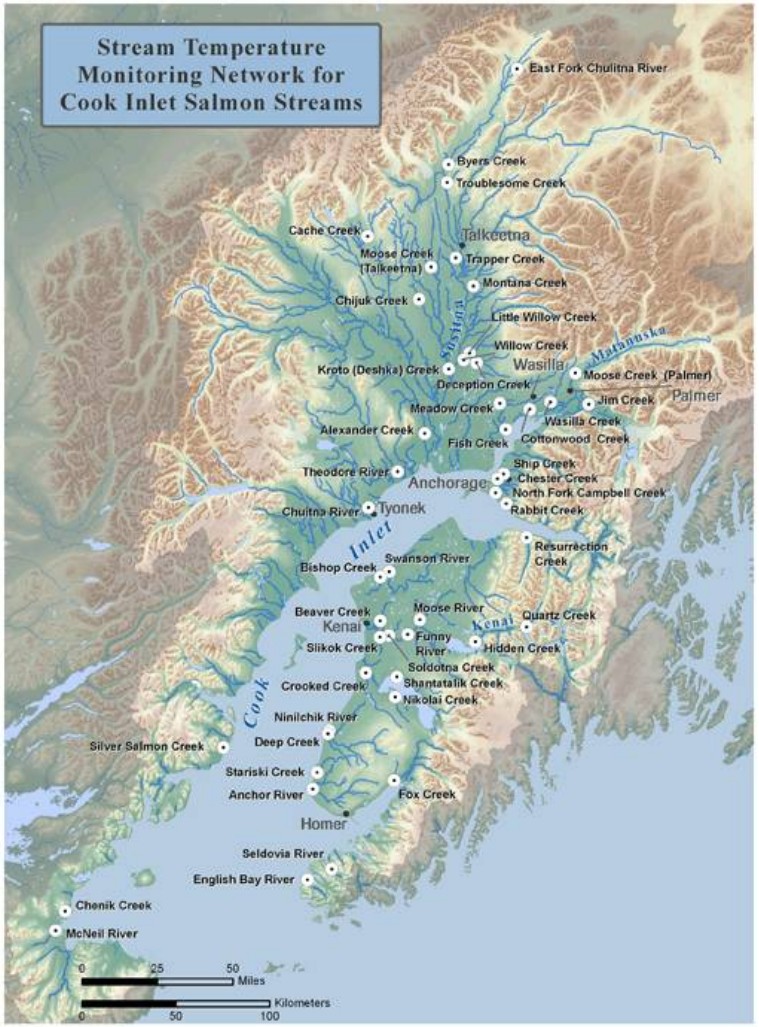
Stream temperatures

[Slightly modified from a presentation by Sue Mauger, Cook Inletkeeper, Anchor River Celebration, April 30, 2011; for more information go to Mauger's article *Changes in Alaska Salmon Stream Habitat due to Climate Warming* (http://inletkeeper.org/resources/contents/changes-in-alaska-salmon-stream-habitat-due-to.)



Stream temperatures matter to salmon: Salmon like cool water. When stream temperatures get warmer, salmon get more stressed; they become more vulnerable to pollution, predation, and disease, and it's more difficult for them to put on weight and to breathe.

For almost 10 years, Cook Inletkeeper (CIK) has been looking at stream temperatures. In 2002, we began looking at stream temperatures in the Anchor River. We use little temperature loggers that can measure temperature year round, every 15 minutes. And what we've found is that for all the eggs that are in the redds, temperatures are already a little bit warmer than optimum, warmer than we would have expected for Alaska streams.

We're trying to understand how water temperature changes every year in relationship to air temperature, because one of the good data sets that we DO have in the state is air temperatures. Some pretty good air temperature data sets from airports go back to about the 1930s. If we can understand how water temperature varies with air temperature, we can get a handle on whether the temperatures salmon are experiencing now are what they've always experienced, or if things are a bit warmer now than they were in the past. And, of course, with climate change, the expectation is that air temperatures will only get warmer. So we're really trying to understand where we are on the curve of stress for salmon in the stream.

Temperature measurements indicate that stream temperatures appear to be warming: We can take current water temperatures and air temperatures and use the relationship between the two to backtrack to what historical water temperatures would have been based on historical air temperatures. Based on this data, streams have historically been below 55 degrees F most of July; 55 degrees is the temperature at which salmon eggs start to become stressed. In the earlier part of last century, stream temperatures were cool enough that salmon eggs were not subject to temperature-related stress. More recently, we see stream temperatures above 55 degrees; and predictions based on air temperature models for future conditions are that those water temperatures will increase; over the next 50-60 years, we're going to begin to get into stream temperatures over 60 degrees F for most of July. This is important for us to understand for managing salmon populations and for making changes to reduce climate changes triggered by carbon emissions.

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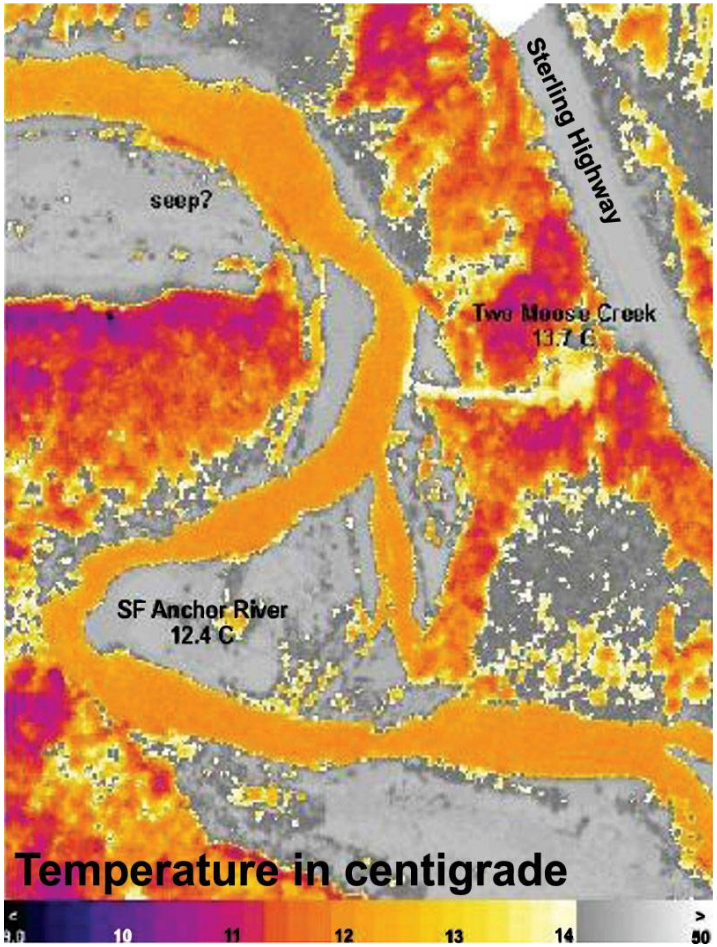
When we think about temperatures at the scale of juvenile fish—from the perspective of the tiny segments of stream in which these small fish feed, rest, and hide (see *introductory article 1: Salmon species and life cycle*)—it's not just air temperature that drives water temperatures. Other factors are important day-to-day and year-to-year. For example, in addition to air temperature patterns, we need to look at how much water is in the stream—a stream with more water in its channel warms up more slowly than if less water is present. Also streamside vegetation can be very important for creating shaded environments that remain cooler than unshaded portions of the channel. In an effort to understand these smaller scale temperature patterns and how they might affect salmon, on June 30, 2010, 34 miles of the Anchor River were flown with a helicopter to collect thermal infrared imagery. These images of the Anchor River give us a signature of surface water temperatures at the time they were taken. That allows us to understand how well-mixed the stream is where the salmon are, whether they see a stream that's all the same temperature or if they find different temperatures as they move to different areas on the left and right sides of the channel. The **thermal image below left** shows what we found where Two Moose Creek empties into the South Fork of the Anchor River at about river mile 5.4, shown in



the photo on the right. It's clear from thermal images temperatures in the channel are different at different locations, and that salmon can experience these differences.

Some places in the river have really good connections with groundwater. At these locations, cooler groundwater enters the stream channel (see aquifers and hyporheic flows). Based on the thermal infrared imagery, Cook Inletkeeper in summer 2011 ground truthed areas where we could see potential groundwater connections—and thus colder water (see http://inletkeeper.org/healthy-habitat/cold-water-refugia). We discovered springs and seeps that are, in fact, contributing cold water to the river's mainstem, sometimes as much as 9 degrees F colder. These areas are often rust colored as the iron-rich groundwater reaches the surface and is oxidized. It's not the rocks themselves, though, that get stained; instead it may be that algae growing on the rocks capture the oxidized iron particles binding to sediments, and thus they look orange. These areas will become increasingly important to salmon if overall stream temperatures continue to rise. In a few cases, we also found tributaries adding warmer temperature water. This ground truthing is an important step to validate the TIR images. With on-the-ground confidence that the images accurately reflect thermal conditions, we can take this work into new watersheds.

How landowners can help "be cool." Seen from this perspective, it's easy to see why it's important for landowners and managers to do anything we can to minimize increases in stream temperatures. We can help rivers and streams "be cool" by doing things like:

- protecting streamside forests and overhanging vegetation. The taller the trees along the south side of a river or stream, the more the channel will be cooled by shade.
- reducing the amount of impervious surfaces we create. Think of how roofs and pavement warm up on even a partly sunny day. Rainfall running off these surfaces tends to be warmer than rainfall flowing down slopes shaded by vegetation or filtered through soil.
- making sure that rainfall has places to infiltrate downward into the soil—places like wetlands, naturally vegetated buffers, or raingardens (see Best Management Practices). These areas increase the likelihood that precipitation will reach nearby streams as subsurface flows, which have cooler temperatures than surface flows with more direct contact with the air.
- making sure that we don't disrupt subsurface drainage systems, since groundwater flowing into stream channels can be a significant source of cooler water.

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Surface runoff

(See also Erosion, Hydrograph, Sediment, Stormwater runoff, Water cycle, Water quality)


Erosion caused by surface runoff

Runoff is rainwater or snowmelt that flows over the land's surface and into streams and lakes. Runoff picks up erodible soil particles and pollutants and carries them to wetlands and waterbodies. Runoff also contributes to flooding. The US Geological Survey (USGS), identifies the following factors that affect runoff (http://ga.water.usgs.gov/edu/watercyclerunoff.html):

Meteorological factors affecting runoff:

- Type of precipitation (rain, snow, sleet, etc.)
- Rainfall intensity
- Rainfall amount
- Rainfall duration
- Distribution of rainfall over the drainage basin
- Direction of storm movement
- Precipitation that occurred earlier and resulting soil moisture
- Other meteorological and climatic conditions that affect evapotranspiration, such as temperature, wind, relative humidity, and season

Physical characteristics affecting runoff:

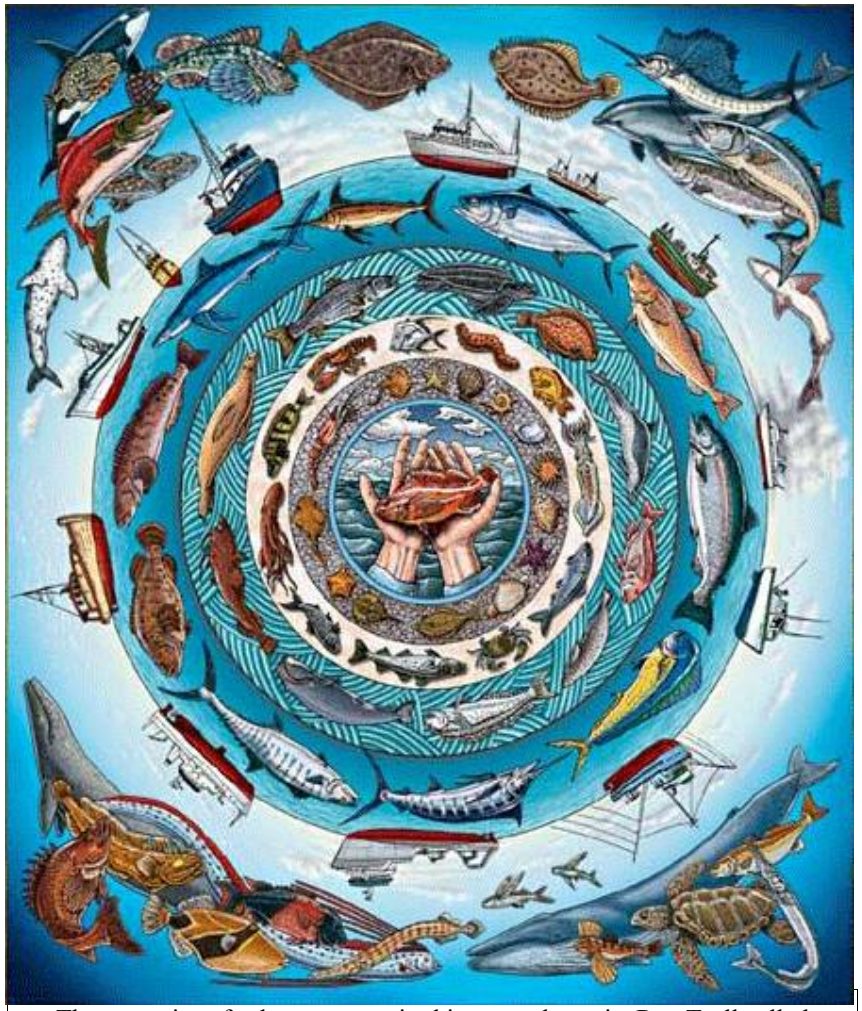
- Land use
- Vegetation
- Soil type
- Drainage area
- Basin shape
- Elevation
- Topography, especially the slope of the land
- Drainage network patterns
- Ponds, lakes, reservoirs, sinks [e.g., many kinds of wetlands], etc. in the basin, which prevent or delay runoff from continuing downstream.

Human activities can affect runoff As more people move into Kenai Peninsula watersheds, and as more development and urbanization occur, more of the natural landscape will be replaced by impervious surfaces such as roads, houses, parking lots, and buildings, which reduce interception of rain and snow and infiltration of water into the ground. These changes accelerate runoff to ditches and streams. Clearing vegetation, disturbing native soils, grading the land surface, and installing drainage networks also contribute to increased storm and meltwater runoff, while also decreasing the time it takes for runoff to reach streams. As a result, the height and frequency of floods can increase in affected streams (see Hydrograph). All of these changes can alter salmon habitats in ways that harm salmon. Anything landowners do to minimize their contributions to surface runoff will benefit salmon populations and habitats.

Sustainable, sustainability

This is a big topic (see for example the World Bank's discussion and educational module on this topic at: http://www.worldbank.org/depweb/english/sd.html; or the discussion at: http://inquiringsystems.org/index.php?option=com_content&view= article&id=62:sustainability&catid= 36:articles&Itemid=65. One commonly used definition of sustainable development is: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (*Our Common Future*, World Commission on Environment and Development, Oxford University Press, 1987). Another definition, more specific to land use activities, is that *sustainable* means using lands and waters in ways that **maintain** their **productivity, biodiversity,** and **healthy functioning indefinitely**. This also maintains the usefulness of these lands and waters to society indefinitely.
This is certainly what we're talking about in this landowner's guide with respect to salmon: helping landowners do things that meet their own needs but in ways that don't compromise the availability of salmon populations for future generations. And the best chance for making this happen (and assuming that oceans stay salmon friendly and local climates don't change TOO much) is if enough landowners, one by one (whether private, Native, borough, city, or state), do everything they can to keep their own lands and waters salmon friendly.

What makes choices related to sustainability and sustainable development so difficult is that we often want to sustain things that are contradictory: we want clean air AND gas-powered vehicles; a robust mining industry AND productive salmon habitat. Making choices between these kinds of alternatives is a struggle. Still, true sustainability is based on a simple principle: Everything that we need for our survival and well-being ultimately depends—either directly or indirectly—on the healthy functioning of our watershed's natural environments, and maybe that's even more true for salmon than for us. So if sustainability is the goal, for ourselves and for local salmon stocks, we can each work to create and maintain conditions on our lands and waters that are closest to conditions occurring naturally. Information in this guide should make it easier to figure out how to do that (see, for example, Best Management Practices, Low Impact Development, and Raingardens).



Three species of salmon appear in this poster by artist Ray Troll called "**Sustainability—It's in Our Hands**. Can you find them? If you go to the online version of this poster, at http://www.nmfs.noaa.gov/speciesid/Sustainability.html, you can click on each fish to find out more about it.

If you'd like to explore the topic of sustainability in more detail, EPA maintains a sustainability homepage with a wealth of information: http://www.epa.gov/sustainability/index.htm. One of the links takes you to a variety of tips you can follow for green living: http://www.epa.gov/gateway/learn/greenliving.html.

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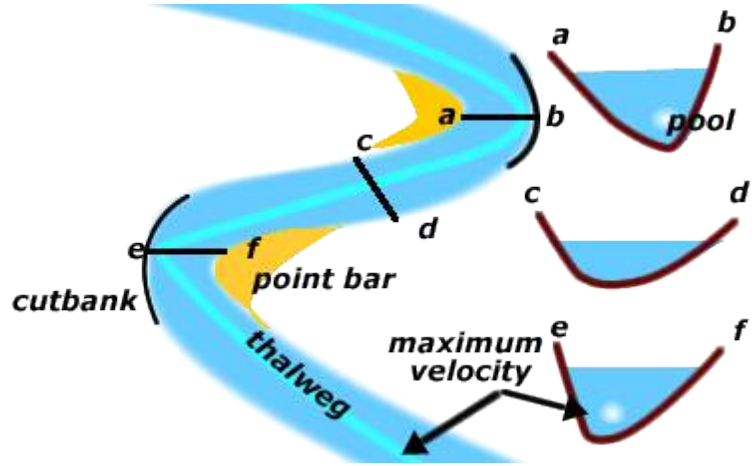
Thalweg

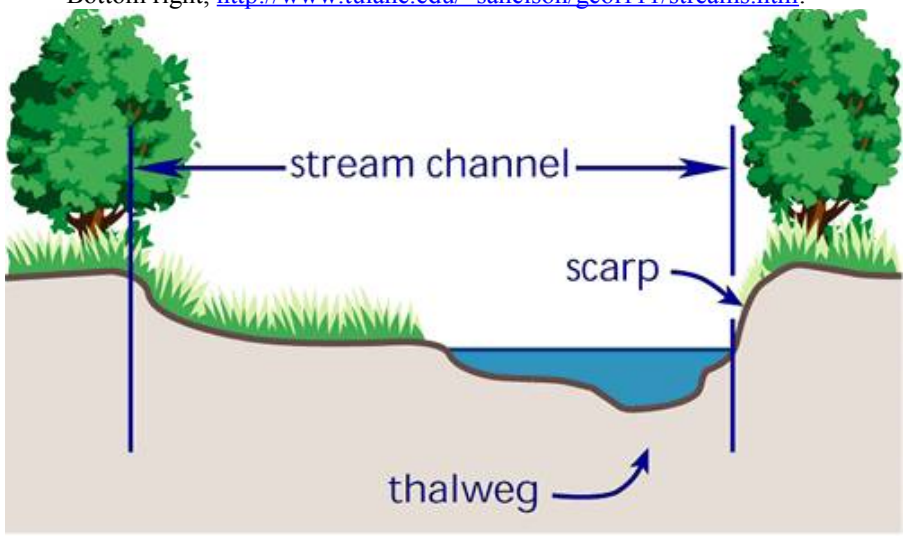
(*see also Stream channel processes*)

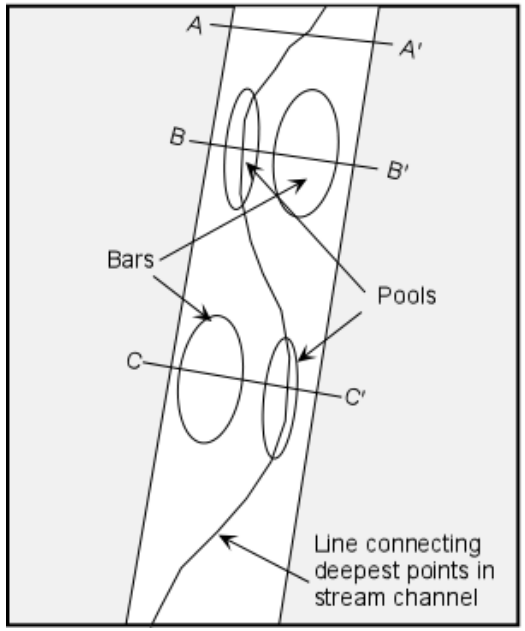
The thalweg is the deepest part of a stream channel. Looking at a stream along its length (longitudinal view), the thalweg is a line connecting the deepest areas of riverbed from headwaters to mouth. Looking at a stream channel cross section, the thalweg is the deepest point in the cross section. The area in the channel where water moves fastest is somewhere above the thalweg (see diagram bottom right), where friction of flowing water against streambed and bank materials is at a minimum. During rising flood stages, the thalweg tends to switch from the outside curves of a channel to the channel's center. This can scour point bars and temporarily straighten out the channel; lower flows (e.g., bankfull discharge) then re-establish the characteristic channel.

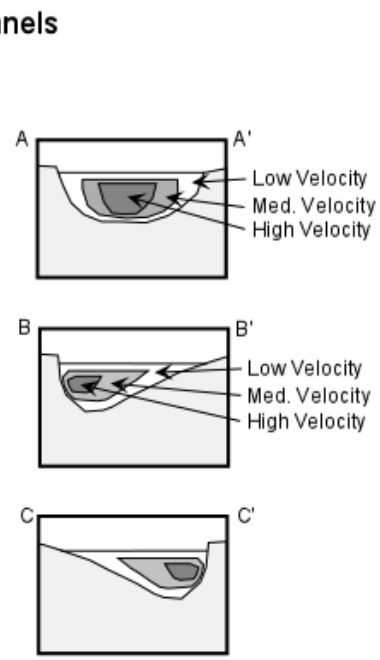
Just as with so many of the complex interactions that maintain salmon habitats, changing the location of the thalweg (for example by dredging out, filling in, or driving through a segment of stream channel) can damage or destroy salmon habitats (both upstream and down). For this reason, Alaska Department of Fish and Game regulates all activities below ordinary high water within anadromous streams.



Various views of the thalweg. Sources for images:
Top right, http://w3.salemstate.edu/~lhanson/gls210/gls210_streams2.htm,
Bottom left, http://www.fgmorph.com/images/03/03_14_01.gif,
Bottom right, http://www.tulane.edu/~sanelson/geol111/streams.htm.







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Till

(see Glacial till)

Another diagram of the water cycle (source: http://www.fgmorph.com/fg_3_4.php).

Tsunamis

This is a brief background on tsunamis to give landowners some basic information they might find useful. For up-to-the-minute tsunami alerts, including maps and estimated arrival time if a tsunami is forecast, go to the West Coast and Alaska Tsunami Warning Center, at http://wcatwc.arh.noaa.gov/. For helpful information on preparing for tsunamis, visit the National Weather Service site Tsunami Ready, http://www.tsunamiready.noaa.gov/. There you can find videos and publications about tsunamis, as well as links to additional websites. To track recent earthquakes worldwide, go to the USGS Earthquake Hazards Program website, at http://earthquake.usgs.gov/.

Definition (from FEMA, http://www.fema.gov/hazard/tsunami/):
Tsunamis, also known as seismic sea waves (mistakenly called "tidal waves"), are a series of enormous waves created by an underwater disturbance such as an earthquake, landslide, volcanic eruption, or meteorite. Earthquake-induced movement of the ocean floor most often generates tsunamis. A tsunami can move hundreds of miles per hour in the open ocean and smash into land with waves as high as 100 feet or more. From the area where the tsunami originates, waves travel outward in all directions. Once the wave approaches the shore, it builds in height. Topography of the coastline and the ocean floor will influence the size of the wave. There may be more than one wave, and the succeeding one may be larger than the one before. That is why a small tsunami at one beach can be a giant wave a few miles away.

All tsunamis are potentially dangerous, even though they may not damage every coastline they strike. A tsunami can strike anywhere along most of the U.S. coastline. The most destructive tsunamis have occurred along the coasts of California, Oregon, Washington, Alaska, and Hawaii. If a major earthquake or landslide occurs close to shore, the first wave in a series could reach the beach in a few minutes, even before a warning is issued. Areas are at greater risk if they are less than 25 feet above sea level and within a mile of the shoreline. Drowning is the most common cause of death associated with a tsunami. Tsunami waves and the receding water are very destructive to structures in the run-up zone. Other hazards include flooding, contamination of drinking water, and fires from gas lines or ruptured tanks.

To learn more about tsunamis, visit the USGS website called Earthquake Topics—Tsunamis, which has links to many sources of fascinating information: http://earthquake.usgs.gov/learn/topics/?topicID=34. FEMA, the Federal Emergency Management Agency, also maintains a tsunami website with information and additional links: http://www.fema.gov/hazard/tsunami/. The more you know, the better you'll be able to prepare. The better prepared you are, the more confident you'll feel. The more confident you feel, the calmer and more effective you'll be in an emergency situation.

The Three Tings You Need to Know About Tsunamis (slightly modified from http://seagrant.oregonstate.edu/themes/hazards/documents/The-Three-Things-You-Need-To-Know-2011.html).
First, there are two kinds of earthquake and tsunami events: *local* and *distant*.
Local events: If you FEEL an earthquake, a BIG ONE, it's a LOCAL event. Duck, cover, and hold on until the shaking stops. Move out of unsafe

buildings. Large earthquakes cause large tsunamis. If you're at or above 50 feet elevation, stay there. If not, run for the highest spot you can get to in 15 minutes. Do not move from high ground for 12 to 24 hours, as there may be several surges. Do not expect to be able to drive or use telephones or cell phones. Do not expect outside help. Expect to be out of contact with loved ones.

Distant events: If you don't feel an earthquake, but HEAR ABOUT a warning on the TV, siren, or radio, it is a DISTANT event (like we've seen after earthquakes in Alaska, Chile, and Japan.) Take a breath. Find out more information. This may be no big deal. Media warnings and sirens tell us that an earthquake has happened somewhere else and that small tsunamis, though on their way, will take hours to arrive here. There are no earthquake issues in this case, and you have plenty of time to evacuate if needed.

Second, know the danger zones in your area.

Danger zones are essentially all areas less than 50 feet in elevation. Danger zones are defined on official tsunami inundation and evacuation maps. These zones indicate the inundation expected by a LOCAL event, a Big One, not a distant event. Identify the dangerous areas where you live, work, shop, play, etc. Note the nearest high ground and the routes to get there. Develop an "eye for the landscape" and discuss with family where the safe places are. Ask for maps at your local fire department or City Hall. Advocate for access and assembly areas at these locations.

Distant tsunamis have no local earthquake and produce smaller waves. The inundation may be similar to floods during a severe winter storm at high tide (beaches, waterways, and low-lying areas). Most people won't need to go anywhere. Those who do need to evacuate should do so for 12 to 24 hours, as there may be several surges. Monitor media for instructions. Be considerate of emergency managers: don't go to the beach to watch!

Third, have a plan to reconnect with loved ones.

The odds of everyone being together when an earthquake or tsunami happens are slim. For a local earthquake, teach loved ones to immediately get to high ground, stay there overnight, and reconnect the next day. Do not insist on rushing to a predetermined location (home, school, etc.), as this will cause people to travel through dangerous areas to get there. Do identify a non-local (out-of-state) person for everyone to call as soon as they can. Although it may take a while, family members can eventually reconnect through this common contact. Preparing with loved ones today will give you greater peace of mind during the actual event. For distant, tsunami-only events, there is typically little problem. At worst, it's the hassle of busy phone lines and potential traffic delays.

Here are a few additional earthquake and tsunami "Geologic Factoids:"

- Essentially, in Alaska, the floor of the Pacific Ocean slowly but continually "subducts," or dives under, the North American continent along the Aleutian Trench Subduction Zone. The two plates move over each other about as fast as a human fingernail grows. That's not a lot, but it builds up great pressure over the centuries. That pressure is released in earthquakes, and earthquakes can generate tsunamis.
- More deaths typically occur from the tsunami than from the earthquake. Aftershocks and landslides could occur for days. Fires are expected. Infrastructure may be damaged, public services scant.
- Tsunamis generated by distant earthquakes take time to get here and are much smaller. It takes 3-4 hours for a tsunami to get to Oregon from Alaska, 9 hours to get to Oregon from Japan, and 10+ from South America (Chile).
- There will be official warnings. Our tsunami buoys and warnings are effective for distant events.
- Inundations will likely be similar to a bad winter storm at high tide, that is, potentially bad in specific locations but not catastrophic. Damage is typically limited to the beach front, waterways, maritime infrastructure, wetlands, and other low lying areas.

- The 1964 Alaskan quake and distant tsunami killed 122 people mostly in Alaska and Crescent City, CA.
- The same distant event today would likely cause more death and damage because there are more people living along the coast and more infrastructure than in 1964.

Ten Common Misunderstandings about Tsunamis (slightly modified from http://seagrant.oregonstate.edu/themes/hazards/documents/The-Three-Things-You-Need-To-Know-2011.html).

- "Tsunamis are waves." A tsunami is not a "wave," which moves up-and-down, but the ocean moving sideways. Here's an analogy. When your dog laps water in his bowl, he's making "waves." When he kicks the bowl across the floor and it slams into the refrigerator and the water spills over the side… that's a tsunami. The approaching tsunami looks more like a storm surge. Even small tsunamis carry tremendous power. Tsunamis come in a series of surges lasting up to 12 hours.
- "Sirens mean run!" Sirens indicate a distant tsunami. Locally affected residents have time to evacuate areas immediately adjacent to the beach and waterways. If you are at home and your home is in such a location, gather your medications and personal items and leave the inundation zone for 12 hours. If you are in a low lying area when the siren sounds, simply go home or visit someone on higher ground. Make friends in high places!
- Consider buying a NOAA All Hazards radio. These radios serve as "personal sirens" for distant events,and immediately provide information on where the earthquake occurred and how long it will take to get here. (Think of them as "smoke detectors for distant tsunamis.") NOAA All Hazards radios are widely available at electronics stores.
- "We live on a hill, so we're safe." That's only true if you're at home when it happens. You might live on a hill, but you're in danger if you happen to be working, shopping, recreating, or driving through, an inundation zone when the Big One hits. Second, people on hills need to worry about falling off those hills during the earthquake and avoiding subsequent landslides. Don't forget the earthquake!
- We are residents of the north coast region and most of us travel in and out of inundation zones all day. We need to "develop and eye for the landscape" to instinctively understand when we're in a dangerous area, and know where we would need to get to.
- "We will drive to safety." After the local Big One, you probably won't be able to drive due to the damage from the earthquake. (If it's obvious that you can do it, do it. But don't plan on it.) Why? Your car may be under the rubble that used to be your garage. Even if your car is OK, the garage door probably won't open. Even if it does, the roads will be impassable due to fallen trees and power poles, damaged bridges, and from the scores of landslides that will occur on major roadways. Don't plan on a car strategy--plan on running to safety. If you live in an inundation zone, practice your evacuation route so you can do it in the dark. (In a distant event, there will be no earthquake damage and you will have plenty of time to leave--if necessary.)
- "We'll connect by phone." After the local Big One, telephone poles and cell towers will topple, and any working lines will be jammed. Satellite phones may work. Critical service providers and other key individuals and agencies might consider getting satellite phones. OnStar systems in cars are satellite phones. Ham radios will work and local operators are prepared. (In a distant event, the phone lines will be intact but overwhelmed. Sometimes text messaging works when phone service doesn't.)
- "I have an emergency kit, so we're covered." After the local Big One, the odds of you having your kit handy are low. I endorse emergency kits (I have one), but it's even more important to take an Advanced First Aid class. You will almost certainly need to administer first-aid to yourself, your family, and your neighbors. Remember, many homes will be OK. You can get supplies from neighbors' pantries and medicine cabinets. Note: prescription medications can be a matter of life and death. Consider identifying people in safe areas who take the same medications as you. Evacuate to their house if you're caught without medicines during the Big One. (In a distant event, grab a go-bag of medications if you need to evacuate a low lying area.)
- "We'll have to camp out for a week after the Big One." Some will, but most probably will not. Residents in outlying areas may be cut-off for several days or weeks due to landslides. But in town, it's more likely that some neighborhoods will be devastated while others will be relatively intact. We should

expect that displaced people will go to homes left standing and be taken in by neighbors. We would be well served to prepare for this at the family and neighborhood level.

- "Someone will come and save us." After the local Big One, emergency management professionals (police, fire, ambulance, etc.) will be in the same boat as everyone else—unable to drive their vehicles over destroyed bridges, landslides, and debris. As good as our local emergency officials are, they will have only a limited ability to help individuals under either scenario. Do not expect personal attention. The more likely scenario is "neighbor helping neighbor." What will that look like? What can we do now, to prepare for that? (In a distant event, emergency managers facilitate the evacuation of people out of the low lying areas. Be nice to them. Stay away from the beaches and waterways.)
- "Tsunami preparedness is Bad for Business." Evidence indicates otherwise. Disney World in Orlando is in "hurricane alley," and the county has one of the highest incidents of lightening strikes in the country. Yet, Disney World is one of the top tourist locations in the USA. Similarly, Disneyland in CA is located in a highly seismic region and it remains highly popular. The Hawaiian Islands are an actively erupting volcano! Hawaii is also vulnerable to hurricanes, earthquakes, local tsunamis and distant tsunamis from all over the Pacific. Yet, everyone still wants to go to Hawaii. The education and attitude of local residents, businesses, and realtors toward these hazards sets the tone for how others respond. Prepared people are confident, and confident people are reassuring. Educate yourself, and train your employees to be proactive. "Own" that Big Ones happen here. "Frame" the way you want to present that to the market. And "capitalize" on the brand! "Own It, Frame It, and Capitalize on It."
- "I have to find my pet." Pets instinctively flee disasters. Follow them!
- "There's nothing I can do. If it happens, it happens." Wrong. You just read several things individuals and families can do to improve their odds of surviving earthquakes and tsunamis. Take an hour to learn what you need to know, and then let it go. Enjoy life on the coast. This is a beautiful place to live, work, and play.

Turbidity

(see also Erosion, Stream load, Stormwater runoff, Water quality)

Turbidity is a change in the optical property of water that is caused by suspended sediments such as silt or clay, by fine particulate organic material, or by microorganisms such as plankton. Local increases in turbidity are almost always due to increases in suspended sediments. Increased turbidities can harm fish and other aquatic life, particularly if conditions of high turbidity persist for a long time. Effects on fish range from avoidance of highly turbid areas and reduced growth to direct mortality because of effects like abrasion of gills. In addition, because turbidity reduces the penetration of light through water, it can make it difficult or impossible for fish—like juvenile salmon—and other aquatic organisms that find food by sight to be able to feed.

Naturally caused increases in turbidity are strongly related to increased stream discharge. When discharge increases and water velocities are high—for example, after heavy rains—increased turbulence occurs at the streambed-water interface. This turbulence churns up and suspends sediments from the river bed. Human-caused increases in turbidity are generally related to increased rates of surface erosion after plant cover has been cleared and soils disturbed, for example, at construction sites or gravel pits. Instream work—such as culvert installation—also disturbs sediments and increases turbidities, as does crossing stream channels with vehicles such as ATVs or ORVs.

Landowners can minimize human-caused increases in turbidities by using Best Management Practices and taking other actions that reduce erosion and stormwater runoff. For information on turbidity studies being conducted on Deep Creek and Ninilchik River, visit: http://inletkeeper.org/healthy-habitat/lower-kenai-peninsula/discharge-turbidity. A 2006 study of turbidity in the North and South Forks of Anchor River can be found at: http://www.dec.state.ak.us/water/acwa/pdfs/fy06_anchorriver_turbidityreport.pdf.

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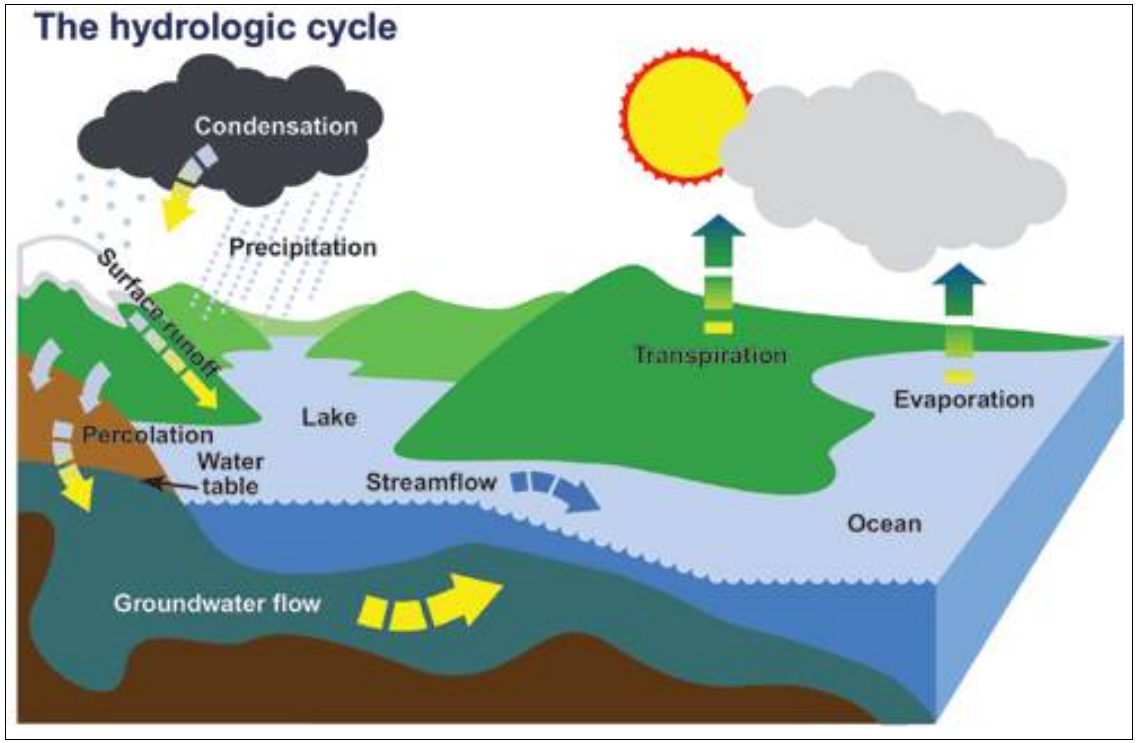
Water (hydrologic) cycle

(Modified from http://www.ec.gc.ca/eau-water/default.asp?lang=En&n=23CEC266-1.) From the beginning of time when water first appeared, it has been constant in quantity and continuously in motion. Little has been added or lost over millennia. The same water molecules have been transferred time and time again from the oceans and the land surface into the atmosphere by evaporation, dropped on the land as precipitation, and transferred back to the sea by rivers and groundwater. This endless circulation is known as the *hydrologic* or *water cycle*. The following processes keep water cycling through the air, land, and sea.



Evaporation: As water is heated by the sun, surface water molecules become sufficiently energized to break free of the attractive force binding them together, and they evaporate and rise as invisible vapor into the atmosphere.

Transpiration: Water vapor is also emitted from plant leaves by a process called transpiration. Every day an actively growing plant transpires 5 to 10 times as much water as it can hold at once.

Condensation: As water vapor rises, it cools and eventually condenses, usually on tiny particles of dust in the air. When it condenses it becomes a liquid again or turns directly into a solid (ice, hail, or snow). These water particles then collect and form clouds.

Precipitation: Precipitation in the form of rain, snow, sleet, and hail comes from clouds. Clouds are propelled by air currents. When they rise over mountain ranges, they cool, becoming so saturated with water that water begins to fall as rain, snow, or hail, depending on the temperature of the surrounding air.

Runoff: If more rain falls or snow melts than can infiltrate into and percolate down through the soil, the excess water drains away as surface runoff. This becomes the overland flow that feeds rivers and streams. Heavy surface runoff can produce flooding. The steeper the land and the less porous the soil, the greater the runoff. Overland flow is particularly high in urban areas where parking lots, roofs, and other impervious surfaces prevent precipitation from being intercepted by plants or sinking into the ground.

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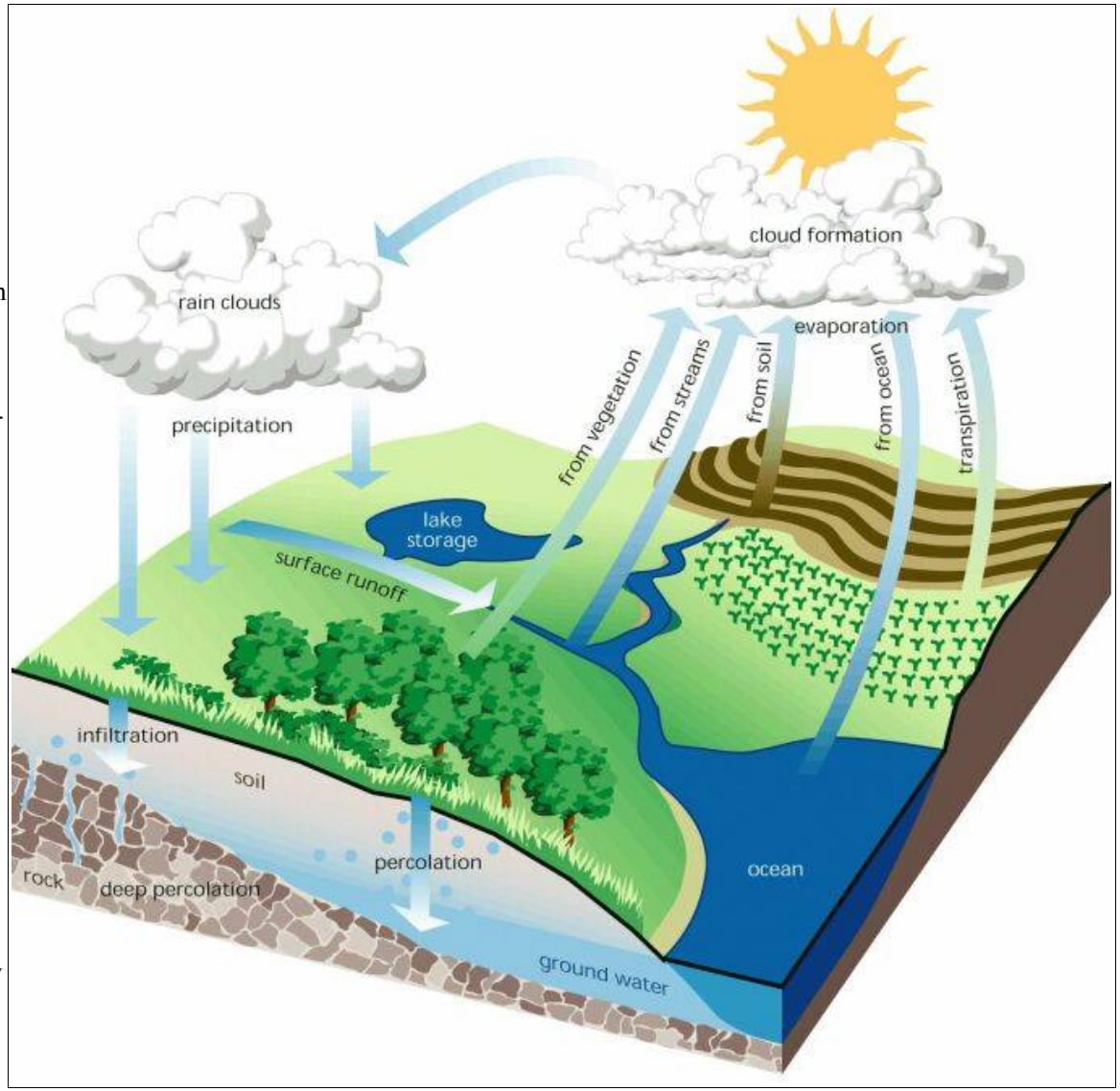
Percolation: Some of the precipitation and snow melt infiltrates downward into the pores between particles of soil and some of it seeps down through cracks and joints in rocks. When this subsurface water reaches the water table, it joins groundwater stored underground in aquifers. Water can also move back up by capillary action or it can move vertically or horizontally under the earth's surface until it re-enters a surface water system.



Groundwater: Subterranean water is held in cracks and pore spaces. Depending on the geology, groundwater can flow to support streams. It can also be tapped by wells. Some groundwater is very old and may have been underground for thousands of years.

Heating of the ocean water by the sun is the key process that keeps the hydrologic cycle in motion. Water evaporates, then falls as precipitation in the form of rain, hail, snow, sleet, drizzle, or fog. On its way to earth, some precipitation may evaporate or, when it falls over land, be intercepted by vegetation before reaching the ground. On average, as much as 40 percent of precipitation in northern latitudes is evaporated or transpired.

Although the hydrologic cycle balances what goes up with what comes down, one phase of the cycle is literally frozen in colder regions during the winter. During the Alaskan winter, most precipitation is simply stored as snow or ice (although some of this is "sublimated" directly into the atmosphere without melting). Later, during the spring melt, huge quantities of water are released quickly, which results in heavy spring runoff and flooding. At these times, areas of the landscape that can store snowmelt and reduce spring flooding (for example, some wetlands) become critically important. For additional information about the hydrologic cycle, including informative diagrams of many surface water-groundwater interactions, see http://pubs.usgs.gov/circ/circ1139/htdocs/natural_processes_of_ground.htm.

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Water quality

(see also Nonpoint source pollution, Permits, Sediment, Stormwater runoff, Sustainability)

It's obvious that salmon need clean, unpolluted water to survive, so protecting watershed water quality is of fundamental importance if we want to have healthy salmon populations (and stay healthy ourselves). Each of us can take many actions to keep local waters free of pollution. A number of these are discussed elsewhere in this watershedipedia, such as ways to reduce stormwater runoff. Below are listed a number of additional actions specific to protecting water quality. The Environmental Protection Agency provides a wealth of information on water quality-related topics at its "Water Home" website: http://water.epa.gov/. The **diagram below** illustrates many actions that can help protect water quality (from: http://www.nrcan.gc.ca/earth-sciences/products-services/mapping-product/geoscape/waterscape/gulf-islands/6405).

Three different state agencies are involved in assuring Alaskan waters are clean, healthy, and available for various uses. The Alaska Clean Water Actions (ACWA) program brings together the Alaska Departments of Environmental Conservation (DEC), Fish and Game, and Natural Resources to deal with state waters in a coordinated and cooperative method (see http://dec.alaska.gov/water/acwa/acwa_index.htm). DEC has primary responsibility for many actions protecting water quality (see http://dec.alaska.gov/water/index.htm). State water quality standards can be found under Water Quality Standards (18 AAC 70.005). DEC also maintains lists of impaired water bodies (see, for example, http://www.dec.state.ak.us/water/wqsar/Docs/2010 impairedwaters.pdf).

(Modified from http://www.ec.gc.ca/eau-water/default.asp?lang=En&n= 2C3144F5-1.) We tend to think of water in terms of a particular purpose: is the quality of the water good enough for the use we want to make of it? Water fit for one use may be unfit for another. We may, for instance, trust the quality of lake water enough to swim in it, but not enough to drink it. Along the same lines, drinking water can be used for irrigation, but water used for irrigation may not meet drinking water standards or be safe for salmon. It's the quality of the water that determines its uses.

Water quality is determined by the kinds and amounts of substances dissolved and suspended in the water and what those substances do to inhabitants of the ecosystem. It is the concentrations of these substances that determine the water quality and its suitability for particular purposes.

Factors Influencing Water Quality

Many factors affect water quality. Substances present in the air affect rainfall. Dust, volcanic gases, and natural gases in the air, such as carbon dioxide, oxygen, and nitrogen, are all dissolved or entrapped

in rain. When other substances such as sulphur dioxide, toxic chemicals, or lead are in the air, they are also collected in the rain as it falls to the ground. Rain reaches the earth's surface and, as runoff, flows over and through the soil and rocks, dissolving and picking up other substances. Where water flows over rocks high in metals, such as ore bodies, it will dissolve those metals.

Another factor influencing water quality is the runoff from urban areas. It will collect debris littering streets and take it to the receiving stream or water body. Urban runoff worsens the water quality in rivers and lakes by increasing concentrations of such substances as nutrients (phosphorus and nitrogen), sediments, animal wastes (fecal coliform and pathogens), petroleum products, and road salts.

Industrial, farming, mining, and forestry activities also significantly affect the quality of rivers, lakes, and groundwater. For example, farming can increase the concentration of nutrients, pesticides, and suspended sediments. Industrial activities can increase concentrations of metals and toxic chemicals, add suspended sediments, increase stream temperatures, and lower dissolved oxygen in the water. Each of these effects can have negative impacts on aquatic ecosystems and species such as salmon.

How does water clean itself?
Water is purified in large part by the routine actions of living organisms. Energy from sunlight drives the process of photosynthesis in aquatic plants, which produce oxygen to break down organic material, such as plant and animal waste. This decomposition produces the carbon dioxide, nutrients, and other substances needed by plants and animals living in the water. The purification cycle continues when these plants and animals die and the bacteria decompose them, providing new generations of organisms with nourishment. Unfortunately, there are many toxic substances which are affected only slowly, or not at all, by this and other processes. These are called *persistent* and are of great environmental concern.

Human Health and Water Quality
In Alaska we are lucky to have plentiful supplies of good drinking water sources. Water-related illnesses -- typhoid fever, cholera, dysentery -- are almost unknown in North America today. Waste and wastewater treatment, the development and enforcement of drinking water guidelines, public health practices and education -- all have resulted in a decrease in water related illnesses. Developing nations are less fortunate: 80% of their diseases are water-related. The price we must pay to prevent water-borne disease is constant vigilance against bacterial contamination.

Of serious concern today are toxic chemicals that enter our waters from many different sources, including industry, agriculture, and the home. Little is known about the effects of many toxic substances on human health; often the effects do not become noticeable for long periods of time, and it is difficult to distinguish them from the effects of other factors that impact on day-to-day life (e.g., nutrition, stress, air quality). Much more remains to be done to control toxic chemical pollution. Meanwhile, we can all contribute to the prevention of water pollution by not abusing the water or the land.

Water Quality Facts

- One drop of oil can render up to 25 liters of water unfit for drinking.
- One gram of 2,4-D (a common household herbicide) can contaminate ten million liters of drinking water.
- One gram of PCBs can make up to one billion liters of water unsuitable for freshwater aquatic life.
- One gram of lead in 20 000 liters of water makes it unfit for drinking. Older homes often contain plumbing made of lead or soldered in lead, which can then leach into water.
- The nitrates in fertilizers promote excessive growth of algae and larger aquatic plants, causing algal blooms and driving out fish.

- Methane gas can often be seen bubbling up from the bottom of ponds; it is produced by the decomposition of dead plants and animals in the mud.
- Calcium and magnesium -- both essential elements for man -- account for most water hardness. Death rates for certain types of cardiovascular disease have been found to be higher in soft water areas than in hard water areas in many parts of the world.
- Copper is another essential element -- for optimal absorption and metabolism of iron and for bone formation -- and fairly common in natural water. More than one milligram per liter may make water unpalatable.

What you can do

Each individual effort to protect water quality is vital. Together, individual actions can and do make a difference to water quality and the environment as a whole. Start by taking the following actions:

- Avoid hazardous household products. Most proprietary household chemicals are safe to use and are environmentally friendly when used according to directions on the package. However, some have a harmful cumulative effects on the environment when they are over-used or incorrectly disposed of.
- Check labels for hazard warnings. Warning symbols are based on shape: the more corners a symbol has, the greater the risk. Read labels to find out how to use products safely and what precautions to take.
- Buy only those environmentally hazardous products you really need, and buy them in quantities you will be able to completely use up.
- Use "environmentally friendly" products now available.
- Don't misuse sewage and septic systems.
- Don't throw waste down the drain just because it's convenient. Toxic household products can damage the environment and return to us through water and food. Toss items such as dental floss, hair, disposable diapers, and plastic tampon holders into the wastebasket, not the toilet—these items create many problems at sewage treatment plants and in septic tanks; always use up completely (or pass on for other people to use) unused contents of oven, toilet bowl, and sink drain cleaners; carpet and furniture cleaners and polishes; bleaches, rust removers, and solvents; paints and glue; and most other acid and alkali products.
- Choose latex (water-based) paint instead of oil-based, and use it up instead of storing or dumping it.
- Adopt alternative pest control methods, such as:
  - hand pulling weeds (see Invasive plants)
  - snipping and discarding infested leaves
  - dislodging insects with insecticidal soap or a water hose
  - practicing companion planting
  - applying a natural insecticide such as diatomaceous earth, available in garden centers
- Don't dump hazardous products into storm drains. Storm drains empty directly into nearby streams in many areas. The contents of storm sewers are generally not processed at sewage treatment facilities and can therefore do immediate harm to fish and wildlife. DON'T pour oils, paint compounds, solvents and other products into storm sewers, onto the street, or into your driveway. DO take them to local recycling or disposal facilities.
- Don't forget about water quality—even when you're having fun; power boats can pollute the water through gasoline leaks and spills. If you use a powerboat, keep the engine in good repair to avoid leaking oil, gasoline, and solvents.
- While camping, always bury biodegradable waste at least 200 feet from any water source. Use only biodegradable soaps, and take your non-biodegradable garbage with you for proper disposal.
- Boycott environmentally harmful products and let stores know why.

- Inform your friends and educate your children about how they can help keep local waters clean.

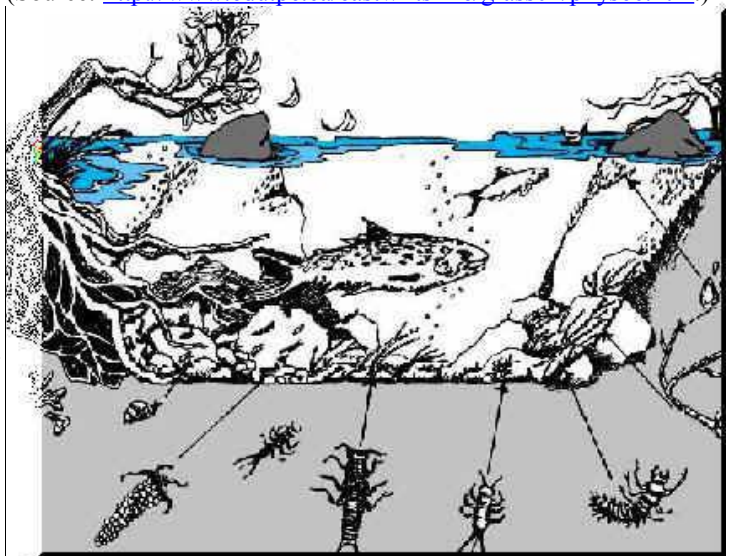
Water reservation for instream flow (or inlake water level)

(See also Baseflow, Hydrograph, Hyporheic flow and zone, Instream flow, Ordinary high water, Stream discharge, Streamflow, Stream stage)

A reservation of water under Alaska Law is a protective legal mechanism that allows for a water right to be held (by anyone) that maintains (rather than removes) a prescribed amount of water within a river, stream, lake, or other waterbody during a specified time of year for specific uses, such as protection of fish habitat or recreation.

(The following information is slightly modified from http://www.dnr.state.ak.us/mlw/water/instream.cfm).
What is reservation of water for instream use? A reservation of water for instream use is a water right that protects specific water uses, such as fish spawning or recreation (see drawing on right). It sets aside the water necessary for these activities and keeps later water users from appropriating water that may affect the instream or inlake activity. A reservation of water for one use may also allow that same water to be used or reserved for another purpose. For example, a reservation for recreation may also benefit fish spawning.

An instream flow reservation (water reservation) protects water flows or water levels within a stream, lake, or other waterbody for a variety of uses, including fish habitat. (Source: http://www.edu.pe.ca/eastwiltshire/grass01/phys6c.htm.)



Water can be reserved for one or more permissible uses on a particular part of a stream or lake during a certain period of time. Under Alaska Statute (AS) 46.15.145, permissible uses include:

- Protection of fish and wildlife habitat, migration, and propagation
- Recreation and parks
- Navigation and transportation
- Sanitation and water quality

What are the benefits of an instream (inlake) water reservation? If you have an instream water right, you have priority use of that water over people who file later for water rights. You can have legal standing in case of conflicting uses of water by people without water rights.

Who can apply for a reservation of water? Private individuals,organizations, and government agencies may apply for a reservation of water for instream (inlake) use. You should apply if you want to ensure that a lake level or stream flow will be available when and where you and the public need it for specific uses, and the water will not be appropriated or diverted for another use.

How can I apply for reservation of water? You can download an Application for a Reservation of Water as a pdf at http://www.dnr.state.ak.us/mlw/forms/ water/rsvr_app.pdf or you can get an application for reservation of water at any Department of Natural Resources (DNR), Water Resources Section office. Your application must be submitted to the office in the area where the proposed reservation of water is to occur. Before submitting an application, you should talk with the office staff about the information needed in your application, including the estimation of the amount

of water use. If your application is accepted, you will have up to 3 years to complete the data collection and analysis needed to justify the requested instream (inlake) reservation.

When your application is complete, it will be reviewed to determine the need for the reservation of water and its impact on other water right holders and the public interest. An assessment will be made to determine if water is available for the reservation and if the information in the application is accurate and adequate. Public notice of the application must be given. After this process, a certificate of reservation may be issued to you. A certificate of Reservation must be reviewed by the Department of Natural Resources every 10 years, but may be reviewed in less than 10 years if necessary.

What costs are involved? A filing fee of $1,500 must accompany an application for reservation of water. You will also be required to pay the cost of a legal advertisement to notify the public of the proposed reservation of water. If a certificate is issued,you may be required to install and maintain stream gages,weirs, or staff gages, and to monitor and report on the reserved instream flow or level of water. You may also be responsible for additional data collection or analysis during the certificate review.

Additional information is available at: http://www.dnr.state.ak.us/mlw/water/wrfact.cfm, http://www.dnr.state.ak.us/mlw/water/instream.cfm, and http://www.adfg.alaska.gov/index.cfm?adfg=habitatoversight.isfhome,

Applications for out-of-stream water rights
Reservations can also be approved for out-of-stream water rights (water withdrawals), for example, where an individual drills a well and then protects the water levels in his or her well through a water reservation. In fact, one reason to reserve *instream* flows is to ensure that enough water remains in the stream for instream uses—including salmon—when water is *withdrawn* from waterbodies or the aquifers that feed them for residential, agricultural, industrial or other uses.

(Slightly modified from http://www.dnr.state.ak.us/mlw/water/wrfact.cfm). A water right is a legal right to use surface or groundwater under the Alaska Water Use Act (AS 46.15). A water right allows a specific amount of water from a specific water source to be diverted, impounded, or withdrawn for a specific use. When a water right is granted, it becomes appurtenant to the land where the water is being used for as long as the water is used. If the land is sold, the water right transfers with the land to the new owner, unless DNR approves its separation from the land. In Alaska, because water wherever it naturally occurs is a common property resource, landowners do not have automatic rights to groundwater or surface water. For example, if a farmer has a creek running through his property, he will need a water right to authorize his use of a significant amount of water. Using water without a permit or certificate does not give the user a legal right to use the water.

To obtain water rights in Alaska, you need to submit an application for water rights to the DNR office in the area of the water use. (An application can be downloaded at http://www.dnr.state.ak.us/mlw/forms/water/wr_app.pdf, for one single-family residence or duplex, or for water use associated with one single-family residence or duplex, an application costs $100; for activities related to oil and gas and associated substances, an application costs $1,200.)

After your application is processed, you may be issued a permit to drill a well or divert the water. Once you have established the full amount of water that you use beneficially and have complied with all of the permit conditions, a certificate of appropriation may be issued. This is the legal document that establishes water rights.

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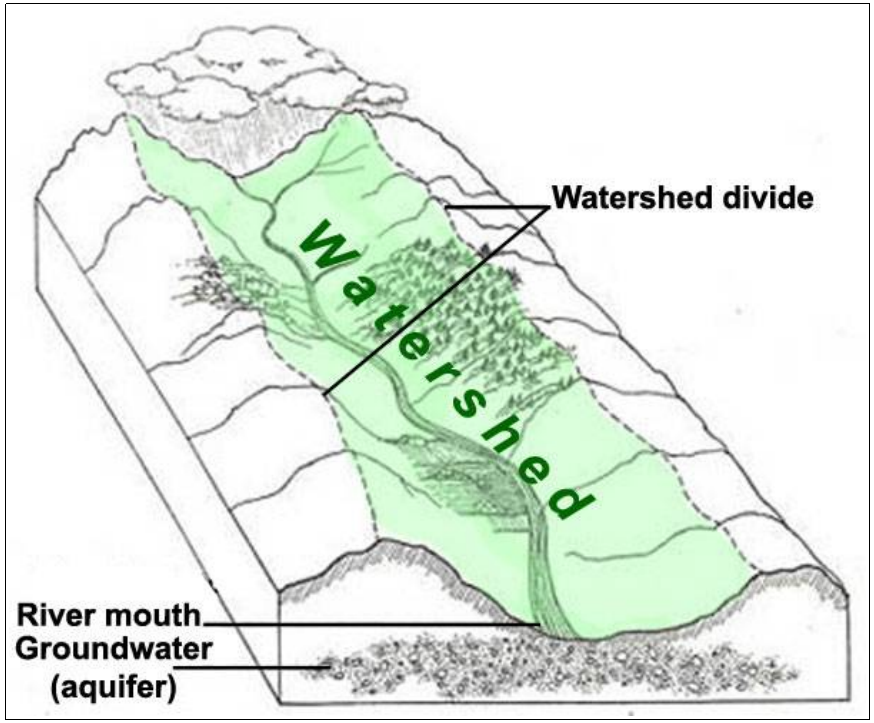
Watershed

(See also Water cycle, listings for individual watersheds)

A watershed is an area of land enclosed by watershed divides. Runoff from this area drains into a particular body of water, such as a stream, lake, bay, sea, or ocean. The watershed contributes water, organic matter, dissolved nutrients, and sediments to the waterbody into which it drains. The area contributing groundwater to a watershed may be different from the area contributing surface water.



An example of a simple watershed (modified from http://www.whidbeywatersheds.org/watershed.html).

It's easy to understand how a watershed works by thinking of it working like a bathtub. When a showerhead sprays down on a bathtub, any spray landing inside the bathtub rim stays in the tub (within the watershed) and any landing outside the rim ends up on the bathroom floor (outside the watershed). Spray trickles down the tub's sides to merge into larger flows running down the middle of the tub (the watershed's central river), and these central flows leave the tub through the drain (into another watershed or out to a lake, bay, or sea). If you fill your bathtub with layers of rocks, sand, coal, and clay and cover this with topsoil and plants, when you turn on the shower you'll have a pretty good example of a little watershed.

So precipitation falling inside our watershed divides—and therefore within local drainage areas or "catchment basins"—flows towards Anchor or Ninilchik Rivers or Deep or Stariski Creeks and then out into Cook Inlet. Sometimes these watershed divides are barely perceptible, sometimes they're obvious. Diamond Ridge Road runs along an obvious watershed divide, with precipitation on the north side of the road flowing into the Anchor River and that on the south side flowing into Diamond Creek.

Thinking in terms of watersheds reminds us how interconnected the processes in a watershed are and alerts us to useful patterns in the landscape. This awareness can help us predict how changes in one part of a watershed might affect conditions downslope. It's worth asking, for example, whether upstream or upslope land uses could alter the quantity or quality of water reaching a particular area, including your land. Watershedipedia entries on topics such as Best Management Practices, Buffers, Low Impact Development, Raingardens, and Soil Bioengineering suggest ways to minimize adverse watershed effects that might result from activities on your property.

Watersheds are named for the main streams, rivers, lakes or other waterbodies that receive their drainage, for example, the Anchor River watershed, the Cook Inlet watershed. Each tributary to a waterbody has its own watershed. All of these "subwatersheds" together make up the watershed of the larger waterbody.

ADF&G has developed a PowerPoint presentation called, "It Takes a Watershed to Raise a Fish." The presentation can be used to teach about watersheds, what freshwater fish need to survive, and how people may affect watersheds and fish habitat. The website for this PowerPoint is

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http://www.adfg.alaska.gov/index.cfm?adfg=curricula.watersheds. If you're online now, you can download the entire presentation below, or download portions.

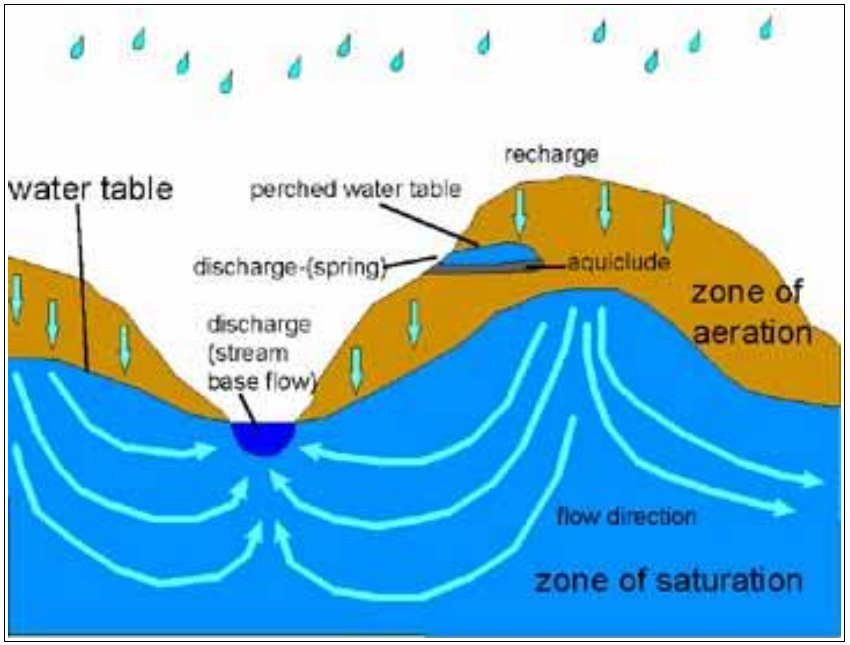
- Full Presentation (PowerPoint file 42,500 kB)
- Part 1: Introduction and Overview (PowerPoint file 743 kB)
- Part 2: Watersheds and Fish Habitat (PowerPoint file 13,133 kB)
- Part 3: Habitat Needs of Alaskan Fishes (PowerPoint file 22,053 kB)
- Part 4: People, Fish Habitat, and Watersheds (PowerPoint file 22,053 kB)

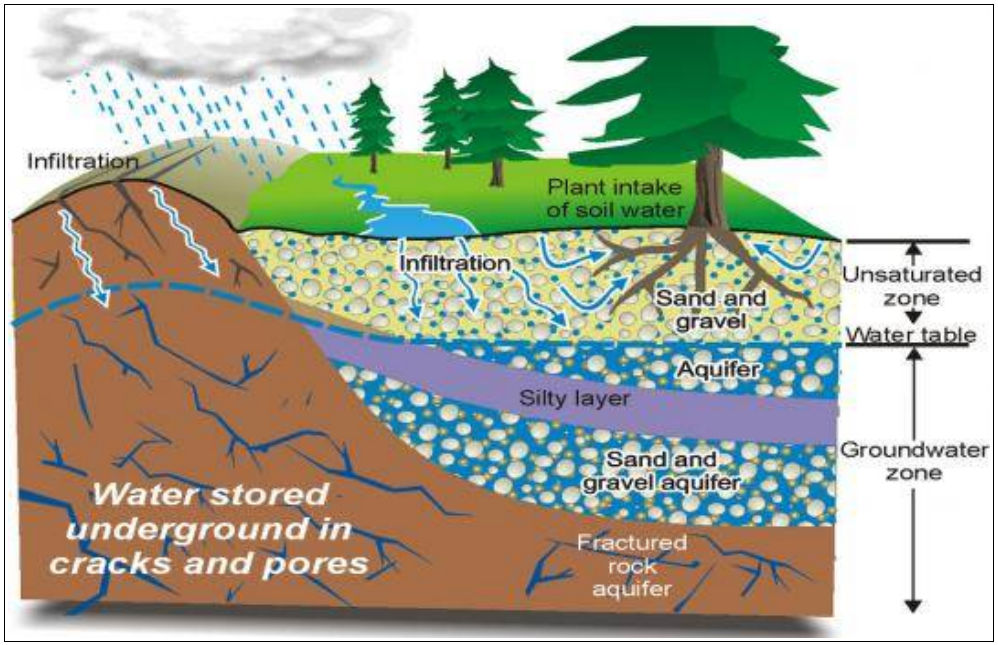
Also check out ADF&G's watershed website: http://www.adfg.alaska.gov/index.cfm?adfg=habitatrestoration.watershed.

Water table

(see also Aquifer, Water cycle)

The water table is the level at which water stands in an open hole dug deep enough to intercept ground that is saturated. Above the water table is the zone of aeration—where air fills the pores around soil and subsoil particles. Below the water table is the zone of saturation, where all pore spaces are filled with water. The water table will rise after heavy rainstorms and drop during dry spells. Water tables can be *perched* on top of impermeable layers of sediment or rock (as shown above the aquiclude in the drawing at left). The water table is sometimes at the ground surface (for example, in many wetlands). The term water table refers to a relatively stable water level, not just a temporary puddle after rain. **Drawings below** show two diagrams of the water table (drawing on left from: http://faculty.weber.edu/bdattilo/parks/parks_t2_review.html, on right: http://conferencetable1.com/wp-content/uploads/2011/05/picture-of-water-table.jpg).





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Weir

A weir is a fence or enclosure of stakes set in a stream as a trap for fish. The **photo below left** shows coho passing through the Anchor River weir on their way upstream to spawn. The **photos on the right** show two views of the same weir, which is located just upstream of the Old Sterling Highway bridge. (Photos are from http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=479&issue_id=90.)

In 2003, the Alaska Department of Fish and Game began estimating the number of chinook salmon entering the Anchor River by using a sonar system called DIDSON (Dual-frequency IDentification Sonar) during high water levels in May and early June. The sonar site was chosen because it was located above the fishery (approximately 2 miles from the river's mouth) and still in a single channel below the Anchor River channel split into North and South Forks. Netting upstream of the sonar site allowed biologists to determine the composition of fish species that passed the sonar site and to measure, sex, and collect scales to determine the age of individual salmon. The project was expanded in 2004 by installing a weir in mid-June when water levels declined and by continuing to count fish through the coho salmon run. Weirs are a better method to identify, count and sample fish when there are multiple species of fish in the river, which is the case in the Anchor River as the season progresses.

Using the sonar and weir, Fish and Game can monitor chinook salmon escapement in season and adjust regulations as required to allow more fish to spawn. Once ADF&G has 14 years—or two life cycles—of Anchor River chinook salmon escapement counts, it will be able to better estimate the maximum number of fish needed to spawn to perpetuate the run at the highest level (the spawning escapement goal, or SEG). Then the fishery could be liberalized if chinook counts look like they will exceed the maximum needed. Fish counts from the sonar/weir project are available at the ADF&G Sport Fish Division website at http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportFishingInfo.fishcounthome

(Modified from http://www.alaskafisheriessonar.org/anchor.html.) ADF&G has been monitoring Anchor Chinook runs since 1962. Since installing the Anchor River sonar and weir site in 2004, Fish and Game's understanding of Anchor River chinook salmon has grown immensely. Prior to 2004, F&G relied on helicopter surveys to monitor trends in chinook escapement and coho escapement was not monitored at all. The current Anchor River program, which counts salmon

using sonar and a weir, has for the first time provided information about the absolute number of spawning fish.

For more information (and photos), see http://www.alaskafisheriessonar.org/anchor_photos.html, for a copy of the Anchor River sonar site brochure, see http://www.alaskafisheriessonar.org/pubs/Anchor_River_Brochure_2011.pdf.

Wetland

(see also Wetland functions and values, Wetland mapping and classification)

To be a classified as a wetland, a site needs to have (1) hydric soil (see below), (2) water at or near the ground surface for a significant part of the growing season, and (3) plant communities dominated by species that grow well in wet, oxygen-poor soil. If all three are present—hydric soils, wet hydrology, and a predominance of what are called hydrophytic plants—then, by definition, a site is a wetland.

Soils become hydric when they are flooded or saturated so often or so long that oxygen in the root zone, and just below it, gets used up by microorganisms and chemical processes. When soils are saturated, the water displaces the air—and more importantly, the oxygen—present in soil pores, making less available. In addition, when soil water is slow-moving or stagnant—as it often is in areas where the water table is high or soils drain poorly—soil organisms and microorganisms use up whatever oxygen IS available in the water. All of this results in the soil becoming oxygen depleted, or anaerobic. Hydric soils are often also organic, that is, largely made of peat or muck, because decomposition occurs more slowly in the absence of oxygen. Each state generates a list of hydric soils, and these are used in making wetland determinations. The list of hydric soils found on the peninsula can be downloaded from the Kenai wetlands website, http://www.kenaiwetlands.net/.

Certain plants adapt to hydric soil conditions, and these are classified as wetland plants. Wetland plants can range from obligate, that is almost always found on wetland soils, to facultative, which means they are found on both upland as well as wetland soils. Percentages of different kinds of plants are used to determine whether or not an area is a wetland. (For a good discussion of these categories, see http://plants.usda.gov/wetinfo.html). Each state generates lists of wetland plants and how dependent they are on wetland conditions. These are used in making wetland determinations.

"Jurisdictional wetlands" meet specified criteria in terms of having wet hydrology, hydric soils, and hydrophytic plants. The Army Corps of Engineers develops regional manuals to guide scientists and other trained personnel to determine whether a site meets jurisdictional wetland criteria and also to delineate wetlands, that is, map their boundaries and extent. The Alaska regional supplement to the Corps wetland delineation manual can be found at http://www.usace.army.mil/CECW/Documents/cecwo/reg/erdc-el_tr-07-24.pdf.

A good site to get background information on wetlands (in addition to http://www.kenaiwetlands.net/), is from the Alaska Chapter of the Society of Wetland Scientists. Their website is http://www.sws.org/regional/alaska/alaska.html.

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Wetland classification and mapping on the Kenai Peninsula

(see also Glacial history of the western Kenai Peninsula, Landforms, Wetlands, Wetland functions and values)

Wetlands on non-federal lands on the Kenai Peninsula were classified and mapped in the early 2000s. The map to the right shows the project area. This discussion is derived from two websites documenting that project: http://www.kenaiwetlands.net and http://cookinletwetlands.info/.

The classification system began by dividing the lowland project area into five landform groups. The list below shows these five groups and the ten wetland ecosystem types associated with them.

1. The **interlobate moraine**, primarily lying north of the Kenai River, between Cook Inlet and the Moose River, is dominated by Kettle and Depression wetlands.
2. The **terraced moraines** on the west side of the Caribou Hills are dominated by Relict Glacial Drainageway and Lakebed wetlands and Discharge Slopes.
3. The **kettle-knob topography** along the Old Sterling Highway southeast of Anchor Point and around Caribou Lake about 22 miles northeast of Homer is dominated by Kettles.
4. The **land terminating moraines** east of Sterling and west of Tustumena Lake are dominated by Depression wetlands.
5. The **Caribou Hills** are dominated by Late Snow, Headwater Fen, and Riparian wetlands (and pre-Naptowne till).

Descrptions of each wetland ecosystem found at http://www.kenaiwetlands.net repeat a common format, they first outline the dominant landscape process responsible for the existence of the ecosystem, then the dominant patterns within each ecosystem. Next, the common geographic locations of the ecosystem, followed by a brief ecosystem characterization (including the common soils found in each system). A description of dominant plant communities and relationships of individual plants within the ecosystem is outlined, including idealized cross-sectional diagrams and a summary table that links plant community names to their descriptions. A summary of the map components and units found in each ecosystem ends the descriptions.

Although plant communities and processes are distinct within each wetland ecosystem, overlap exists between them. Sometimes the boundaries are blurry, as where a relict glacial lakebed grades into a relict drainageway, then to a modern stream channel emptying into a lake with a tidal outlet to Cook Inlet. Classification is by necessity simplification. The ecosystems, mapping units, and plant communities described all represent "centroids," distinctions between them grow increasingly

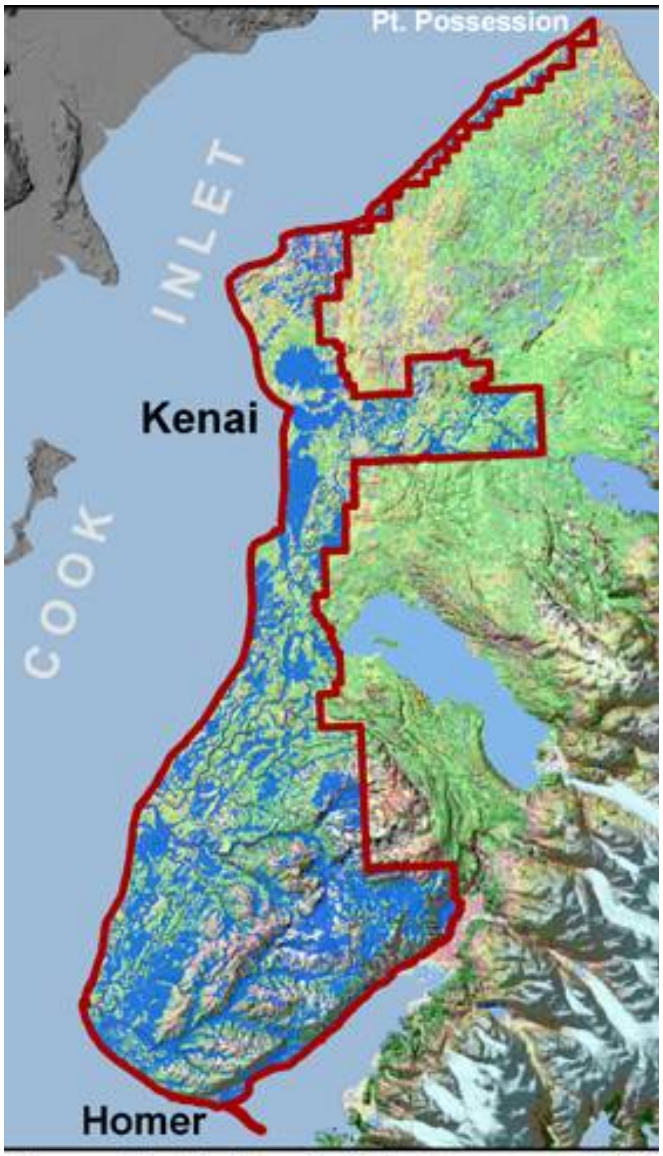


Figure 1. Wetlands (blue) occupy 41% of the project area (red).

blurry towards the margins. The intention was that the classification framework would help focus discussion about Kenai wetland functions and processes (see Wetland functions and values). The following key can help you figure out the ecosystem type represented by a particular wetland. Wetland ecosystem summaries are included alphabetically in this watershedipedia.

Key to Kenai Lowland wetland ecosystems. First, choose between the two Number 1s , then numbers in right-hand column direct you to next numbered choice.

1. Wetland periodically inundated by salt water.	TIDAL
1. Wetland **not** periodically inundated by salt water.	2
2. A wetland on a recent moraine, with no wetland connection to navigable waterway, although the wetland could be a navigable-in-fact lake.	DEPRESSION
2. Wetland connected by other wetlands to a navigable waterway.	3
3. Channelized flow present, with bed and bank morphology.	RIPARIAN
3. If flow is present, not in a channel exhibiting bed-and-bank morphology.	4
4. Wetland a large linear feature in a valley bottom, but without a defined modern channel; or adjacent to an underfit stream; often with a water table near the surface, even when forested.	DRAINAGEWAY
4. If a wet forest is present, then wetland lies along a slope break, or has a deeper water table, usually over a flat peatland and not in a valley bottom.	5
5. Slope break influences groundwater discharge; usually at a foot- or toe-slope landscape position on a terraced moraine, often over a mineral soil.	DISCHARGE SLOPE
5. Wetland **not** along a slope break; a peatland, or over a mineral soil.	6
6. A peatland above about 350m elevation in the headwater basin of a first order stream.	HEADWATER FEN
6. Wetland below about 350m elevation, or otherwise located on the landscape.	7
7. Wetland above 500m, often extensive and over mineral soil; if a peatland then smaller.	LATE SNOW.
7. Wetland below 500m, a peatland.	8
8. Wetland an island floating on a human-created lake, or moored to the shoreline, rare.	FLOATING ISLAND
8. Wetland **not** floating on a lake.	9
9. Wetland an extensive, flat peatland, below 350 m elevation. Strang and flark features frequently present or nearby.	LAKEBED
9. Wetland smaller, usually on a moraine, adjacent to kame(s) which are often modified, or at the distal margins of lakebeds; can occur up to about 350 meters elevation, especially near Caribou Lake.	KETTLE

Maps developed by the Kenai Peninsula wetland mapping project are available for viewing online at the Kenai Peninsula Borough's GIS website. (see

introductory article 3: Exploring your watershed with online tools).

National Wetland Inventory (NWI): A second classification system is used by the US Fish and Wildlife Service in its national wetlands inventory (NWI) program. This is described in *Classification of Wetlands and Deepwater Habitats of the United States*. The NWI classifies wetlands in terms of growth forms of dominant plants and the dominant water regimes: marine, estuarine, riverine, lacustrine (lake), and palustrine (nontidal vegetated wetlands traditionally given names like marsh, swamp, bog, and fen). The Alaskan USFWS office that oversees NWI mapping is: http://alaska.fws.gov/fisheries/nwi/index.htm.

Wetland delineation and determination
(see also Army Corps of Engineers, Wetlands, Wetland classification and mapping, Wetland permits)

To figure out whether a particular site is a wetland, a wetland determination is made. The *Wetlands Delineation Manual* developed by the Army Corps of Engineers provides detailed instructions for making wetland determinations and is the reference used by professionals (see http://www.mvn.usace.army.mil/ops/regulatory/reg_manual.asp). The Alaska supplement to the Corps' manual is available at http://www.usace.army.mil/Portals/2/docs/civilworks/regulatory/reg_supp/erdc-el_tr-07-24.pdf.

If, on the other hand, the outline and borders of a wetland need to be mapped, a delineation is required. This involves identifying the wetland's "edge," that is, where it grades into upland conditions.

Wetland functions and values
(see also Wetlands)

Wetlands provide many—and often unique—beneficial **functions** (the things they do) and **values** (the services they provide to society, like improved salmon habitats, reduced flooding, and places to recreate). Homer Soil and Water (in partnership with other agencies and nonprofits) is assessing wetland functions and values using data from the wetlands mapping done on the Kenai Peninsula (see Wetland classification and mapping). Homer Soil and Water is also using data from other sources and tailoring this information to its wetland assessment. Wetlands are being assessed at the same scale at which they were mapped, that is, at 1:25,000 (see Map scale). This scale leads to what's called a "landscape-level" assessment, rather than a more detailed site-specific assessment. Check out http://www.homerswcd.org/projects/wetlands.php for more information on the assessment project.

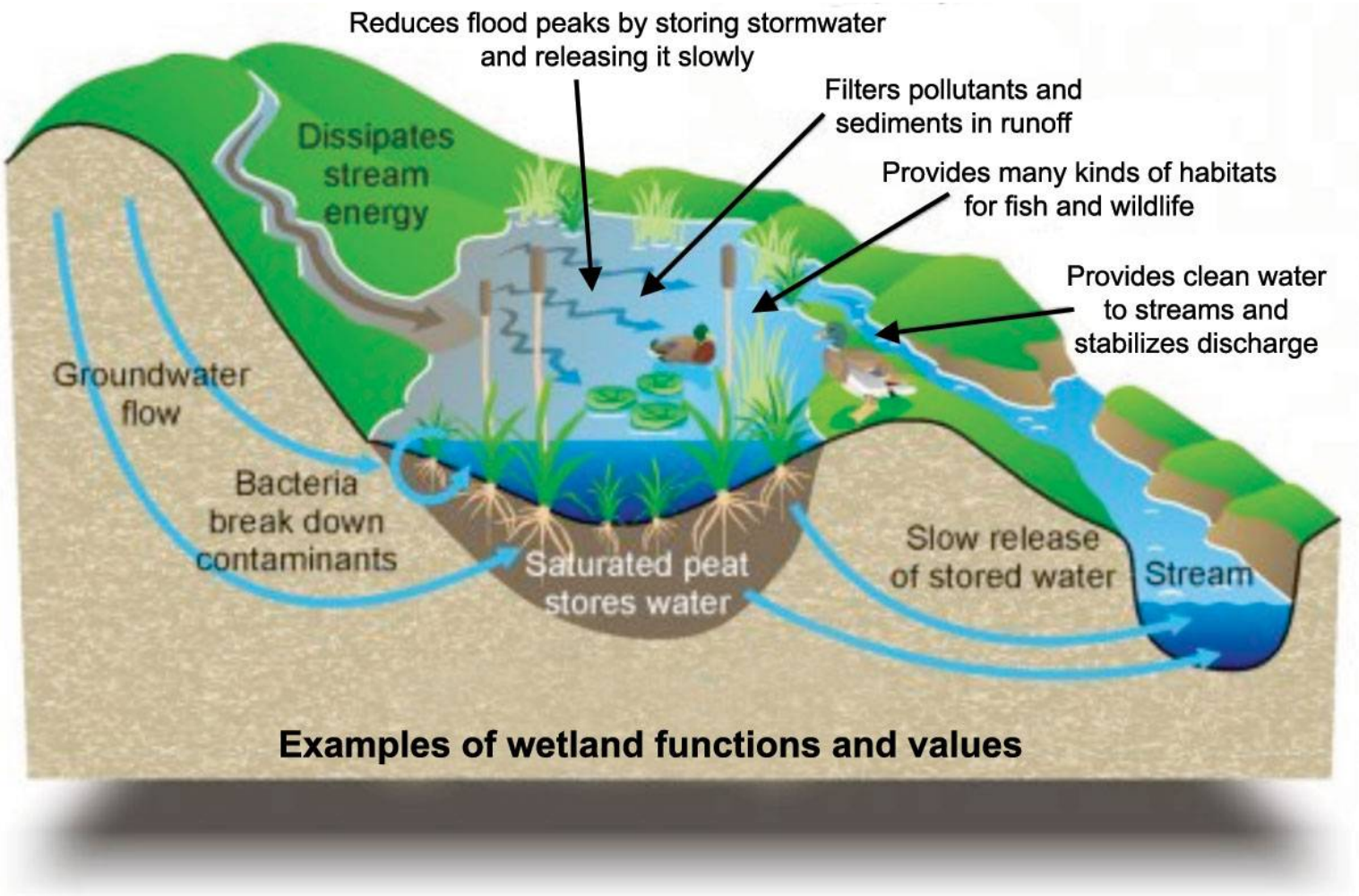
As mentioned above, functions are what wetlands **do**, and values are the benefits and services wetlands provide us. Homer Soil and Water is assessing wetlands in terms of three categories: hydrology, biology, and social/community/cultural.

- **Hydrology functions and values** are the things wetlands do with water. These include storing runoff, reducing flood peaks, filtering pollutants, recharging wells, and maintaining water levels in streams (for example, see Base flows).
- **Biology functions and values** are the things wetlands do for animals and habitats. These include protecting habitats like salmon spawning and rearing areas, winter moose foraging areas, or waterfowl nesting and staging areas, as well as supporting the overall biodiversity and health of plant and animal species.
- **Social/community functions and values** are the places and experiences wetlands can provide people. These include places to hunt, fish, recreate, and explore, as well as places associated with cultural history, heritage, and education.

Not all wetlands do all of these things, and not all wetlands do these things to the same degree. This assessment will identify which things are done by which

wetlands and to what relative degree. Assessment results will be linked to the wetlands maps found on the borough's website to make those results easy to find and use (see *introductory article 3: Exploring your watershed with online tools*). When completed, this project will give anyone interested in peninsula wetlands some useful information about their functions and values in a context that makes sense. This should help us all use, manage, and enjoy wetlands in ways that are safe, suitable, sustainable, and salmon friendly.

Examples of wetland functions and values (adapted from: http://beachwoodhistoricalalliance.wordpress.com/2009/03/08/).



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Wetland permits

(see also Army Corps of Engineers, Clean Water Act, Ordinary High Water, Permits)

When people talk about a "wetland permit," what they mean is a permit granted by the US Army Corps of Engineers (COE), which authorizes the permittee to "dredge" and/or "fill" in what are called "jurisdictional wetlands." These permits are required under Section 404 of the Clean Water Act, so they're also sometimes called "404 permits." A little background will help this make more sense, but to go straight to the link that tells you how to get a Corps permit in Alaska, click here: http://www.poa.usace.army.mil/reg/Permits.htm. The first thing you'll see is the following paragraph:

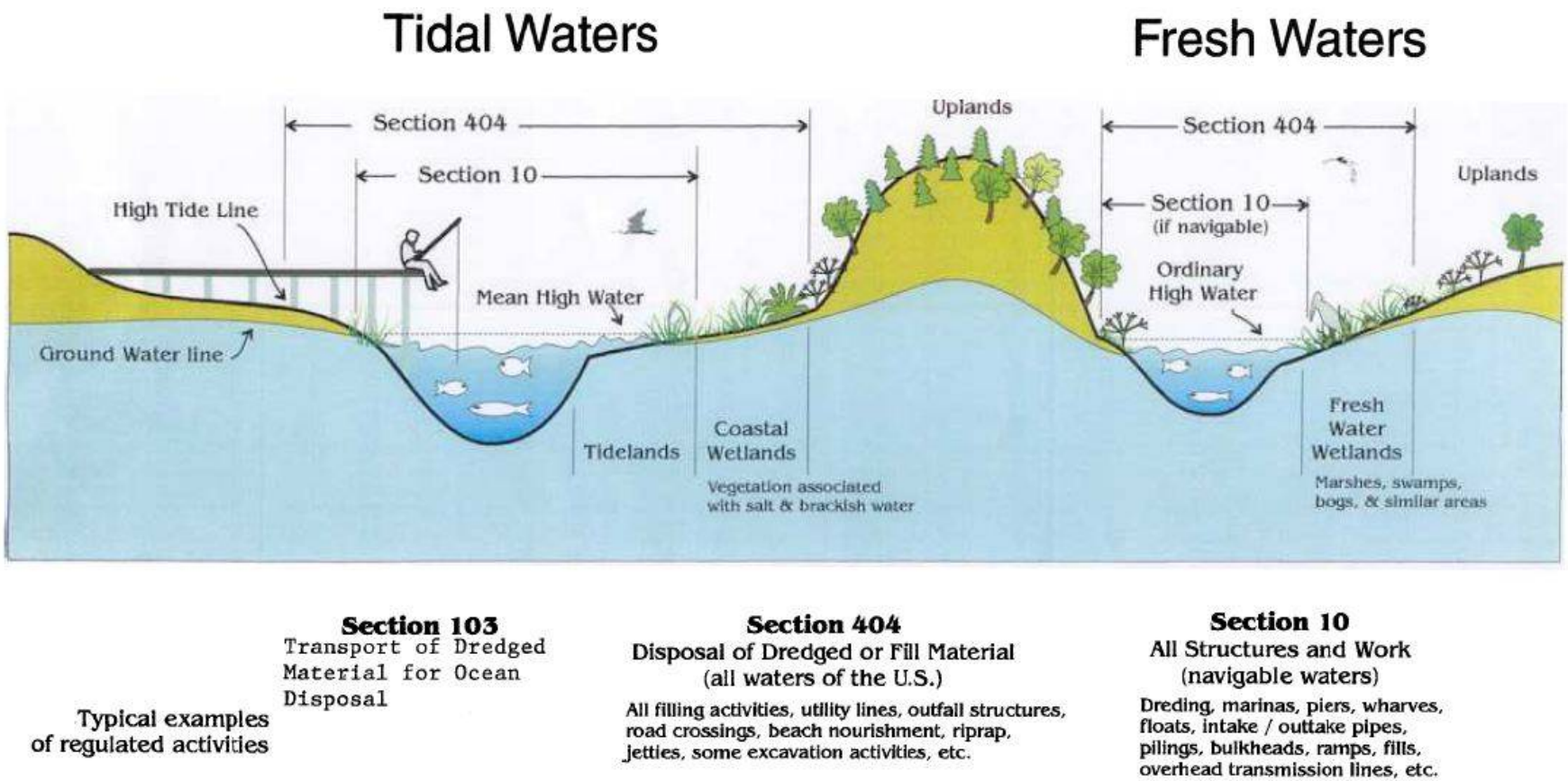
Any person, firm or agency (including federal, state and local government) planning to place structures or conduct work in navigable waters of the United States, or discharge (dump, place or deposit) dredged or fill material in waters of the U.S. must first obtain a permit from the Corps of Engineers. Other federal, state, and local statutes may require additional permits, licenses, variances or similar authorization.
Types of permits include:

- Nationwide Permits (http://www.poa.usace.army.mil/reg/Permits.htm#Nationwide%20Permits)
- Letters of Permission (http://www.poa.usace.army.mil/reg/Permits.htm#Letters%20of%20Permission)
- Regional General Permits (http://www.poa.usace.army.mil/reg/Permits.htm#Regional%20General%20Permits)
- Individual Permits (http://www.poa.usace.army.mil/reg/Permits.htm#Individual%20Permits)
- Alternative Permit Process (APP, http://www.poa.usace.army.mil/reg/Permits.htm#APPs)

The contact information for the Corps office that serves the Kenai Peninsula is: US Army Corps of Engineers, Alaska District, Kenai Regulatory Field Office Benco Building, 805 Frontage Rd., Suite 200, Kenai, AK 99611-775, 907-283-3519.

Why are wetlands subject to these permits?
(Modified from http://www.kenaiwetlands.net/EcosystemDescriptions/Intro.htm.) Wetlands support a variety of functions, from wildlife habitats to flood control (see Wetland functions and values). Because these functions cross property lines and belong to many of us, they are a public good. If an activity in a resource upstream affects downstream property owners, then that upstream resource belongs to more than just the upstream property owner. Because so much activity has occurred in wetlands nationwide, and so many impacts to valuable resources are being felt on a widespread and costly nationwide scale, dredge and fill activities in wetlands are regulated under section 404 of the Clean Water Act. The figure **on the next page** shows where Corps Section 404 permits are needed (as well as Section 10 permits, which relate to navigable waters). (To learn what a wetland is, and more about Kenai Peninsula wetlands, go to these watershedipedia topics: Wetlands, Wetland classification and mapping, Wetland delineation and determination, Wetland functions and values.)

Return to list of watershedipedia topics
(Words or phrases highlighted in blue have their own watershedipedia entry—jump to them through the link above.)



The **figure above** shows Corps of Engineers regulatory jurisdictions; Sections 10 and 404 refer to sections in the Clean Water Act (see http://www.epa.gov/lawsregs/laws/cwa.html). (The image is from: http://dec.alaska.gov/water/wwdp/wetlands/docs/ CorpsRegulatoryJurisdiction.pdf.)

The Alaska Department of Environmental Conservation (DEC) offers this summary of wetland permits (see http://dec.alaska.gov/water/wwdp/wetlands/index.htm): Section 404 of the Clean Water Act (referred to as Section 404) established a permitting program to regulate any person, company, tribe, or government agency planning to work in waters of the United States or to discharge dredged or fill material into waters of the U.S.. The regulated activities typically requiring a Section 404 permit include:

- Discharging dredged or fill material in waters of the U.S., including wetlands;
- Site improvement fill for residential, commercial, or recreational development;
- Construction of revetments, groins, breakwaters, levees, dams, dikes, and weirs; and

- Placement of riprap and fill material for roads, airports, or buildings.

The DEC, Division of Water, Wastewater Discharge Authorization Program also has a role in wetland permitting. Section 401 of the Clean Water Act provides states with the legal authority to review an application or project that requires a federal license or permit (in this case a 404 permit) that might result in a discharge into a water of the U.S. The applicant must apply for and obtain a *Certificate of Reasonable Assurance* from the Alaska Department of Environmental Conservation to conduct a regulated activity. By agreement between the Corps and DEC, the Corps' "Public Notice of Application for Permit" for an individual permit serves as DEC's application for a *Certificate of Reasonable Assurance*. DEC reviews the project described in the Corps public notice; coordinates with other state and federal agencies and local governments; reviews any public comments; and either approves, approves with conditions, waives, or denies the project based on compliance with the Clean Water Act, state water quality standards, and other applicable state laws. DEC charges a fee to develop the *Certificate of Reasonable Assurance*. See the links below for specific information.

ADEC Process for Issuing a Waiver of a Corps Permit
ADEC On-line Permit Search
ADEC Permit Fees
Reassignment of 401 Certificate
Handbook on 401 Water Quality Certifications

As explained under Environmental Protection Agency, EPA works with the Corps to develop guidance and environmental criteria used in evaluating wetland permit applications. EPA staff in Alaska review projects and have the authority to prohibit, deny, or restrict the use of any defined area as a disposal site. For more information on EPA's role, see EPA's excellent and informative wetlands link: http://www.epa.gov/owow/wetlands/.

The links below provide specific information on the permit application and issuance process.

Corps Regulatory Division Main webpage http://www.poa.usace.army.mil/reg/
Corps FAQ about wetland permits http://www.poa.usace.army.mil/reg/FAQ.htm
Corps listing of permit Public Notices http://www.poa.usace.army.mil/reg/PNNew.htm
Sketch of Corps Regulatory Jurisdiction (This is the figure shown above.)

For more information on this topic, see also the State Wetlands Information Tool (SWIFT), at http://www.envcap.org/statetools/swift/swift2.cfm?st=AK.

Woody debris
(see Large woody debris)