Kenai River Landowner's Guide

On the front cover:
upper right photo: A well-designed floating dock protects the riverbank and riparian plants.
main cover photo: To protect both the river and their house, the Hardy's chose a building site with few soil or site limitations, built their home back from the river's edge, and left an undisturbed buffer of trees and natural groundcover between their house and the river. They also built a deck for outdoor activities. The deck protects the ground from foot traffic, which prevents soil erosion and promotes riverbank stability.

Kenai Soil and Water Conservation District
P.O. Box 987, Soldotna, AK 99669
February 12, 1992

Dear Follower of the Kenai River Cooperative River Basin Study,

We are pleased and excited to send you this copy of the *Kenai River Landowner's Guide*. As you know, this *Guide* was many months in the making, and as the credits and acknowledgments show, incorporates the input of many individuals, from agency staff to landowners. Much of the soil, plant community, and riverbank information discussed in the *Guide* was collected by the USDA Soil Conservation Service from 1988 through 1991.

This *Guide* provides many kinds of information that can assist landowners in deciding how to develop and manage their Kenai River parcels. We refer you to the 1-page section called "How to use this Guide" for a quick and handy introduction to what the *Guide* is all about and how it can be used.

Because we are still learning about the Kenai River—about its seasonal patterns, the conditions and processes of its riverbanks and adjacent lands, about the methods we can use to manage these conditions and processes while protecting fish and other river resources, the *Guide* will inevitably evolve as we gain new information. For that reason, the *Guide* is designed so that you can add and remove information as our understanding of the river grows. If you want to receive future revisions and additions to the *Guide*, please return the form attached to this letter. Also, if you come across material that you think would be useful to other Kenai River landowners and managers, please send a copy to the Soil Conservation Service at Box 400, Homer, AK 99603; they will be happy to serve as a clearinghouse and distribution center for such material.

This edition of the *Guide* represents a first printing of only 250 copies. We plan to arrange for additional printings if interest warrants. (Future editions of the *Guide* will have to be sold for the cost of printing, binder, and color cover, or between $10.00 and $15.00 per copy, depending on vendors used.) If you would like to be notified when we start to arrange a second printing, please indicate so on the attached form. Also, we may be able to make corrections and minor revisions to the *Guide* before the second printing, so please let us know of any improvements you suggest.

We hope you find the *Guide* useful and we welcome any feedback on it that you have. We also look forward to working together in the future to increase our understanding of both the Kenai River system and how we can manage its resources in productive and sustainable ways.

Sincerely,

Mike Swan
Chairman, Kenai Soil and Water Conservation District

Kenai River

Landowner's Guide

A Reference Guide to help Kenai River landowners understand and manage plants, soils, and riverbanks and protect Kenai River resources.

Prepared by **the U. S. Department of Agriculture, Soil Conservation Service (SCS)**

for **the Kenai Soil and Water Conservation District**

(first printing, December 1992)

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the Kenai Soil and Water Conservation District

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Kenai Soil and Water Conservation District

Kenai Peninsula Borough

Alaska Division of Parks and Outdoor Recreation

Kenai River Property Owners Association

City of Soldotna

Alaska Department of Fish and Game

USDA Forest Service

U. S. Geological Survey

(All who helped are listed in Acknowledgments)

Kenai River Landowner's Guide
Table of Contents

(More detailed chapter contents are listed on the first page of each chapter.)

How to use this Guide

I. Introduction

A. Was this Guide written for you? I.2
B. What's so special about the Kenai River? I.3
The River as seen through the eyes of its friends I.3
C. What is the "Kenai River Cooperative River Basin Study"? I.6

II. Description of areas covered by this Guide

A. Description of the physical environment of the lower Kenai River II.2
B. Description of wildlife along the lower Kenai River II.8
C. Description of culture and economy along the lower Kenai River II.20
D. Description of political, management, and regulatory environments along the lower Kenai River II.30
(who governs, manages, or permits what happens on and along the river)

III. Understanding the Kenai River

A. The nature of rivers: systems, parts, and processes III.2
B. Human impacts on rivers III.35

IV. Living with the Kenai River

A. Introduction to "do-it-yourself" resource planning and action IV.3
B. Using **soil** information IV.7
C. Using **plant** information IV.19
D. Using **riverbank** information IV.61

V. Sharing the Kenai River

A. Linked by the Kenai River V.2
B. Brainstorming for the future V.3
(Programs to help landowners protect Kenai River resources)
C. "Streamwatching" V.12
(Citizens' programs to keep an eye on Kenai River resources)

VI. Getting more help — sources of help and information

A. How to use this Chapter VI.2
B. Sources of help by category VI.2
C. Directory of agencies, organizations, and commercial businesses VI.8

VII. Maps of the Kenai River study corridor

A. Before using maps... VII.2

(What is map scale? Why is it so important?)

B. Tables related to lower Kenai River maps

(Soil connotative legend, plant community map codes, plant community interpretations)

C. Maps

(Index map, soil maps, plant community maps)

VIII. References

Acknowledgments

Appendix: Selected chronology of the Kenai River Cooperative River Basin Study coordinated by the USDA Soil Conservation Service (current through 1992)

HOW TO USE THIS GUIDE

This is a REFERENCE GUIDE to the lower Kenai River (from Skilak Lake to the mouth).
You can look up and use just the information you need.

This *Guide* provides several references in one cover:

* parts of it provide "BACKGROUND INFORMATION" (see Chapters II, III, IV, and V);
* parts of it provide "HOW TO" information (see Chapters IV and V);
* one chapter provides a "DIRECTORY" of river-related businesses, agencies, and organizations (see Chapter VI);
* one chapter provides an "ATLAS OF SOIL AND PLANT COMMUNITY MAPS" (see Chapter VII).

We suggest you use this *Guide* in one of three ways:

(1) BROWSE THROUGH THE MATERIAL.
We've tried to make this *Guide* "suitable for browsing" by including many illustrations and other graphics. We've also highlighted key text and located key quotes on the center of many pages. If you flip through the *Guide* looking at illustrations and reading quotes and highlighted text, you will get a good introduction to what's in the *Guide*.

(2) LOOK UP PARTICULAR TOPICS.
Follow these steps to look up particular topics:
1. Look at the opening "Kenai River Landowner's Guide Table of Contents" to see which chapters may contain the kind of material you're looking for.
2. Go to the beginning of chapters that may contain relevant information. (Colored dividers indicate the beginning of each chapter.) Use the *chapter* table of contents to identify sections related to your interests.

(3) Use "INDEX TABLES."
This *Guide* contains two tables in which we summarize material and refer you to related information throughout the *Guide*.

Use Table 1 in Chapter III (page 6) when you want to locate discussions about a particular kind of resource along the lower Kenai River. This table lists the main "parts" of the Kenai River watershed (water, soils, plants, animals, etc.) and shows where they are discussed in the *Guide*. Use this table to find information about the resources occurring on your land.

Use Table 10 in Chapter III (page 37ff) when you want to know how to solve or avoid particular resource-related problems. This table lists problems caused by human activities (e.g., increased bank erosion, reduced water quality) and where in the *Guide* to look for practical ways to avoid or solve them, for example, with "spruce tree revetments," "boardwalks," "bioengineering practices," etc.

(Note: throughout this *Guide*, when the text refers you to a specific page, figure, or table, they are found in the chapter you're reading unless another chapter is specified.)

I. INTRODUCTION

CHAPTER CONTENTS

A.	**Was this guide written for you?**	**2**
B.	**What's so special about the Kenai River?**	**3**
	A sampling of what's so special about the Kenai River	**3**
	(*The river as seen through the eyes of its friends*)	
C.	**What is the *Kenai River Cooperative River Basin Study*?**	**6**
	Goal of the study	**6**
	Brief history of the study	**6**
	Brief introduction to study data and methods	**8**

I. INTRODUCTION

A. WAS THIS GUIDE WRITTEN FOR YOU?

This *Guide* is based on two assumptions about Kenai River landowners: **(1) They have personal goals for themselves and their families, which determine what they choose to do on their Kenai River property; and (2) They care a lot about the Kenai River and are willing to take actions that protect its fish and other values.**

Given these assumptions, we believe that most Kenai River landowners want more information about their lands and resources than they have right now. They want information about conditions along the river and how they might affect development. They want information that can help them anticipate and avoid problems when they plan septic systems, roads, landscaping, or building foundations. They want information on how to develop a boat dock or river access without making their riverbanks unstable and erosion prone. If their banks *are* eroding, they want information on how to protect them while also protecting fish habitats in the process. Basically, they want information that can help them pursue the goals they value for themselves and their families while at the same time doing what's best for the river system they love and share (particularly its fish).

WE BELIEVE THAT KENAI RIVER LANDOWNERS WANT MORE INFORMATION ABOUT THEIR LANDS AND RESOURCES THAN THEY HAVE RIGHT NOW.

If you are a Kenai River landowner who feels this way, this *Guide* was developed for you. In it we've brought together a lot of information that should help you (1) understand the Kenai River, (2) minimize problems, and (3) help you develop your property in river-conscious ways. (And because we've had regulatory agencies review this information, the guidelines and recommendations included here are conceptually compatible with existing regulations and agency concerns.)

Some information is summarized from other sources (and we often cite references that offer more detail). But much of the soil and plant information discussed here is new and was collected by Soil Conservation Service field crews (in cooperation with Kenai River landowners) from 1988 through 1991. This new resource information is much more detailed than most inventory information available up to now, and most of it was collected specifically for Kenai River landowners. These data can be useful in many situations typically faced by landowners.

In this *Guide*, we've tried to make information as easy as possible to understand and use. Kenai River landowners helped us do this by reviewing draft sections. (Those who helped are listed in the Acknowledgments.) If you'd like more help in understanding or applying this material, Chapter VI provides a directory of agencies, organizations, and businesses that offer information, services, and products related to the Kenai River. In addition, all references mentioned in this *Guide* are listed in Chapter VIII, References, along with information about obtaining copies.

All who contributed to this *Guide* know that this is only a start. As you use the *Guide*, you'll come across many cases where we point out that more information would be useful but isn't available yet (and you'll come up with your own unanswered questions). We hope that by pointing out existing holes in our knowledge, we'll help start the process of filling these holes.

If you have suggestions for improvements, corrections, or additions to this *Guide*, let us know[1]. If the *Guide* turns out to be a useful tool, chances are good that we'll be able to update and improve it over time. In the meantime, we hope it helps the thousands of Kenai River landowners in our study area (described below) successfully balance pursuit of their goals with protection of the great river whose health and productivity their actions can affect.

B. WHAT'S SO SPECIAL ABOUT THE KENAI RIVER?

The Kenai River is special to a lot of people for a lot of reasons. For anglers from Alaska and around the world, the Kenai is special because it offers a chance to catch the biggest salmon in the world in a beautiful setting. For kids who grow up on its banks, it's special because something different and amazing can happen any day, whether it's an eagle splashing down to carry off a flash of silver in its talons, or a young moose calf tottering on spindly legs.

But what's happening is that the Kenai River is becoming special to many people who don't know how their actions affect it. The river is the most popular sport fishing river in Alaska. As a result, **the sheer numbers of people recreating, living, and working on the river are changing it bit-by-bit and cumulatively**, usually not for the better. Trampled and denuded banks erode faster than they used to. More and more runoff from streets, parking lots, storage yards, and construction sites carries pollutants into the water. Bank-edge fish habitat is slumping, eroding, and being cleared away.

Few if any of these changes are intentional. Almost no one wants to damage the river. Almost everyone who knows the Kenai River knows that it's special and wants it to stay that way. If people are damaging the river's ability to produce fish or other resources, it's usually because they don't understand the effects of their actions or don't know other ways to meet their goals. Or they think that their actions, the small damaging changes they bring to the river, are too insignificant to matter.

The problem is, **no one can predict when the sum total of thousands of small, individually insignificant actions in the river system will reach a "critical mass" that impairs the river's ability to function "normally."** As Terry Bendock (a Fisheries Biologist who's studied the Kenai River for years) points out: "The best analogy that I've heard is that altering fish habitat on a lot-by-lot basis is like drilling rivets out of an airplane wing. Surely we don't need all of the rivets, but even an engineer can't predict which one, when removed, will result in the wing falling off."

As Kenai River landowners, you have a special relationship with the Kenai River. You, more than anyone else, know why it's so special. You, more than anyone else, want the river to continue offering its bounty for years to come. And you, more than anyone else, can determine how many "rivets" will be left holding the whole river system together. This *Guide* is intended to help you protect what's so special about the Kenai River.

A SAMPLING OF WHAT'S SO SPECIAL ABOUT THE KENAI RIVER

The river as seen through the eyes of its friends

The following quotes share how some of those who are "closest to the river" (literally) feel about it. All quotes but one are from Kenai River landowners. Quote number four is from Terry Bendock, a Fisheries Biologist with the Alaska Department of Fish.

1 This is particularly true with this first printing (December 1992). We will very likely be able to include some revisions before the second printing in 1993.

From Will Josey:

My feelings about the Kenai River are very deep and widespread. The river generates a peaceful contented frame of mind when I am near it, and a sense of well-being — that the world is all right when I am drifting along on my boat. I would say that the river makes my life worthwhile, and that I am a better person because of it. I care very much about the river and hope to leave it in good hands when I die. It is, without a doubt, the most beautiful place I have ever seen. I sure am fortunate to be here, and I hope to spend the rest of my days enjoying the wonderful Kenai River.

*From **Claudia Knickerbocker**:*

My little home on the Kenai River is more than the fulfillment of a 20-year dream, it is a legacy and an obligation. A legacy to my children and their children's children. An obligation to protect the river so those children can fish on "the greatest river in the world."

*From **Billie Hardy**:*

It's this beautiful, living thing flowing past our house. I love the river, whether it's high or low, green or silty, filled with fish fighting upstream or dead ones spawned on the bank. I love to watch the seagulls float down it and the ducks fly over it. I love to paddle a canoe downstream and feel the adrenalin rush as we maneuver swift water. It's the first thing I look out the window to see in the morning and the last thing at night: our river.

*From **Terry Bendock**, Alaska Department of Fish and Game, Sport Fish Division, in Soldotna:*

The Kenai River is home to 27 species of fish. Different species of fish are famous for different reasons, but the variety of species found in the Kenai River is a testament to the habitat diversity and overall productivity of this stream.

The Kenai is famous for its 19 International Game Fish Association records for sport-caught salmon including all-tackle world records for three of the five species of Pacific salmon. It apparently is not famous for its two species of lampreys even though lampreys are the most primitive fishlike animals in the world. I think that beluga whales are more famous than the two species of smelt that attract them to the Kenai River. The arrival of whales in the spring coincides with the hooligan run, while a fall run of long-finned smelt fattens them up for the winter. How about longnose sucker, three different species of sculpin, and two kinds of stickleback? Did you know that threespine stickleback go to sea each summer just like our anadromous Dolly Varden? Along with round whitefish, we have collected Bering cisco from the lower Kenai River, which really got the juices flowing in some coregonid specialists in the Interior. Are you still with me? Exotic species in the Kenai River include northern pike and arctic grayling. Lake trout and rainbow trout are abundant, and yes, all five species of Pacific salmon have been reported.

Starry flounder can be found as far upstream as Eagle Rock... [and] we don't want to forget Pacific herring and Pacific tomcod. Even the snailfish, which has evolved a sucker on its lower side that allows it to hang onto rocks in heavy surf, has found a home in the Kenai River. That should be 26 species, so the only one I haven't mentioned must be the slender eelblenny — need I say more.

Many species in the Kenai River range throughout the drainage, but the greatest diversity (22 out of 27) is found within the lower 10 river miles. In contrast, only 14 species are found in the upper river between Kenai and Skilak Lakes.

Fish facts aside, the Kenai River is a real jewel. I didn't even mention that it has two runs of chinook salmon, two runs of sockeye salmon, and two runs of coho salmon every year!

From Bob Hunter:

We've fished the Kenai since 1973. Finally moved down to live on the river. I don't guide — it's just my way of life, and fishing it is most important. When you're past 60, you don't fish it in a drift boat. Bank stabilization is important, but the Kenai will have its way, on its own. It's a very powerful river. If there is a way to protect it, I'll be glad to help, but I'm not overwhelmed with do-gooders racing in to limit the use, and no real assured results.

From Pat Bower:

The Kenai River means:
- Watching an eagle catch a fish twenty feet from me.
- Seeing the look of delight on my grandson's face when he caught his first red.
- Listening to my husband explain how he caught an 80 lb king in the "good old days" on the river.
- Going every summer to see if the loon has returned to his island on the river.
- Watching people fish and enjoy the river as much as I do.
- My being concerned enough in saving the river to become involved in the Kenai River Property Owners Association and a part of the Habitat Protection program.
- Drifting the river on a slow day and looking for wildlife...

From Ruth Knorr, "resident since 1968"

I love the river for its beauty and vitality. It's my little bit of heaven on earth. It's also a means of transportation and a way to enjoy the beauty of Alaska — to share with friends and to preserve for future generations in its natural "pristine" state.

From J. D Chadwick:

The peace, tranquility of the River is its greatest part. After 25 years, I still love to just sit and look at the River.

From Roger Byerly:

I love the River. I enjoy watching the different colors, changing depths, the smells, and the wildlife and birds that use the river. The Kenai River is also, indirectly, the largest employer on the Kenai Peninsula, with commercial fishing and sports fishing being the largest employers in this area.

From Al White:

Started fishing the Kenai in 1952 and decided at that time that I would work toward retirement on the river. I'm very interested in saving the river in every aspect. I do feel the U.S., State, Borough, and cities should be doing their part in river protection...

From R. Bloes:

Received my land as a recreation sight from BLM in 1958, and final patent in 1962. It's been an experience to build the cabin and fish the river for 30 plus years. It's also sad to see how it's been changed: good fishing places gone to pot because of silt covering the gravel, ruining the spawning grounds; also the way some people treat the river as a garbage dump.

From Lyle Roberts:

I like the river because it's so beautiful. I like to be able to dock my boat on my beach, to fish and smoke fish.

From Warren and Betty Hoflich:

We live on the Kenai River year round and love it. It's a beautiful place, and we hope to help keep it that way. It's so nice to watch the eagles fly up and down looking for their food. We spent 31 years in the U. S. Air Force and traveled to many places in the world, and we chose to retire here, on the Kenai River.

C. WHAT IS THE *KENAI RIVER COOPERATIVE RIVER BASIN STUDY*?

Goal of the study

This *Guide* is a direct outgrowth of the *Kenai River Cooperative River Basin Study* (for convenience, called the "Kenai River Study" in this document). The principal goal of the Kenai River Study was stated in its *Plan of Work*: "...to provide detailed soil and vegetation maps and interpretations useful to all land owners and managers along the Kenai River" (SCS 1988b:15). In other words, the goal was to put useful, practical information into the hands of Kenai River landowners.

Brief history of the study

When the 1984 Alaska Legislature established the "Kenai River Special Management Area," and turned responsibility for these state lands over to the Alaska Division of Parks and Outdoor Recreation, lack of resource data was already a familiar problem along the Kenai River. Need for more data became increasingly clear as the Division of Parks began working on the *Kenai River Comprehensive Management Plan* required by the 1984 legislation. Several agencies, among them the Alaska Department of Fish and Game, the Division of Parks, and the Soil Conservation Service (SCS), met to discuss how to organize and fund collection of useful resource information (see the study chronology in the Appendix). In 1986, the Kenai Soil and Water Conservation District formally asked the SCS to undertake "...a detailed inventory and study of the soil and soil related resources along the Kenai River." That request led to the Kenai River Study, and development of this *Guide*.

PUT "HOW TO" AND "WHY" INFORMATION IN THE HANDS OF LANDOWNERS.

In 1988, an SCS field crew (in cooperation with Kenai River landowners) began mapping and inventorying soils and plant communities in a corridor about 1/4 mile wide on each side of the river. (Methods used were based on a 2-week "test run" of field procedures done in 1987.) This Kenai River study corridor extends downstream from the boundary of the Kenai National Wildlife Refuge (about 4.5 river miles below Skilak Lake) to the river's outlet in Cook Inlet (see Figure 1). The 1/2-mile-wide corridor contains roughly 46 linear river miles and approximately 12,000 acres.

As soil and plant information was collected and mapped, the Kenai Peninsula Borough began digitizing collected data and entering it into its computerized geographic information system, or GIS. (Later on, within the City of Soldotna, bank inventory information was also collected and digitized, as discussed in Chapter IV.) Digitized data can be accessed quickly and analyzed in many ways as various land use questions arise.

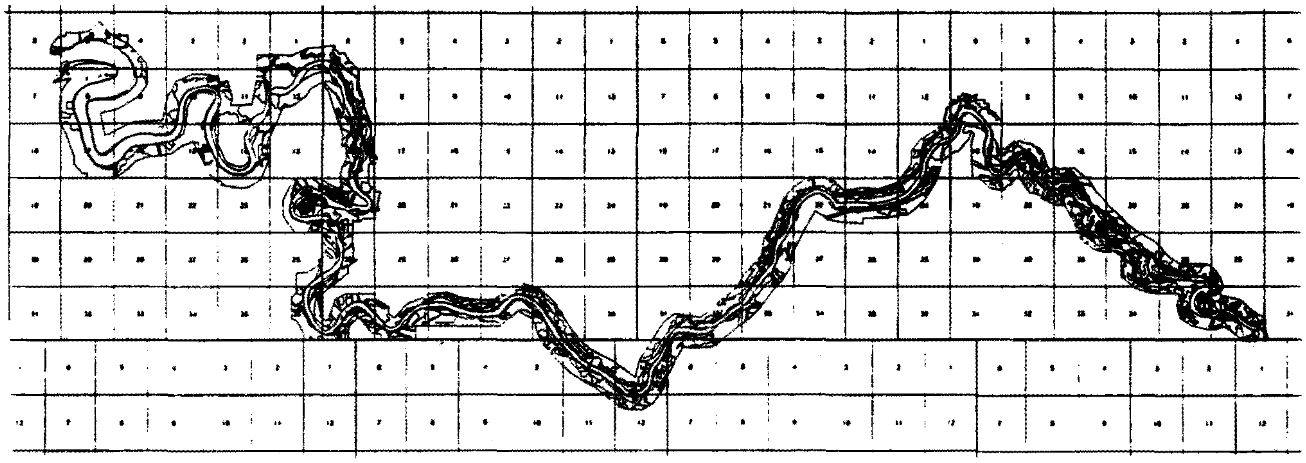
The study focused on a narrow corridor along the lower Kenai River for two main reasons:

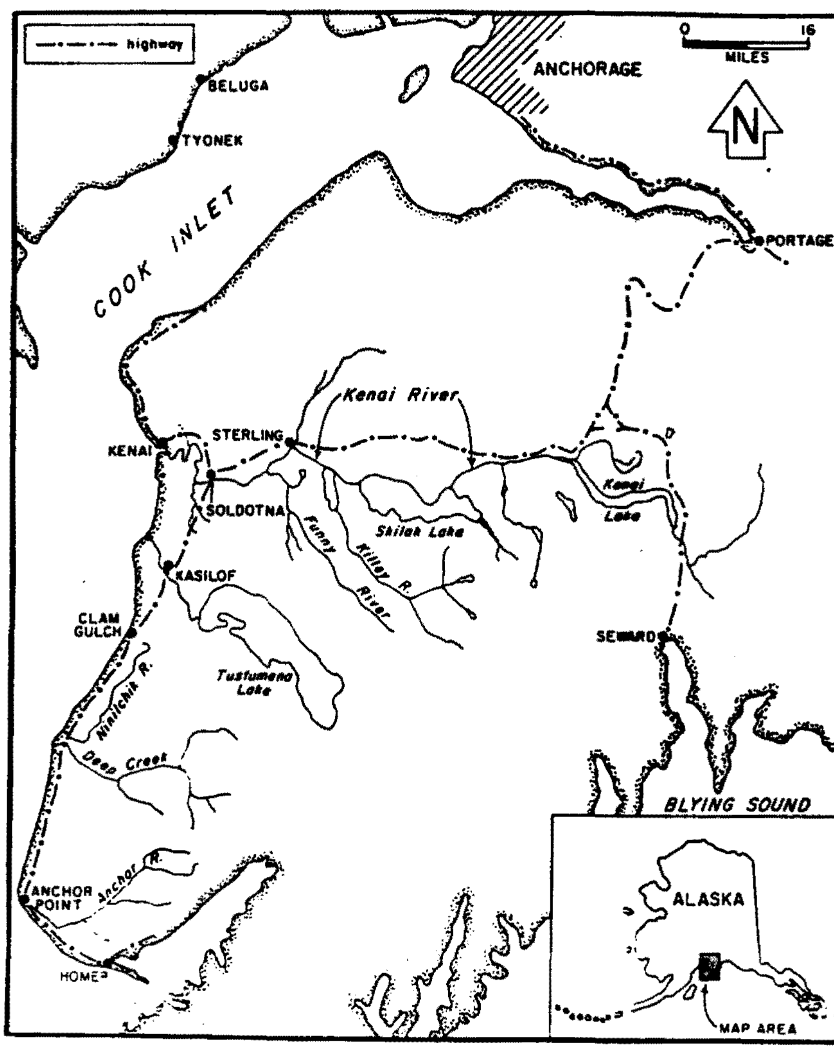
(1) Development activities are concentrated on these lands because most of them (66%) are privately owned. Local governments own another 15% (e.g., the cities of Soldotna and Kenai and the Kenai Peninsula Borough), and the state also owns 15%. The remaining 4% of lower Kenai River lands are within the Kenai National Wildlife Refuge managed by the U.S. Fish and Wildlife Service.

(2) Funding for the study was limited. Because the goal of the study was to provide information to those landowners whose activities could potentially most affect the river, it made sense to concentrate on lands nearest the river. Not only do these lands and landowners affect the river most directly, they also can serve as Kenai River "early warning systems." For example, if watershed activities outside the study corridor start changing air or water quality in ways that might affect the Kenai River, Kenai

River landowners will usually experience these "offsite effects" before they reach the river itself. We assume (and hope) that as Kenai River landowners watch out for "offsite effects" that reach their lands, they will also inevitably help watch out for "offsite effects" that might reach the river and impair its health.

Figure 1. Top - Kenai River study corridor (1/4 mile-wide corridor on each side of the lower Kenai River). (These lands are the focus of this *Guide.*)
Bottom - Location of the Kenai River (from Estes and Kuntz 1986a).





Brief introduction to study data and methods

As noted above, the Kenai River Study focused on mapping and inventorying soils and plant communities within 1/4 mile of each river bank along the lower 46 miles of river. (In addition, riverbanks were inventoried within the City of Soldotna, see Chapter IV.)

The photographic base used in making soil maps and plant community maps was color infrared aerial photography flown by the Alaska Department of Fish and Game in 1987. (The photograph on the back cover of this *Guide* is an example of the photography used.) The photographs have a scale of approximately 1:4800, meaning that a distance of 1 inch on the photographs covers a distance of 4800 inches (or 400 ft) on the ground. (Thus, a photo distance of 13.2 inches covers 1 mile of ground distance; for an explanation of map and photo scale, see Chapter VII.)

Chapter IV discusses soil and plant community information collected during this study, and suggests a number of ways landowners can use this and related information. Chapter VII contains "digitized" soil maps and plant community maps generated by the Borough's Geographic Information System (GIS) staff from mapped data. (Note, although soil and plant information was mapped at a scale of 1:4800 on the photographic base, computer-generated maps contained in Chapter VII have a scale of 1:8400 in order to save space in this *Guide*. In the "Technical Report" for the Kenai River Study, due out this spring, digitized maps will be printed at the actual mapping scale of 1:4800.)

A key way in which collected information can be used is in making land use "interpretations." Interpretations are discussed in Chapter IV, and a number of interpretations are provided in Chapter VII. For example, mapped plant information has been interpreted to show which plant communities are good sources of materials useful in revegetating banks, which are susceptible to attack by spruce bark beetle, and which are used by particular wildlife species. Soils information has been interpreted to show which areas are suitable for specific land uses such as:

* residential buildings (with or without basements),
* septic tank absorption fields ("leach fields")
* small commercial buildings,
* local roads and streets,
* shallow excavations,
* grassed waterways,
* lawns and landscaping,
* camping areas, and
* paths and trails.

As explained in Chapter IV, however, interpretations of individual soils are not included in this *Guide* because we don't have space here to list how hundreds of mapped soil codes were interpreted for all rated land uses. Complete soil interpretations will be included in the "Technical Report" for the Kenai River Study, due this spring. Until then, you can find out how your soils were rated for particular land uses by calling the Soil Conservation Service. Chapter IV tells you how.

As background for Chapter IV, Chapter II describes the lower Kenai River, including its physical environment, wildlife, cultures, economy, and political/management/regulatory setting. Chapter III provides an introduction to watersheds, explains how rivers work, and provides useful information about the Kenai River as a physical system. Chapters V and VI suggest where landowners can get more help in managing their Kenai River lands, and identifies some programs designed to assist landowners in their efforts to take care of the Kenai River.

We hope you find this information interesting and helpful. This *Guide* was written for you.

II. DESCRIPTION OF AREAS COVERED BY THIS GUIDE

CHAPTER CONTENTS

A.	**Description of the physical environment of the lower Kenai River**	**2**
	Streams in the watershed	2
	Watershed geology	5
	Watershed topography and surface sediments	6
	Watershed climate	7
B.	**Description of wildlife along the lower Kenai River**	**8**
C.	**Description of culture and economy along the lower Kenai River**	**20**
	Native cultures and early history of the lower Kenai River	20
	A summary of Kenai Peninsula prehistory	20
	Post-contact history and disruption of Native populations	25
	Current population and economy	28
D.	**Description of political, management, and regulatory environments along the lower Kenai River** *(Who governs, manages, or permits what happens on and along the river)*	**30**

II. DESCRIPTION OF AREAS COVERED BY THIS GUIDE

Each time you learn something new about where you live or recreate, it improves your vision: you start seeing details or patterns you'd missed before. The more you learn about your place, the more you start to see it. This chapter provides a **brief introduction** to the physical, biological, socioeconomic, and political **environments that encompass the lower Kenai River** (Figure 1). The physical environment of the Kenai River itself (its hydrology and "river dynamics") is discussed in Chapter III. Soils and plant communities along the lower Kenai River are discussed in Chapter IV (and are mapped in Chapter VII).

A. DESCRIPTION OF THE PHYSICAL ENVIRONMENT OF THE LOWER KENAI RIVER

written with assistance from Mark Kinney, SCS District Conservationist, and Douglas J. Van Patten, SCS Soil Scientist

Streams in the watershed

The Kenai River is a glacially fed river draining a watershed area of approximately 2,150 square miles (Figure 2). The river is easily divided into two sections (Figure 1). Its "upper reach" is 17 miles long and flows from the outlet of Kenai Lake (located roughly 450 ft above sea level in the Kenai Mountains) to Skilak Lake. Its "lower reach" is 50 miles long and flows from the outlet of Skilak Lake (located roughly 200 ft above sea level) to Cook Inlet. There are two gages on the river, one at the outlet of Kenai Lake in Cooper Landing (gage height, 420 ft above sea level) and one at the Soldotna Bridge in Soldotna (gage height 35 ft above sea level).

Because the Kenai River flows into coastal waters, its lower 12 or so miles are subject to tidal fluctuation. Over the course of a year, tides at the mouth of the Kenai River can range from a low of about minus 5 ft to a high of plus 25 ft; the mean tidal range at Kenai is about 17.7 ft.

Kenai River flows fluctuate widely with the seasons. "Summer flows, ranging from 5,000 to 30,000 cubic ft per second [see Chapter III], are dominated by melt water originating from the icefields in the river's headwaters and accordingly convey a load of glacial flour that gives the waters their renowned turquoise-green color. Winter flows, ranging from 800 to 5,000 cfs, are dominated by waters originating from groundwater sources and the river's large natural lake reservoirs" (Estes and Kuntz 1986a:2).

Ten tributaries feed the Kenai River. These, and their river miles (RM) from Cook Inlet, are:

Juneau Creek	RM 79.5
Cooper Creek	RM 79
Russian River	RM 73.5
Skilak River	RM 64
Killey River	RM 44
Moose River	RM 36.5
Funny River	RM 30.5
Soldotna Creek	RM 22
Slikok Creek	RM 19
Beaver Creek	RM 10.5

Six of these (in boldface) join the "lower Kenai River." Of these six, only the Killey River is fed by glacial meltwater and as a result flows highest during summer months when glacier ice is melting most rapidly. The other

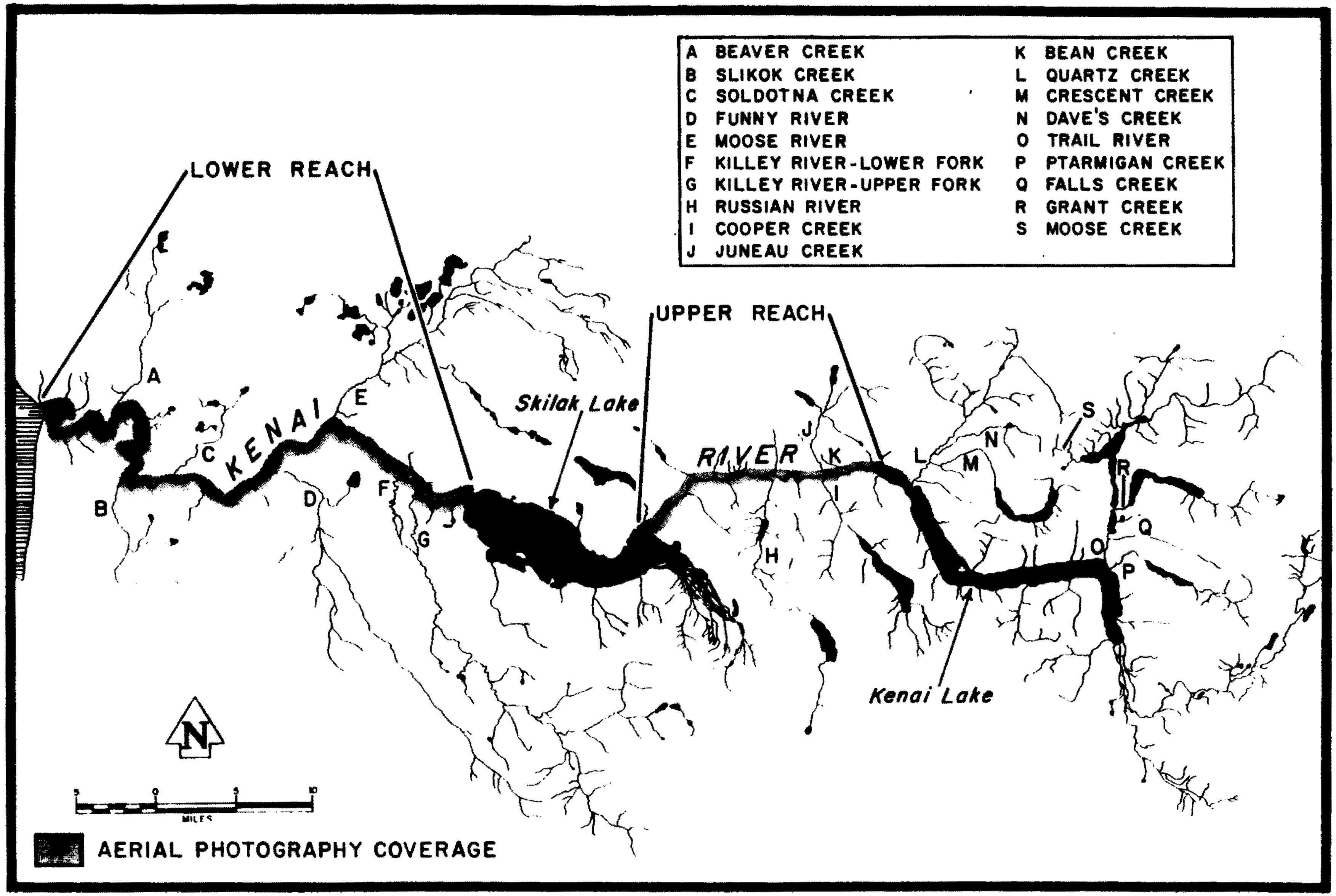
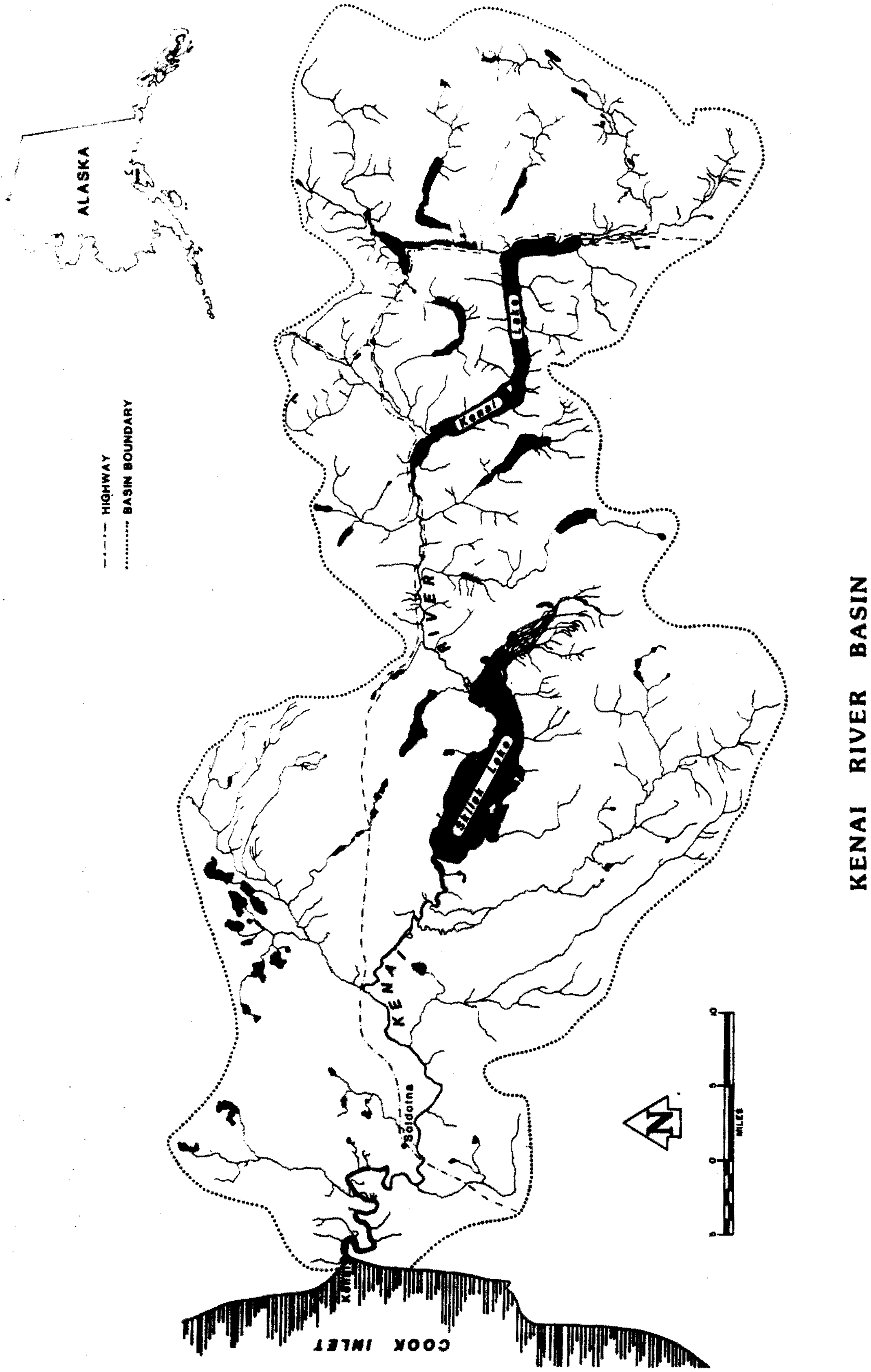


Figure 1. The "upper" and "lower" reaches of the Kenai River and their tributaries (from Estes 1987).

Figure 2. The Kenai River watershed (from Estes 1992).



five "lower" tributaries are nonglacial and flow highest during spring, when snows melt, and again during fall, when rainfall is highest. As mentioned above, winter low flows, or *base flows*, in the Kenai River are maintained by groundwater sources (which feed both the river and its tributaries) and by discharge from Kenai and Skilak Lakes.

Watershed geology

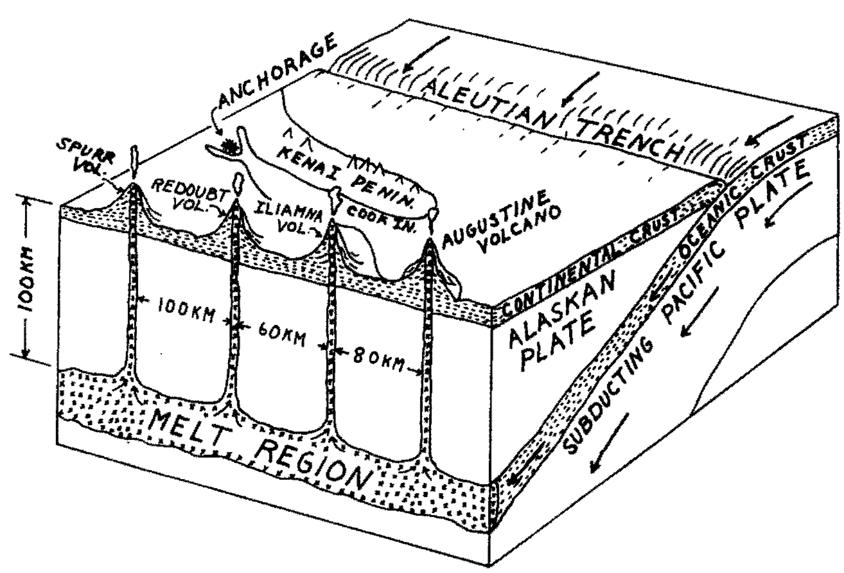
(based on Karlstrom 1964)

The lower Kenai River flows through "the Kenai Lowlands," a section of the "Cook Inlet Basin" that was uplifted above sea level. The Cook Inlet Basin itself is part of a larger *structural trough* (a long linear depression caused by earth movements) that runs from Shelikof Strait through Cook Inlet and up the Susitna Valley. The trough is bordered on the northwest by the inactive Bruin Bay Fault and the Aleutian, Alaskan, and Talkeetna Mountains. On the southeast, it's bordered by the inactive Border Ranges Fault and the Kodiak, Kenai, and Chugach Mountains (U.S. Army Corps of Engineers 1978:58).

Before it was uplifted, the Kenai Lowlands, like other parts of the Cook Inlet Basin, accumulated marine strata tens of thousands of feet thick. These have since been overlain by *Tertiary* age nonmarine and estuarine strata of similar thickness. More recently, the Lowlands accumulated hundreds of feet of *Quaternary* sediments, particularly sediments deposited by *Pleistocene* glaciers and *pro-glacial* lakes (see below) during glacial advances and by glacer-fed rivers during glacial retreats. (The Tertiary Period began about 65 million years ago and ended about 1 million years ago, at which time the Quaternary Period began. The first portion of the Quaternary Period encompasses the *Pleistocene Epoch*, or "Ice Age;" the second portion consists of the *Recent Epoch*, which continues today.)

Large-scale movements of the earth's crust still shape all parts of the Kenai Peninsula, causing both earthquakes and volcanic eruptions. Figure 3 illustrates how the "Pacific Plate" is diving (*subducting*) beneath the "Alaskan Plate" at the "Aleutian Trench" in the Gulf of Alaska. The movement of these plates causes earthquakes. In addition, as subducted oceanic crust is forced deeper under the Alaskan Plate, increasing pressure causes it to melt. Pressurized molten rock then moves upwards through cracks in the earth's crust, creating the volcanoes that line the west side of Cook Inlet.

Figure 3. Earth movements that affect the Kenai Peninsula: The Pacific oceanic plate moves northwest to subduct under southern Alaska at the Aleutian Trench. Plate movements cause earthquakes. In addition, melting of subducted material at depths near 100 km creates magma that floats up through overlying rocks, feeding volcanoes on the west side of Cook Inlet (from Davis 1982:105).



As a result of its geological history, the Kenai Lowlands are underlain at variable depths by sedimentary rocks of Tertiary age that are mantled by Quaternary deposits. As mentioned above, Quaternary sediments are often hundreds of feet thick, and few exposures of underlying bedrock occur.

Watershed topography and surface sediments

The present-day Kenai Lowlands form a broad, low shelf 20 to 50 miles wide and 106 miles long, covering an area of about 3,600 square miles. Surface terrain consists of low hills, broad level plains, many small lakes (outside the lower Kenai River study area), and natural wetland areas. Most of the Lowlands are less than 400 feet above sea level. Drainage is generally poorly developed, and numerous lakes, marshes, and muskegs cover more than one-third the total lowland surface area.

To a great extent, the Kenai Lowlands topography that we see today reflects repeated episodes of glacial advance and retreat. At least five major Pleistocene (or "Ice Age") glaciations and two minor post-Pleistocene glacial advances have been distinguished by geologists. Three of the Pleistocene glaciations, the *Eklutna, Knik,* and *Naptowne*, deposited *moraines* in the Kenai River study area. A moraine is an accumulation of rock debris deposited chiefly by glacial action; the usually hummocky topography of moraines is independent of the surface on which they lie. The most recent glacial advance, the Naptowne, deposited several broad morainal belts whose boundaries suggest regrouping of ice tongues and glacial readvances following retreats from earlier positions. Pleistocene and post-Pleistocene glacial advances were fed by glaciers flowing from the same alpine areas that today still contain large concentrations of glacial ice.

During the Knik and Naptowne glaciations, ice flowing from the mountain ranges on either side of Cook Inlet completely filled the narrow northern and southwestern sections of the Cook Inlet Basin. Glaciers merging at the southwestern end of the Basin created an immense ice dam. A "proglacial lake" formed behind this dam. When it emptied during glacial retreats, it left behind lake deposits and high-level strandlines, or shoreline deposits. Comparable but more temporary lake environments probably also existed in Cook Inlet during initial phases of advance and later phases of retreat of earlier and more extensive glaciations. In the central and widest section of the Cook Inlet Basin, where glaciers never coalesced, widely separated, spatula-shaped complexes of end moraines were deposited along lowland margins.

In general, surface deposits of the lower Kenai River belong to three main *stratigraphic units* (units of rock layers, or *strata,* mostly sedimentary). The three units are:

(1) a thin, nearly continuous surface mantle of very fine wind-blown sediments (*loess*), with localized thicker deposits of windblown sand,

(2) proglacial-lake sediments of Naptowne age, which underlie the loess mantle nearly everywhere (lake sediments consist of varying thicknesses of essentially unweathered blue-gray-to-gray stratified gravel and sand, layered silt and sand, and massive to rudely stratified stony silt), and

(3) a complex of older sediments, including buff to gray *till* (nonstratified, nonsorted glacial deposits) and ice-contact deposits left by glacial lakes and glacier-fed rivers (these deposits underlie both loess and proglacial-lake sediments).

These strata, and their relationship to local soils, are discussed in more detail in Chapter IV.

Watershed climate

The Kenai lowlands are situated in a transitional climate zone between the maritime climate of the eastern Kenai Peninsula (adjacent to Prince William Sound and the Gulf of Alaska), and the continental climate typical of interior Alaska. Average mid-winter temperatures in the Kenai River drainage range from -10 degrees Fahrenheit to -41 degrees F. Average mid-summer temperatures range from 40 degrees F to 65 degrees F. Extremes of -47 degrees F and +90 degrees F have been recorded.

Annual precipitation in the Kenai lowlands ranges from 18.5 inches at Kenai to 27 inches at Homer. Topography greatly influences precipitation. Moisture-laden air masses lose water in the Kenai and Chugach Mountains as they travel northwestward to the lowlands. Annual precipitation exceeds 40 inches in the Kenai Mountains, which accounts for much of the Kenai River's flow.

Temperatures are critical to plant growth. Many Alaskan plants will grow only when temperatures exceed 40 degrees Fahrenheit. "A growth index called the *growing-degree unit* has been compiled for several Alaskan locations. To obtain the index value for each *day* (a *growing-degree day*, or GDD) the Fahrenheit maximum and minimum temperatures for that day are added together and the sum is divided by two. This gives a sort of average temperature for the day. From this average temperature, one subtracts 40 degrees, the temperature at which most Alaskan crops start to grow" (Davis 1982:142). If you know the GDD requirements of particular plants, you can compare their GDD needs to the total number of growing-degree days typical of a location of interest to you. If the growing season in your location does not provide as many GDD's as a plant needs, the plant will not survive there. Table 1 indicates average growing degree days for the Kenai area, based on historical records from 1970-1990. In addition, Kenai typically has 122 frost free days.

Table 1. Average growing-degree days along the Kenai River (base 40^{0} F) (from Alaska Agriculture Statistics 1991).

May	126
June	311
July	453
August	427
September	200
Total	1517

Another aspect of local climate important to landowners is *sun angle*. The elevation of the sun at different times of year affects when sunlight will strike particular areas of your property (or windows of your house). Table 2 gives the angle of the sun above the horizon at noon on the 21st day of each month in the year. (The 21st day is used because the longest day, June 21, and the shortest day, December 21, both occur on that date.)

Table 2. Elevation of the sun at noon, in degrees above the south horizon, in Kenai and Homer on the 21st day of the month (from Davis 1982:189).

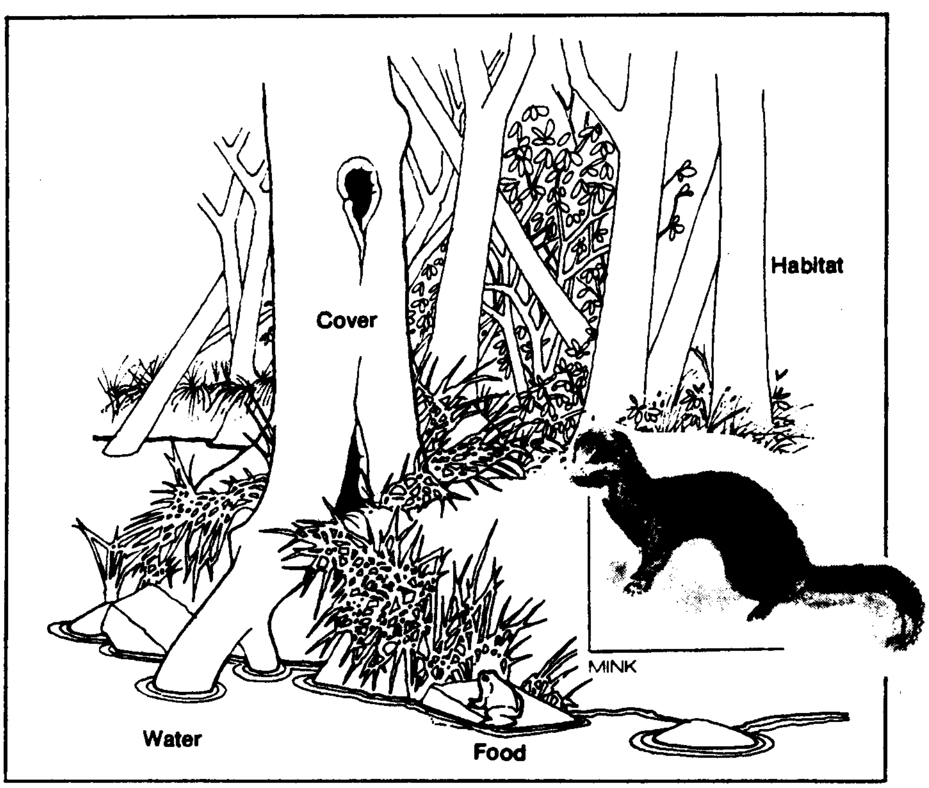
Dec	Jan Nov	Feb Oct	Mar Sep	Apr Jul	May Aug	Jun
6	10	19	30	41	50	53

B. DESCRIPTION OF WILDLIFE ALONG THE LOWER KENAI RIVER

If we spend time along the Kenai River, we tend to be aware of fish (and wish there were more of them) and people (and wish there were fewer of them and the signs they leave behind). Maybe we're also aware of moose and eagles and bears because we want to hunt them or see them or avoid chance encounters, respectively. In other words, we tend to be aware of creatures that affect us personally. That leaves most of us largely unaware of the tremendous variety of other kinds of life along the Kenai River. We can't begin to detail this variety here, but we can provide some idea of how *much* variety there is, and where you can learn more about it.

The creatures you find in an area are there because the area provides them with one or more suitable *habitats*. Habitats, as you probably know, are the places where creatures can find what they need to survive: food, water, shelter from the elements, places to hide from enemies, places for mating and for bearing young, etc. (Figure 4). Obviously, different species have different habitat needs, and the needs of any individual creature change with the seasons and over the years. That means that creatures may use several kinds of habitats throughout the year and throughout their lives — feeding habitats, nesting habitats, spawning habitats, overwintering habitats, etc. Some creatures, like moose, snow geese, and salmon, move from habitat to habitat with the changes of the seasons or as new life cycle phases begin. Others, like squirrels, minks, and magpies, use the same habitats year round, year after year.

Figure 4. An animal's habitat provides food, water, cover, and other needed elements (modified from Richberger and Howard, no date:7).



Habitats consist of combinations of environmental variables. For moose, for example, the most important *summer habitat* variables are certain plants; the most important *winter habitat* variables include certain plants (mainly willows) and snow depth. For salmon, the most important *spawning habitat* variables involve streamflow, water quality, and channel conditions, but in *open ocean habitats*, other variables (many as yet unknown) are critical.

Along the Kenai River, as along many natural river systems, an unusually high diversity of environmental variables (see Table 1, Chapter III) creates an unusually high number of terrestrial and aquatic habitats. Broadly speaking, these habitats can be divided into three categories: (1) upland habitats, (2) riparian[1] and wetland habitats, and (3) instream habitats. *Upland* habitats are usually defined in terms of plant communities and physical features like soils and landforms, for example: "well-drained, south-facing white spruce forest habitats." *Riparian* and *wetland* habitats are also defined in terms of plants, soils, and landforms, but in addition, presence of open water or saturated soils is critical. *Instream* habitats are usually defined in terms of streamflow variables, water quality parameters, and channel characteristics. Table 3 lists general terrestrial habitat categories commonly used in bird and mammal field guides. (These particular categories are from Quinlan et al. 1983). More detailed plant- and soil-based habitats along the lower Kenai River can be distinguished using soil and plant information discussed in Chapter IV and mapped in Chapter VII. Table 4 lists some of the instream habitats distinguished by biologists studying the Kenai River (Estes and Kuntz 1986b).

AS WE GROW MORE AWARE OF THE CREATURES THAT SURROUND US, WE GROW MORE ALERT TO THE WAYS WE CHANGE THEIR LIVES.

The great diversity of habitats currently found in and along the Kenai River means a great diversity of plants and animals can find suitable places to live. Creatures that live in the Kenai River corridor range from single-celled micro-organisms and simple invertebrates to complex vertebrates like fish, birds, mammals, human beings, and even one frog (the wood frog *Rana sylvatica*).

We don't have room here to discuss these species and their habitat needs. For that kind of information, we refer you to the many excellent field guides and wildlife references that are readily available. In addition, the *Kenai River Comprehensive Management Plan* (ADNR 1986) includes a good general summary of fish and wildlife distribution and use in the Kenai River corridor.

But because it's always nice to know *what* species you're likely to find in your area, we're including some of that information here. Table 5 lists mammals of the Kenai River corridor, along with the basic habitat types they use. Table 6 lists birds of the Kenai River corridor, and provides some indication of their abundance, when they use the area, and what general habitat types they prefer. (Terry Bendock already identified the 27 species of fish found in the Kenai River in the Introduction.) In Chapter IV, we suggest how you can attract birds and mammals to your parcel (see #2 under "Twelve ways to use plants to your advantage").

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1 The word *riparian* can be defined in a number of ways. The Soil Conservation Service defines *riparian areas* as: "...ecosystems that occur along watercourses or waterbodies." These areas are "...distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil" (SCS GM 1991). Riparian areas are transitional between terrestrial and aquatic ecosystems. For wildlife, however, "nearness to open water" is often most critical in determining whether or not an area is "riparian" to them. "Nearness" is a function of animal size and mobility; what's "near" for a moose may be very far away for a muskrat.

Because salmon are of such great interest to Kenai River landowners, their habitat needs are discussed in somewhat more detail throughout this *Guide*. In particular, we refer you to How people are impacting fish habitats along the Kenai River (Chapter III, Section B) and The relationship between riverbanks and fish (Chapter IV, Section D). In addition, in Chapter IV, we suggest ways to improve bank-edge habitat for salmon fry. In Chapters VI and VIII, we list additional sources of information about Kenai River fish. A good source of information on fish life histories and habitat needs is *The Freshwater Fishes of Alaska* (Morrow 1980, listed in References.) Table 7 indicates when salmon and a few other fish species use the Kenai River and its tributaries.

The material in this *Guide* barely scratches the surface when it comes to Kenai River fish and wildlife. Becoming really aware of and familiar with most of the creatures found in and along the Kenai River is probably not humanly possible. Realistically, the best most of us can do is learn about the species that interest us most — salmon, moose, or bald eagle; red fox, flying squirrel, or chickadee — and then try to consider their needs as we go about transforming their habitats into ours. But just an awareness that all kinds of life go on around us, and that we exist in relationship to this diverse community, can make us more alert to the effects our actions may have on the habitats of others.

If you read the Introduction to this *Guide*, you'll remember Terry Bendock's analogy of the rivets that hold the wings on an airplane. In one way or another, each species in the Kenai River watershed is like one of those rivets. We may not know what each rivet does, or how important it is, but we know that the more rivets we leave in place, the better the whole Kenai River system will hold together and function.

Table 3. General habitat types for birds and mammals (from Quinlan et al. 1983). (Those in boldface occur along the lower Kenai River.)

1. hemlock-spruce forest
2. **spruce-hardwood forest**
3. **tall shrub thickets**
4. **muskeg**
5. alpine tundra
6. moist tundra
7. wet tundra
8. **freshwater rivers, lakes, riparian habitats**
9. glaciers and ice fields
10. **coastal wetlands: river deltas, mudflats, salt marshes, and sandy beaches**
11. barrier islands-lagoon systems
12. coastal islands, cliffs, and rocky shores
13. marine waters
14. **human altered habitats**

Table 4. Instream habitats of the Kenai River (from Estes and Kuntz 1986b).

I. **Peripheral main channel habitats**

A. Main channel bank habitats (developed, nondeveloped)
B. Side channel bank habitats (developed, nondeveloped)
C. Island bank habitats (developed, nondeveloped)
D. Tidally influenced habitats (developed, nondeveloped)
E. Bar/shoal habitats

II. **Non-peripheral main channel habitats**

A. Main channel habitats (developed, nondeveloped)
B. Side channel habitats (developed, nondeveloped)
C. Tidally influenced habitats

III. **Slough habitats**

A. Backwater habitats (developed, nondeveloped)
B. Free flowing habitats (developed, nondeveloped)

IV. **Tributary habitats**

A. Clear water tributary habitats
   1. bank habitats (developed, nondeveloped)
   2. non-bank habitats (developed, nondeveloped)
B. Turbid water habitats
   1. bank habitats (developed, nondeveloped)
   2. non-bank habitats (developed, nondeveloped)

V. **Tributary mouth/delta habitats**

A. Clear water tributary confluence habitats (developed, nondeveloped)
B. Turbid water tributary confluence habitats (developed, nondeveloped)

VI. **Lake habitats**

A. Non-shore habitats
B. Shore habitats (developed, nondeveloped)

VII. **Wetland habitats**

A. Contiguous (developed, nondeveloped)
B. Non-contiguous (developed, nondeveloped)

Table 5. Mammals of the Kenai River corridor (from USFWS KNWR).

Common name	habitats used in the Kenai River corridor (from Quinlan et al. 1983)
moose	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands
caribou	spruce/hardwood, muskeg, coastal wetlands
coyote	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered
wolf	spruce/hardwood, tall shrub, muskeg, riverine
red fox	spruce/hardwood, tall shrub, muskeg, riverine, human altered
black bear	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered
brown bear	spruce/hardwood, tall shrub, riverine, coastal wetlands
marten	spruce/hardwood, tall shrub, riverine
ermine	spruce/hardwood, tall shrub, muskeg, riverine, human altered
least weasel	spruce/hardwood, tall shrub, muskeg, riverine
mink	tall shrub, muskeg, riverine, coastal wetlands
wolverine	spruce/hardwood, tall shrub, muskeg, riverine
river otter	tall shrub, riverine, coastal wetlands
lynx	spruce/hardwood, tall shrub, riverine
belukha whale	frequently enter the mouth of the Kenai River at high tide
killer whale	enters the mouth of the Kenai River, usually to feed on belukha whales
snowshoe hare	spruce/hardwood, tall shrub, muskeg, riverine
red squirrel	spruce/hardwood, riverine
northern flying squirrel	spruce/hardwood, coastal wetlands
beaver	riverine
northern red-backed vole	spruce/hardwood, tall shrub, muskeg, riverine, human altered
meadow vole	tall shrub, muskeg, riverine, coastal wetlands, human altered
tundra vole	spruce/hardwood, tall shrub, riverine, coastal wetlands
muskrat	muskeg, riverine, coastal wetlands
northern bog lemming	tall shrub, muskeg, riverine, coastal wetlands
Norway rat and house mouse (introduced)	human altered
meadow jumping mouse	tall shrub, riverine, coastal wetlands, human altered
porcupine	spruce/hardwood, tall shrub
common (masked) shrew	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered
dusky shrew	spruce/hardwood, tall shrub, muskeg, riverine, human altered
pygmy shrew	spruce/hardwood, tall shrub, muskeg, riverine, human altered
little brown bat	spruce/hardwood, riverine, human altered

Table 6. Birds of the Kenai River corridor (legend at end).
(Habitat data from Quinlan et al. 1983; species list and occurrence data based on USFWS KNWR 1985.)

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
common loon	riverine	c	c	c		x
arctic loon	muskeg, riverine, coastal wetlands	c	c	u		x
red-throated loon	muskeg, riverine	u	u	r		
horned grebe	muskeg, riverine, coastal wetlands, human altered	u	c	c		x
double-crested cormorant	riverine	u	u	u		x
tundra swan	muskeg	c		c		
trumpeter swan	riverine, coastal wetlands	c	c	c	r	x
Canada goose	muskeg, riverine, coastal wetlands, human altered	c	r	c		x
greater white-fronted goose	riverine	u		u		
snow goose	riverine, coastal wetlands	c		r		
mallard	muskeg, riverine, coastal wetlands, human altered	c	u	c	r	x
northern pintail	muskeg, riverine, coastal wetlands, human altered	a	c	c		x
green-winged teal	muskeg, riverine, coastal wetlands, human altered	c	c	c		x
American wigeon	muskeg, riverine, coastal wetalnds, human altered	u	u	u		x
northern shoveler	spruce/hardwood, muskeg, riverine, coastal riverine,	u	r	u		x
greater scaup	muskeg, riverine, coastal wetlands	u	u	u	r	x
common goldeneye	muskeg, riverine, coastal wetlands	c		c	u	
Barrow's goldeneye	muskeg, riverine, coastal wetlands	c	c	c		x
bufflehead	muskeg, riverine, coastal wetlands	u		u	i	
oldsquaw	muskeg, riverine, coastal wetlands	r		u		
harlequin duck	riverine	u	u	u	i	x

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
white-winged scoter	muskeg, riverine, coastal wetlands	r	u	u	i	
common merganser	muskeg, riverine	u	u	c	u	x
red-breasted merganser	muskeg, riverine	u	u	u		
northern goshawk	spruce/hardwood (see p.__)	c	c	c	c	x
sharp-shinned hawk	spruce/hardwood	u	u	u		x
red-tailed hawk	spruce/hardwood, muskeg, riverine, human altered	u	u	u		x
golden eagle	spruce/hardwood	u	u	u		x
bald eagle	spruce/hardwood, riverine, coastal wetlands	c	c	c	u	x
northern harrier	muskeg, coastal wetlands, human altered	u	u	u		x
peregrine falcon	spruce/hardwood	u	r	r	i	
merlin	spruce/hardwood, muskeg, riverine, coastel wetland	u	u	u		
spruce grouse	spruce/hardwood, muskeg	c	c	c	c	x
willow ptarmigan	tall shrub, muskeg	c	c	c	c	x
sandhill crane	muskeg, riverine, coastal wetlands	c	u	c		x
semipalmated plover	riverine, coastal wetlands	u	u	u		x
lesser golden plover	coastal wetlands, human altered	u		u		
black-bellied plover	coastal wetlands	u		r		
common snipe	muskeg, coastal wetlands	c	c	c		x
whimbrel	coastal wetland	u	r	u		
spotted sandpiper	riverine	c	c	c		x
solitary sandpiper	muskeg, riverine, coastal wetlands	u	u	u		x
wandering tattler	riverine	u	u	u		
greater yellowlegs	muskeg, riverine, coastal wetlands	a	a	a		x
lesser yellowlegs	muskeg, riverine, coastal wetlands	c	c	c		x

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
pectoral sandpiper	riverine, coastal wetlands, human altered	c		c		
least sandpiper	muskeg, riverine, coastal wetlands	c	c	u		x
dunlin	riverine, coastal wetlands	u		r		
short-billed dowitcher	muskeg, coastal wetlands	c	c	c		x
western sandpiper	riverine, coastal wetlands	c	r	u		x
red-necked phalarope	muskeg, riverine, coastal wetlands	c	c	u		x
parasitic jaeger	coastal wetlands	u	u	r		
glaucous-winged gull	riverine, coastal wetlands, human altered	c	c	c	r	x
herring gull	riverine, coastal wetlands, human altered	c	c	c		x
mew gull	riverine, coastal wetlands, human altered	a	a	c		x
Bonaparte's gull	muskeg, riverine, coastal wetlands	u	u	u		x
arctic tern	muskeg, riverine, coastal wetlands	a	a	u		x
great-horned owl	spruce/hardwood, tall shrub, riverine	c	c	c	c	x
northern hawk-owl	muskeg, riverine	u	u	u	u	
short-eared owl	muskeg, coastal wetlands, human altered	u	u	u	r	x
boreal owl	spruce hardwood, riverine	u	u	u	u	
belted kingfisher	riverine, coastal wetland, human altered	u	u	u	i	x
hairy woodpecker	spruce/hardwood, human altered	u	u	u	r	x
downy woodpecker	spruce/hardwood, tall shrub, human altered	u	u	u	r	x
three-toed woodpecker	spruce/hardwood	u	u	u	u	x
alder flycatcher	tall shrub, muskeg	c	a	a		x
olive-sided flycatcher	spruce/hardwood, riverine	r	u	r		x

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
horned lark	coastal wetlands, human altered	u	u	u		
violet-green swallow	spruce/hardwood, muskeg, riverine, coastal wetlands, human altered	c	c			x
tree swallow	spruce/hardwood, muskeg, riverine, coastal wetlands, human altered	c	a			x
bank swallow	riverine, coastal wetlands, human altered	c	a	c		x
cliff swallow	riverine, coastal wetlands, human altered	r	u			x
gray jay	spruce/hardwood, muskeg, riverine, human altered	c	c	c	c	x
Steller's jay	spruce/hardwood, muskeg, riverine, human altered	r	r	r	r	x
black-billed magpie	spruce/hardwood, tall shrub, muskeg, riverine, human altered	c	c	c	c	x
common raven	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered	c	c	c	c	x
black-capped chickadee	spruce/hardwood, tall shrub, muskeg, riverine, human altered	u	u	u	r	x
boreal chickadee	spruce/hardwood, muskeg	c	c	c	u	x
brown creeper	spruce/hardwood	u	r	u	r	x
American dipper	riverine, human altered	u	u	u	u	
American robin	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered	c	c	c		x
varied thrush	spruce/hardwood, tall shrub, muskeg, riverine, coastal wetlands, human altered	c	c	c		x
hermit thrush	spruce/hardwood, tall shrub, muskeg, riverine	c	c	u		x
Swainson's thrush	spruce/hardwood, tall shrub, riverine	c	c	u		x

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
gray-cheeked thrush	tall shrub, muskeg, riverine	u	c	u		x
golden-crowned kinglet	spruce/hardwood	u	u	u	r	x
ruby-crowned kinglet	spruce/hardwood, tall shrub, muskeg	a	a	c		x
water pipit	riverine, coastal wetlands	c	c	c		x
bohemian waxwing	muskeg, riverine	c	c	c	r	x
northern shrike	spruce/hardwood, tall shrub, muskeg, riverine	u	u	u	r	
orange-crowned warbler	spruce/hardwood, tall shrub	c	c	u		x
yellow warbler	spruce/hardwood, tall shrub	u	u	r		x
yellow-rumped warbler	spruce/hardwood, tall shrub	a	a	c		x
blackpoll warbler	spruce/hardwood, tall shrub, muskeg, riverine	r	u	r		x
northern waterthrush	tall shrub, riverine	c	c	u		x
Wilson's warbler	spruce/hardwood, tall shrub, muskeg, riverine	u	c	u		x
rusty blackbird	tall shrub, muskeg, coastal wetlands, human altered	u	u	u	i	x
pine grosbeak	spruce/hardwood, tall shrub, muskeg, human altered	u	u	u	r	x
rosy finch (gray crowned)	riverine, coastal wetlands	u	u	u		
common redpoll	spruce/hardwood, tall shrub, muskeg, human altered	c	c	c	c	x
white-winged crossbill	spruce/hardwood	u	u	u	u	
savannah sparrow	muskeg, coastal wetlands, human altered	c	a	a		x
dark-eyed junco	spruce/hardwood, tall shrub, muskeg, coastal wetlands, human altered	c	a	c		x
American tree sparrow	tall shrub, muskeg	u	u	r		x
white-crowned sparrow	spruce/hardwood, tall shrub, muskeg	c	c	c		x
golden-crowned sparrow	tall shrub, muskeg	c	c	u		x
fox sparrow	tall shrub, muskeg	c	c	u		x

Common name	habitats used in the Kenai River corridor	spring	summer	fall	winter	nests
Lincoln's sparrow	tall shrub, muskeg, riverine, coastal wetlands	u	u	r		x
Lapland longspur	coastal wetlands	c		u		
song sparrow	tall shrub, coastal wetlands	r	r	r	r	x
snow bunting	coastal wetlands, human altered	u	u	u	u	x

Footnotes:
a = abundant (easy to see), c = common (should see),
u = uncommon (might see), r = rare (seldom seen), i = irregular (not seen every year)
x in nest column = regularly nests in the Kenai River corridor.
spring = April-May summer = June-July
fall = August-October winter = November-March

Table 7. Periodicity of Kenai River salmon (from Estes 1989)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CHINOOK SALMON												
Passage					XXXX	XXXX	XXXX	XXXX				
Spawning							XXXX	XXXX	XXX			
Incubation	XXXX	XXXX	XXXX	XXXX	XXXX		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
COHO SALMON												
Passage							XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Spawning	XXXX	XXXX	XXXX					XXXX	XXXX	XXXX	XXXX	XXXX
Incubation	XXXX	XXXX	XXXX	XXXX	XXXX			XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
PINK SALMON												
Passage							XXXX	XXXX	XXX			
Spawning								XXXX	XXXX	X		
Incubation	XXXX	XXXX	XXXX	XXXX				XXXX	XXXX	XXXX	XXXX	XXXX
Rearing			XX	XXXX								
SOCKEYE SALMON												
Passage					XXXX	XXXX	XXXX	XXXX	XX			
Spawning							XXXX	XXXX	XXXX	XXXX		
Incubation	XXXX	XXXX	XXXX	XXXX			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
CHUM SALMON												
Passage							XXXX					
Spawning							XXX	XXX				
Incubation	XXXX	XXXX	XX				XXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing			XXXX	X								
RAINBOW TROUT												
Spawning					XX	XX						
Incubation					X	XXXX	XXXX					
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
DOLLY VARDEN												
Spawning									XX	XXXX	XX	
Incubation	XXXX	XXXX	XXXX	XX						XX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
EULACHON												
Passage					XXXX	XXXX						
Spawning					XX	XXXX						
Incubation ?												
Rearing												

Based on professional judgement of ADF&G biologists.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available.

C. DESCRIPTION OF CULTURE AND ECONOMY ALONG THE LOWER KENAI RIVER

Native cultures and early history of the lower Kenai River

When you decided that Kenai River lands offer good places to build a home, hunt and fish, bring your family, spend at least part of the year, you echoed a decision about the Kenai River that human beings have been making for about 10,000 years (and a decision that, we hope, will still make sense 10,000 years from now — in the year 11992). The popularity of the Kenai River as a place to settle is reflected in the number of archaeological sites along the river: 90 reported sites between the river's mouth and Skilak Lake. These are just *reported* sites "...and in all probability do not represent the entire population of sites that exist along that stretch of the river" (Dale 1992, pers. comm.) As the Alaska Office of History and Archaeology notes: "The lower Kenai River is very rich in resources and has been heavily used for a very long time... There are: 64 prehistoric sites (which include, but are not limited to cache pit sites and living/habitation sites); 9 prehistoric/historic village and burial sites; and 17 historic sites (which include 12 historic sites/buildings in the City of Kenai). (If you want to report a site to the State Archaeologist, contact the Office of History and Archaeology[1]; see Chapter VI for agency addresses and phone numbers.)

You represent the fifth human culture to occupy Kenai River lands (the sixth, if you distinguish between early Russian and American arrivals). There is a responsibility inherent in connecting to a history that stretches thousands of years back in time: the responsibility to learn about those who came before us. The following sections introduce you to "landowners" who began patterns of Kenai River settlement that you now reshape and carry on. Figure 5 illustrates the chronological relationships among the four cultures that have occupied the Kenai Peninsula and the Kenai River corridor before you. Dena'ina Indians, survivors of the culture inhabiting the Peninsula at the time of "Western contact," still live along the Kenai River. (We would like to thank Dr. Alan Boraas for permission to use the following summary.)

A Summary of Kenai Peninsula Prehistory

Alan Boraas, Ph.D.
Anthropology Department
University of Alaska
Kenai Peninsula College, Soldotna

Introduction

In the early 1930's, a young archaeologist from Bryn Mawr College named Frederica de Laguna began an archaeological project that was to establish the basic prehistoric framework for the Kenai Peninsula, Cook Inlet Basin, and Prince William Sound areas in Alaska. In one of the first problem oriented archaeological studies done in the north, de Laguna established that a maritime culture, now called the Kachemak tradition, preceded the Dena'ina Athabaskans in Cook Inlet and the Chugach Alutiiq in Prince William Sound. Since her pioneering effort, archaeologists have contined to unearth evidence of prehistoric peoples, filling many gaps in the prehistoric record and pushing the known human occupation of this area back to about 8,000 B.C. Much remains to be learned about the prehistoric era of the Kenai Peninsula. After 60 years of research, archaeologists are only now building a record of "what" happened. The more interesting question of "why" those events happened remains to be answered.

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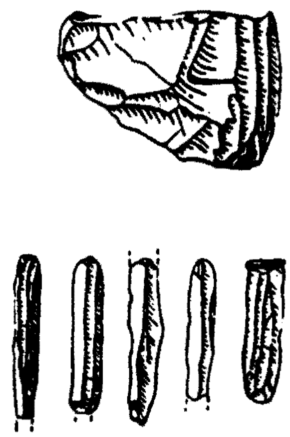
1 The state does <u>not</u> claim rights over archaeological sites on private lands; what you find on your land belongs to you. However, archaeological sites are protected under Section 106 of the National Historic Preservation Act of 1966. This law requires federal agencies to take into consideration cultural resources when granting federal licenses, permits, or funds to projects that could affect such resources.

Paleo-Arctic Tradition
(ca. 8,000 B.C. to ca. 4,000 B.C.)

The *Paleo-Arctic tradition* represents evidence of the first migrants across the Bering Land Bridge from Siberia to Alaska and Canada. Among the tools which record their legacy are distinctive stone artifacts called *microblades* which were struck from equally distinctive stone nodules called *cores*. Microblades are small, thin slivers of rock (chert chalcedony, or other cryptocrystalline rock) that are extremely sharp and may have been used in wood or hide working or inset into bone or wood and used as arrow points, lance points, or knives.



Cores and microblades

Figure 5. Preliminary cultural chronology, Kenai River drainage (from Reger 1985:269).

	KENAI RIVER PREHISTORY	CULTURAL TRADITIONS
	HISTORIC	
1750	LATE PREHISTORIC	INDIAN / ESKIMO
1000	?	
A.D. 0 B.C.	KENAI "VARIANT"	NORTH PACIFIC MARITIME CO–TRADITION ? (Kachemak/Norton Influences)
1000	?	
2000	NOTCHED POINTS	NORTHERN ARCHAIC
3000	?	
4000	?	
5000		
6000	?	
7000	CORES/MICROBLADES	AMERICAN PALEO–ARCTIC
	?	
8000		

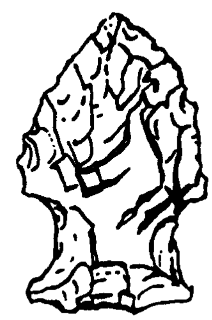
Cores and microblades occur in Siberia's Dyuktai Culture about 15,000 B.C. The Dyuktai or closely related people migrated across the Bering Land Bridge and appear in Alaska about 8,000 B.C. where the microblade makers are referred to as the Paleo-Arctic tradition. In Alaska the Paleo-Arctic tradition has several regional variations, among them are the Denali Complex found in the Mount Denali/Tangle Lakes area, and sites on the Alaska Peninsula in the Ugashik and Naknek regions.

On the Kenai Peninsula, Paleo-Arctic cores and microblades have recently been found at three sites, two in the Cooper Landing area and one at Beluga Point (now a State Parks pull-off along Turnagain Arm just east of McHugh Creek Wayside). As yet, no organic material has been found associated with these artifacts at any of the Kenai Peninsula sites, consequently they have not been dated by radiocarbon dating methods. However, because cores and microblades are found below all other artifacts, and because they are virtually identical to the Denali/Ugashik/Naknek microblades, the Kenai Peninsula sites are considered part of the Paleo-Arctic tradition and assumed, for now, to date between 8,000 B.C. and about 4,000 B.C.

The Kenai Peninsula could have been inhabited about 8,000 B.C. because, by then, the glaciers from the last stage (Wisconsin) of the Pleistocene ice age had retreated from the Kenai Peninsula lowlands. After an episode of tundra vegetation, boreal and coastal forests expanded to the lowlands and mountain valleys they occupy today. The large fauna hunted by Paleo-Arctic people in interior Alaska (mammoths, mastodons, saber-toothed cats, camels, etc.) have not been found on the Kenai Peninsula, and as yet no faunal remains have been found associated with the cores and microblades at the three sites mentioned above. The Kenai Peninsula Paleo-Arctic people may have hunted mammoths and mastodons, but probably subsisted on caribou, small mammals, and fish.

Northern Archaic Tradition
ca. 2,500 B.C. to ca. 2,000 B.C.

The *Northern Archaic tradition* is represented by distinctive arrow points with side notching — hence the name "side-notched points" — which appear in Alaska between 4,000 B.C. and 2,000 B.C. The Archaic tradition originated in the Eastern Woodlands area of what is today the United States and Canada and is called the Eastern Archaic. From there the Archaic spread west and north. The Northern Archaic may represent the spread of a technology which efficiently utilized northern boreal forest resources. In Alaska there are sites with both Paleo-Arctic tradition microblades and Northern Archaic tradition side-notched points. These sites may, therefore, represent a "mixing" of people or a "mixing" of ideas.



Side-notched point

On the Kenai Peninsula, side-notched points have recently been found at a single site along the Kenai River drainage (although they are also known from private collections). Radiocarbon dates from charcoal collected at this site indicate the side-notched points date between 2,500 B.C. and 2,000 B.C.

Since this site is situated inland, it suggests the people were utilizing land mammals and fish for subsistence and were not marine mammal hunters.

Kachemak Tradition
1000 B.C. to A.D. 1000?

The *Kachemak tradition* represents the first evidence of a maritime adaptation on the Kenai Peninsula. However, a maritime adaptation utilizing coastal resources (sea mammals, sea flora) appears much earlier (4,000 B.C.) on the Alaska Peninsula where it is called the *Ocean Bay tradition*. At present the evidence of a Kenai Peninsula Ocean Bay occupation is slight, but it is extremely likely that sites of this culture will be found in the future. It is also quite likely that the Kachemak tradition developed from the Ocean Bay tradition. In the Kodiak area the Ocean Bay tradition ends about 2,000 B.C. and is immediately suceeded by the Kachemak tradition.

On the Kenai Peninsula, the Kachemak tradition is represented by sites located in Kachemak Bay, the outer and eastern Peninsula, the Palugvik site in Prince William Sound, and at several places on the west side of Cook Inlet. [In addition, sites representing a river-oriented variant of this tradition occur along the Kenai and Kasilof Rivers, as described below.] Subsistence-wise, the key artifacts at Kachemak tradition sites are barbed and toggling harpoons. With these wickedly efficient weapons, the Kachemak people were able to harvest the nutrient-rich coastal sea mammal resources. Other artifacts include: ground slate ulus, ground slate knives and spears, scrapers, abraders, wedges, chipped stone points, notched stones, and a variety of carved ivory and bone implements. The Kachemak tradition people invested great effort in art. The inventory of Kachemak artifacts includes beads, labrets, pendants, carved animal figurines, carved human figurines, and elaborate pecked stone lamps. The artifact complex is similar to those found at later Eskimo sites, suggesting that the Kachemak people were Eskimo. However, it is difficult to demonstrate either ethnic identity or linguistic affiliation on the basis of artifacts alone...

Kachemak tradition harpoons

The *Kenai variant* or *riverine Kachemak tradition* occurs along the Kenai and Kasilof Rivers and possibly at other sites in the Upper Inlet. Artifacts at these sites represent an amalgamation of two traditions. Many riverine Kachemak tradition artifacts are similar or identical to maritime Kachemak tradition styles, while others are typical of Norton tradition artifacts prevalent in Southwestern Alaska during the same period. The co-mingling of Norton and Kachemak traditions in the riverine variant may represent a migration of people or the spread of ideas which overlapped in Cook Inlet. The riverine Kachemak tradition people differ from the maritime Kachemak people in that they were primarily riverine fishermen as opposed to maritime hunters.

The riverine Kachemak tradition's primary subsistence food was salmon which they caught with nets in shallow tributaries of the Kenai and Kasilof Rivers. From this time on, the largest population density on the Kenai Peninsula was along the major salmon spawning drainages.

Kenai Peninsula Late Prehistoric
A.D. 1000 to A.D. 1800

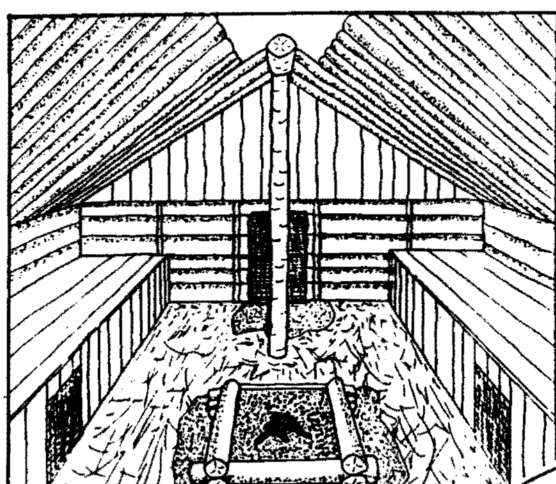
During the Late Prehistoric Period the major unanswered question is when and why the *Dena'ina (Tanaina) Indians* moved into the Cook Inlet Basin. The Dena'ina are Athabaskan speakers who have customs typical of Athabaskans of interior Alaska. Yet, as the only Athabaskans to occupy coastal Alaska, they adopted some of the technology of the Alutiiq (Eskimo) including kayaks, harpoons, and waterproof clothing. Both Captain Cook [who sailed into Cook Inlet in May 1778] and Captain Vancouver [who reached Cook Inlet in April 1794] thought the Dena'ina were the same as the Chugach (Pacific Eskimo) Alutiiq of Prince William Sound, though Russian writers (Davydov, Wrangell, Shelikov) clearly distinguished between the Dena'ina and the Chugach Alutiiq.

From oral traditions and legends, we know the Dena'ina believed the casual disposal of material items (i.e. littering) was offensive to nature and such behavior resulted in grave consequences. As a result these original non-litterers left very few artifacts behind, and only a handful have been found associated with the multi-roomed, rectangular houses they called a *nichił* (commonly called *barabaras*) even though remains of hundreds dot the landscape as silent witnesses to the presence of the prehistoric Dena'ina of Cook Inlet.

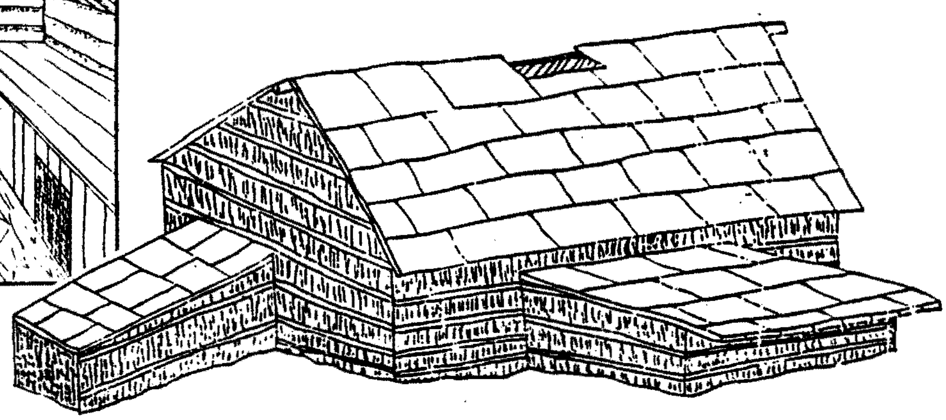
Linguistic evidence suggests the Dena'ina have occupied Cook Inlet for about a thousand years. Archaeological excavations at the Point West and Seal Beach sites at the southern extreme of Dena'ina territory in Kachemak Bay indicate the Dena'ina occupied that area by about A.D. 1100. It is likely the Dena'ina occupied the upper reaches of Cook Inlet, their ethnohistoric heartland, toward the end of the first millennium A.D.

During the Late Prehistoric period the Chugach Alutiiq, the probable descendents of the Kachemak tradition, occupied the eastern shore of the Kenai Peninsula, the outer part of Kachemak Bay, and Prince William Sound. Unfortunately, most of the sites in that area have been wiped out due to subsidence caused by seismic activity.

Late Prehistoric sites also show that copper, traded from the Copper River area and cold-hammered into artifacts, made its appearance in Cook Inlet. The practice of taking a sweat-bath, as evidenced by massive amounts of fire-cracked rock, appears to have gained in popularity at this time. Beads and iron artifacts usher in the historic period, which begins in the late-1700's and caused monumental changes in the Dena'ina and Alutiiq cultures.



Dena'ina house (nichił)



The following description by the late Alex Wilson of Kenai, grandson of Chief Stephan Mishakoff, suggests the seasonal pattern of life followed by the Dena'ina before white men arrived in the late eighteenth century (quoted by Mishler 1985:32). In addition, Table 8 lays out the seasonal cycle of Dena'ina activities.

These ancestors of mine followed the game and fishes. Starting at Chkee-took [...near the mouth of the Kenai River] during a summer, they'd catch the salmon with nets made by their wives, of sinew... When the salmon runs are over, the families stayed on at Chkee-took until the ground and lakes are frozen enough to travel. They would then follow the river (which is now the Kenai River)... to a lake which is now called Skilak Lake. There would be the headquarters for the winter. Here the salmon came up to spawn and fish were caught fresh. Moose were scarce as they were just coming into the country and were more feared than any other big game. Black and brown bear were the main meat diet, which were taken with spears and hunted with dogs as well... Beavers were also caught with spears. A hole would be cut in a beaver house, then the long wait for the animal to return. Other smaller game were taken with 'dead falls.' In the summer months, the Indians would range quite far in hunting sea animals. They traveled in bidarkas or canoes made of animal hide. They'd travel from the mouth of (now Kenai River) all the way around the Kenai Peninsula. Food was no problem as long as there was wild game. Eggs of different sea birds was a change of diet, as well as herbs, ferns, and roots of some vegetation.

THE OLD WAYS WERE PHYSICALLY HAZARDOUS AND DOMINATED BY THE QUEST FOR FOOD, BUT THEY WERE RICH IN THAT THE PEOPLE UNDERSTOOD THEIR RELATIONSHIP TO THEIR SURROUNDINGS. THEIR CONCEPT OF COMMUNITY INCLUDED LAND AND ANIMALS AS WELL AS HUMAN BEINGS.

PETER KALIFORNSKY (1991)

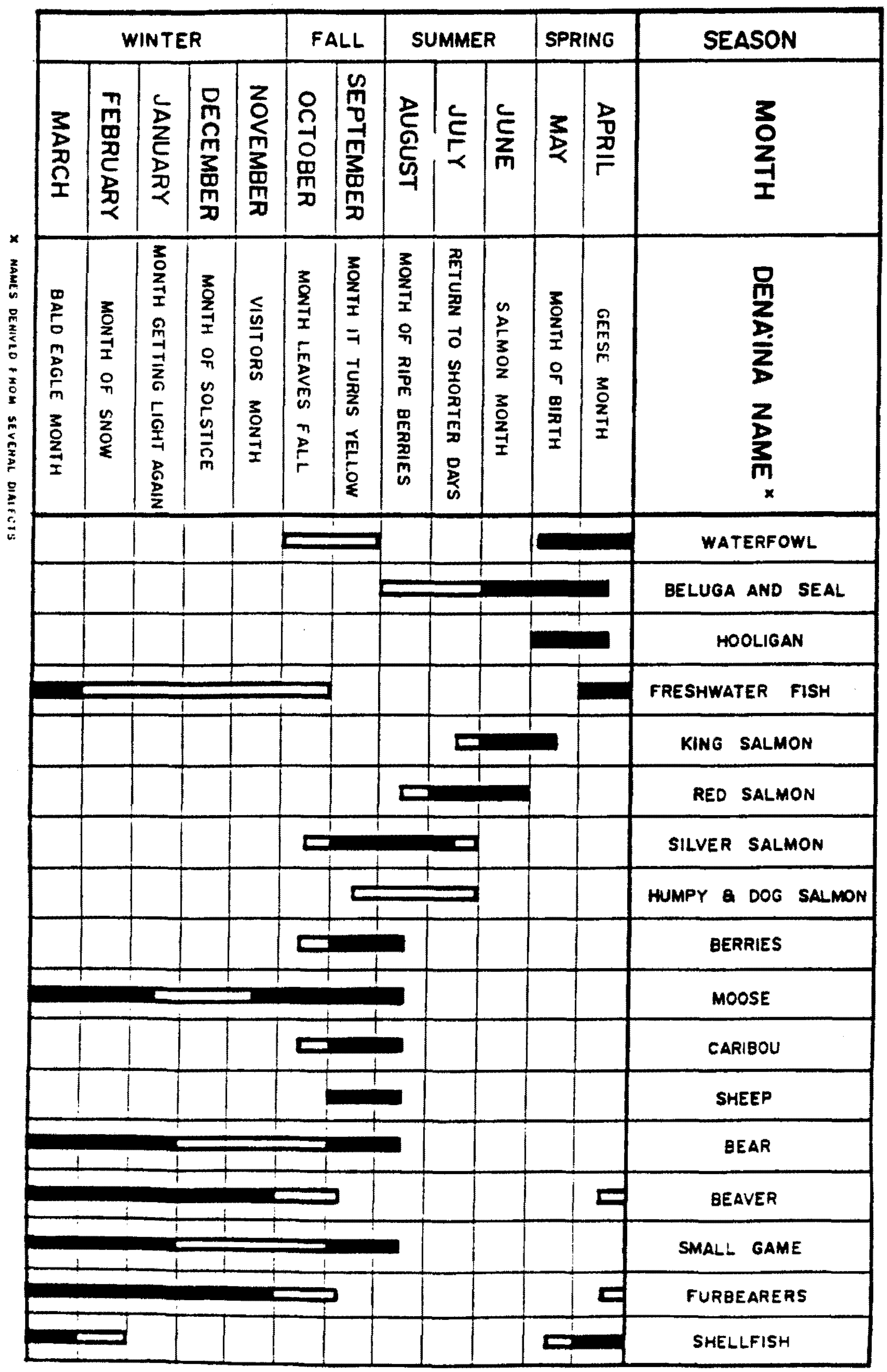
Post-contact history and disruption of Native populations

Along the Kenai River, the historic period began in the late 1700's as Russian fur hunters, traders, and missionaries started settling the Kenai Peninsula. The arrival of Europeans marked the beginning of a rapid and traumatic decline in Cook Inlet Native populations.

Between Captain Cook's trip up Cook Inlet in 1778 and Captain Vancouver's arrival 16 years later, Russian traders had established four settlements on the Peninsula (at English Bay, Kasilof, Kenai, and Tyonek). Accounts of the interactions between Russian traders and Dena'ina Indians tell a story of "systematic oppression and exploitation of the Dena'ina's. This oppression led to repeated incidents of violence and bloodshed which were not confined only to the 1790's but extended well into the middle of the 19th century" (Mishler 1985:25).

Even more disastrous to Dena'ina and other Native populations were European contagious diseases to which they had had no prior exposure. Beginning with the first known epidemic in 1798, Native villages were decimated by smallpox, tuberculosis, typhoid fever, syphilitic diseases, diptheria, measles, broncho-pneumonia, and influenza. James Fall (cited by Mishler 1985:43) estimates that smallpox, combined with starvation caused by disruption of subsistence activities, reduced Native populations around Cook Inlet by 50 percent in the late 1830's. In the early 1900's, "...records from the Kenai Mission show that among the Orthodox population (which was predominantly Dena'ina and creole) the number of deaths outstripped the number of births for the entire period between 1907 and 1916" (Mishler 1985:45). In 1918, influenza reduced Native population by perhaps another third (Borass in Kalifornsky 1991:475). As diseases emptied villages, survivors abandoned their homes and consolidated in larger communities, like Kenai and Tyonek.

Table 8. The seasonal cycle of Dena'ina activities (dark bars indicate activities pursued most intensively) (from A. Boraas).



As Native lives were disrupted by disease, their lifestyles were dismantled and reshaped by succeeding waves of social, economic, political, religious, environmental, and educational change brought by white settlers. First came the Russian fur hunters, traders, and missionaries in the late 1700's and early 1800's. In 1867, the United States purchased Alaska from the Russians, and American fur hunters and traders began arriving. In the mid- and late-1800's, miners came to the Kenai Peninsula seeking gold and other mineral resources. "Mineral exploitation was responsible for greatly increasing the white population of the Kenai Peninsula during this period in its history. However, many miners did not remain; when the gold rush ended and coal mining languished, only a handful of the immigrants stayed" (Reed 1985:15).

The commercial salmon fishing industry came to the Kenai Peninsula in the late 1800's. In 1882, a salmon cannery was built at the mouth of the Kasilof River, followed in the 1890's by canneries in Seldovia and Kenai. "By the turn of the century, hundreds of transient fishermen and cannery workers were coming to Cook Inlet during the summer" (Boraas in Kalifornsky 1991:473).

QADANALCHEN'S SONG

ANOTHER DARK NIGHT
HAS COME OVER ME.
WE MAY NEVER BE ABLE
TO RETURN HOME.
BUT DO YOUR BEST IN LIFE.
THAT IS WHAT I DO.

(FROM: KALIFORNSKY 1991)

In the early 1900's, extension of the federal homestead act to Alaska brought a new wave of settlers, although many homesteads failed and were refiled and abandoned repeatedly. After World War II, federal lands from Ninilchik to the Kenai area were opened for homesteading, and a Veteran's clause added to the Homestead Act made it easier for Veteran's to prove up on their land. This caused a rapid increase in homesteading. "While in 1939 there were only 33 families homesteading on the western Kenai Peninsula, by 1949 this figure had risen to 108 families" (Reed 1985:16). Among these were four families that homesteaded what is now Soldotna and one family that homesteaded Sterling (U.S. Army Corps of Engineers 1978). Homesteading, however, was hard, and "although much settlement activity was generated, by 1955, 59 percent of all entered homesteads had become unoccupied. Only about one-half of the 851 homesteads staked [on the Peninsula] eventually came into private ownership" (Reed 1985:17). Nonetheless, homesteading brought many white Americans to the Kenai Peninsula and led to improved overland transportation systems and increased awareness of the Peninsula's economic potential. In 1951, the Sterling Highway was completed, linking Kenai with Anchorage and Seward. That same year, the Wildwood Army Station was established northwest of Kenai, bringing to the area military personnel, their families, and construction jobs.

Then came oil. In 1957, the Swanson River oil fields were discovered. Thousands of new residents moved to the Kenai Peninsula to take jobs in the oil industry, as well as in service and retail industries begun to meet the needs of the growing population. Kenai and North Kenai became oil boom towns.

In the mid-to-late 1970's, the popularity of Kenai River sport fisheries began growing dramatically. This spurred additional growth in hunting- and fishing-related tourism and recreation, which had been promoted by establishment of the Kenai National Moose Range in 1941 (now the Kenai National Wildlife Refuge).

"By 1980, the population of the Kenai Peninsula Borough was 25,282, an increase of 280 percent from 1960. In the four years following the 1980 census, the borough-wide population grew by 54 percent, to 38,919" (Reed 1985:19). Today, over 40,000 people live in the Kenai Peninsula Borough.

Native cultural traditions and lifestyles were nearly lost in this onslaught of change, but "in the early 1970's a sense of cultural revival began among the Kenai Dena'ina largely as a result of efforts to settle Alaska Native land claims. The Kenai Dena'ina began to emerge both as a cultural and economic entity. The Kenai Native Association, the Salamatof Native Association, and later, the Kenaitze Indian Tribe were formed" (Borass in Kalifornsky 1991:479).

Current population and economy

Mark Kinney
SCS District Conservationist, Homer

Population

Population figures for the Kenai Peninsula Borough indicate a current stable population of 40,802 (KPB EDD, Inc. 1991a:8). This is a 58% increase from the 1980 census, when 25,282 permanent residents were counted. Future growth predictions range from 2% to 6% per year.

Approximately 99% of the Borough's population lives on the Kenai Peninsula. The west side of Cook Inlet is sparsely populated, except for the village of Tyonek and the Beluga area. On the central and upper peninsula (from Kachemak Bay to Turnagain Arm), there are four first class/home rule cities, including the cities of Kenai and Soldotna on the Kenai River. (The two other cities are Homer and Seward.) Kenai and Soldotna are population centers for the central peninsula (see Table 9). The Kenai Peninsula Borough also has a number of unincorporated communities and villages, including Cooper Landing and Sterling along the Kenai River.

Kenai and Soldotna are easily accessible from Anchorage, both by road and air. Highway distance between Kenai and Anchorage is about 163 miles, between Soldotna and Anchorage, 150 miles.

Table 9. Historical Borough population by city (from KPB EDD, Inc. 1991a:7).

	1960	1970	1980	1990
Kenai	778	3,533	4,324	6,327
Soldotna	332	1,202	2,320	3,482
Seward	1,891	1,587	1,873	2,699
Homer	800	1,083	2,209	3,660
Total Borough	9,053	16,586	25,282	40,802

Economy

A glance at the basic resources and industries in the Kenai Peninsula Borough, and events affecting their development, gives an indication of the current economic situation and future prospects for the region.

Oil and gas

Cook Inlet oil and gas industries continue to represent the greatest percentage of gross sales by industry, with over $318 million reported in 1990 (KPB EDD, Inc. 1991a). Three local refineries are presently operating at or near capacity, and continued exploratory drilling is currently planned. Construction of a multi-million dollar dock and expansion of the North Kenai Refinery are both scheduled, and over the next 3 years, deliveries of liquified natural gas to Japan are expected to increase 13%.

Tourism and recreational fishing

A recent study shows tourism to be a $90 million per year industry on the Peninsula, and suggests several opportunities to expand its size through aggressive marketing (KPB EDD, Inc.

1991b:14). The Kenai River is a major contributor to this figure, accounting for 34% of all sport fishing trips made to the Kenai Peninsula, and 14% of all sportfishing trips in Alaska in 1991 (Mills 1992). Total number of anglers fishing the river between Cook Inlet and Skilak Lake in 1991 was 107,628 (79,557 nonguided anglers, 28,071 guided anglers). These anglers accounted for 270,211 angler days[1] (237,475 nonguided angler days, 41,736 guided days) (Mills 1992:92-95). The Alaska Division of Parks is currently conducting a "carrying capacity" study to document the amount of human use on the Kenai River and its effects on recreational experiences.

The value of Kenai River sportfisheries is estimated at over $44 million annually. This includes angler expenses for sportfishing goods and services, such as charters, fishing gear and equipment, bait, boats, and trip-related expenses (e.g., transportation, food, lodging, etc.). These expenditures generate significant employment and related income for the local economy (Jones and Stokes 1987). In 1990, 330 fishing guides were registered on the Kenai River; in 1992, 275.

Commercial fisheries

Total ex-vessel value of all five species of salmon caught in the Cook Inlet Region in the 1990 season was $41.5 million (KPB EDD, Inc. 1991b:15). Overall, commercial salmon, groundfish, and shell fish industries remain critical to the region's economy.

Timber

Segments of both the public and private sectors are currently exploring initiatives to expand harvests and use of peninsula timber (see, for example, ADNR DOF 1992). Many of those involved in this process are motivated by an interest in harvesting white and Lutz spruce killed by spruce bark beetles. These beetles have killed trees on more than 700,000 acres of the Peninsula since 1970. Beetle-killed timber harvested in the Cooper Landing area is spurring some increase in the production of homes and furniture on the Peninsula.

Timber harvests can potentially damage water quality and fish habitats. As a result, plans to log large areas of public land will elicit much public discussion about the potential benefits of harvesting timber versus the potential costs of damaging fisheries and other public resources. For more information on proposed timber activities, contact the Alaska Division of Forestry, Soldotna Office (see Chapter VI).

Other industries

Additional industries within the Kenai Peninsula Borough include coal and mineral extraction, construction, aquaculture, wholesale and retail trade, and related services. Borough "gross sales" in 1990 totaled about $1.35 billion (KPB EDD, Inc. 1991a:24).

This is the socioeconomic environment in which the Kenai River exists. As you can imagine, the rate of future population growth, where and how settlement occurs, which kinds of industries expand, how and where expansion takes place, and other factors related to the socioeconomic evolution of the Peninsula will all have significant effects on the Kenai River watershed and the Kenai River. In Chapter III, we look at how human settlement and development have tended to impact watersheds and fisheries, as well as at some changes now taking place on the Kenai River.

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1 An angler day is any day, or part of a day, that an angler visits a site to fish.

D. DESCRIPTION OF POLITICAL, MANAGEMENT, AND REGULATORY JURISDICTIONS ALONG THE LOWER KENAI RIVER

(Who governs, manages, or permits what happens on and along the river)

When large numbers of people live in close proximity, they generally lay out some basic rules to promote "the common good." These rules usually focus on protecting public health, safety, and shared resources (like fish and wildlife). In some cases, rules are implemented through laws or ordinances that articulate non-negotiable, blanket "do's" and "don'ts." For example, "do drive on the right side of the street," "don't fish for king salmon in the Kenai River after July 31" (assuming the season hasn't closed earlier by emergency order). In other cases, however, more flexibility is needed than is offered by "do-or-don't" rules. Some actions need to be reviewed on a case-by-case basis. Permits allow this kind of flexibility and provide an alternative to non-negotiable "do's" and "don'ts."

But is there any process as stressful and frustrating to a landowner as trying to get a permit? First you have to know whether or not a permit is required for the action you're planning. Then you have to figure out which kind of permit you need, who can grant it, and where they're located. Then begins the task of learning how to apply for that permit, which may require an intimidating mass of paperwork. And once you've collected all the necessary information and submitted reams of documentation, it's time to begin what seems like an endless wait to find out when (or if) you'll get your permit.

DON'T BE SHY ABOUT ASKING REGULATORY AGENCIES FOR ASSISTANCE WITH PERMITTING: THEY'RE SUPPOSED TO HELP YOU THROUGH THE PROCESS, THAT'S THEIR JOB.

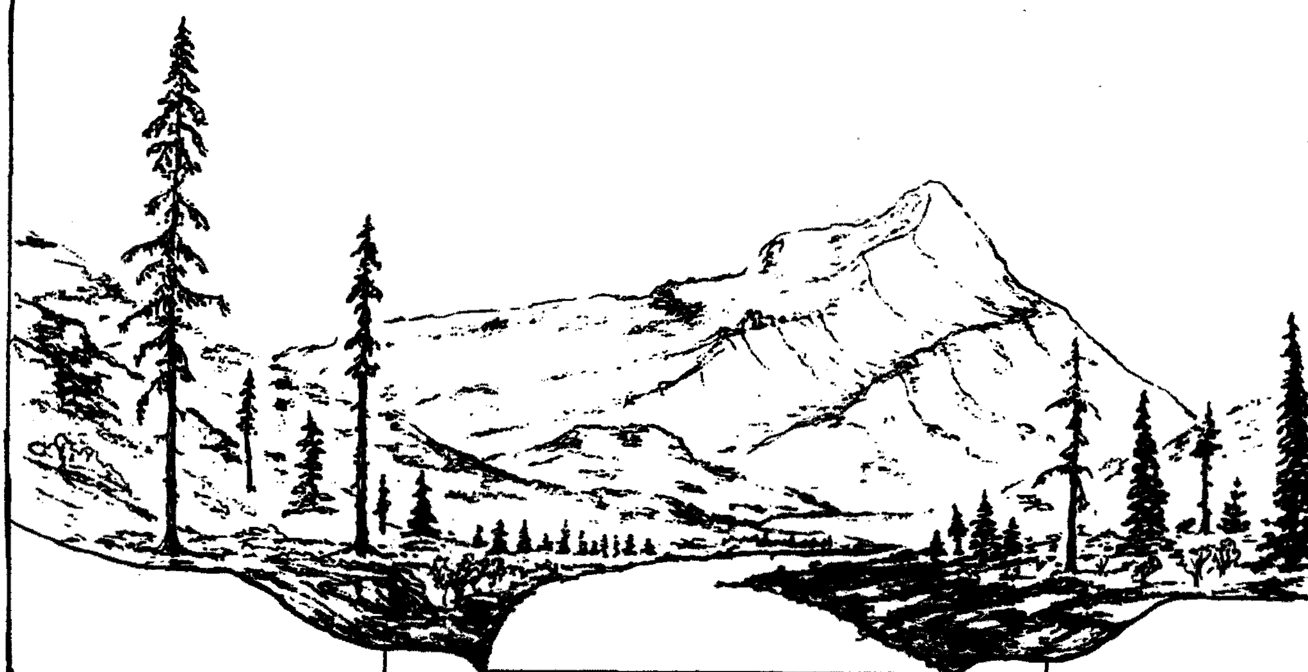
You're not alone in being frustrated with permitting: even *agencies* often get frustrated trying to get permits from other agencies! Derive what comfort you can from the fact that everyone needing a permit goes through the same cumbersome process. And try to remember that permits ultimately do a lot to protect resources you value — like salmon habitats and clean drinking water — from the tremendous cumulative pressures and impacts of humanity. This section is intended to make permitting on the Kenai River a little less intimidating and confusing than it might otherwise be.

The first step in permitting is figuring out: Do I need a permit? If the answer is "Yes," the second step is going to the right agency for help. If you find the right help, it won't matter how little you know about permitting to begin with, you'll be able to get the answers you need when you need them. DON'T be shy about asking regulatory agencies for assistance: they're supposed to help you through the process, that's their job.

In Figure 6, we illustrate who has management, regulatory, or other authority with respect to the lower Kenai River, adjacent lands, and river-related resources. This gives you some idea of the spectrum of agencies involved and the areas covered by their authorities. Some agencies advise permitting agencies, although they themselves don't grant or deny permits. A permit may be denied for a particular action if an advisory agency objects to it strongly. You'll notice that we've included landowners in this graphic because, in reality, you make most of the decisions about what happens on your land.

In the following paragraphs, we list general categories of activities for which permits are required. After each category, we identify the permitting agency you should contact about permits for that category. Addresses and phone numbers of all agencies are listed in Chapter VI.

Figure 6. Political, management, and regulatory jurisdictions along the lower Kenai River.



	on lands along the Kenai River	river-banks	in the Kenai River below "ordinary high water"	river-banks	on lands along the river
WHO GOVERNS (passes laws)*	*governing bodies*: United States, State of Alaska, Kenai Peninsula Borough, local cities (Soldotna, Kenai, etc.)	same as for lands	United States, State of Alaska, Kenai Peninsula Borough within designated zones of the regulatory flood plain.	same as for lands	see other side
WHO MANAGES (makes decisions, takes actions)*	*landowners*, including: private and Native landowners, and public land managers (Alaska Division of Parks, KPB, cities, USFWS, etc.).	same as for lands	*resource management agencies*: ADF&G, DEC, EPA, DNR (especially Division of Parks, under AS 41.21.500-514), USFWS and *resource users*: landowners, recreationists, etc. Also Kenai Peninsula Borough within designated zones of the regulatory flood plain.	same as for lands	see other side
WHO PERMITS (develops regulations, grants permits)*	*regulatory agencies*: ADF&G, DEC, EPA, DNR, Army Corps of Engineers, City of Soldotna (within "Kenai River Overlay District"); USFWS advises on federal permits; DGC coordinates agency reviews within the "Coastal Zone."	same as for lands	*regulatory agencies*: ADF&G, DEC, EPA, DNR, Army Corps of Engineers; NMFS and USFWS advise on federal permits; DGC coordinates agency reviews. Kenai Peninsula Borough within designated zones of the regulatory flood plain.	same as for lands	see other side
WHO ADVISES them all	state advisory boards, special interest groups, the general public	same as for lands	same as for lands along the river	same as for lands	see other side

* As of 1992; political boundaries, jurisdictional authorities, agency mandates, etc. may change over time.
Agency acronyms: ADF&G = Alaska Department of Fish and Game, DEC = Alaska Department of Environmental Conservation, DGC = Alaska Division of Governmental Coordination, DNR = Alaska Department of Natural Resources, EPA = U.S. Environmental Protection Agency, KPB = Kenai Peninsula Borough, NMFS = National Marine Fisheries Service, USFWS = U.S. Fish and Wildlife Service.

The Alaska Division of Parks and Outdoor Recreation, Kenai Area Office, can provide help with permits related to the Kenai River. They are located on the Kenai River near Sterling, at 35850 Morgan Landing Rd., 262-5881. There is also a Permit Information Referral Center in Anchorage.

You need permits if you want to take any of the following actions in or along the Kenai River (see Chapter VI for agency addresses and phone numbers.):[1]

a. **any actions that might affect fish habitats.** This includes actions like: changing the shape of riverbanks, riprapping riverbanks, putting structures or objects in the river (even "spruce tree revetments"), driving across river channels, changing streamflows in any way...

Contact: Alaska Department of Fish and Game, Habitat Division

b. **any actions that might affect the river below "ordinary high water."** This includes actions like building boat docks, developing ramps into the river, operating equipment in the river, constructing anything that will extend out *over* the river, etc.

Contact: Alaska Department of Fish and Game, Habitat Division

c. **any actions that might degrade water quality, either surface waters or groundwater.**

Contact: Alaska Department of Environmental Conservation, Soldotna Office

d. **dredge or fill in wetlands.**

Contact: U. S. Army Corps of Engineers, Regulatory Branch

e. **any of the following actions in the "Kenai River Overlay District" within City of Soldotna city limits[2]:**

development of land

surface or subsurface extraction of natural resources

storage of hazardous or toxic materials or fuels

filling or excavation of lands

Contact: City of Soldotna, City Manager

f. **any actions that might affect the navigability of the Kenai River.**

Contact: U. S. Army Corps of Engineers, Regulatory Branch

g. **any actions that might affect threatened or endangered plants or animals or disturb bald eagle nests.** Peregrine falcons may occasionally use the Kenai River corridor, but no other threatened or endangered animals are known to use the area.

Contact: U. S. Fish and Wildlife Service, Kenai National Wildlife Refuge

h. **develop lands within the Kenai River floodplain.**

Contact: Kenai Peninsula Borough, Planning Department

In addition, "the State of Alaska uses a multiple agency coordinated system for reviewing and processing all resource-related permits, leases and other authorizations which are required for proposed **projects in or affecting coastal areas of Alaska** [which includes the Kenai River]. This system is called "project consistency review" (DGC 1992). To get help with a "consistency review," contact the Division of Governmental Coordination (DGC) in the Alaska Office of the Governor. They will send you a Coastal Project Questionnaire. Then, if your project is a "direct federal action," requires a federal permit (like a wetlands permit), or requires permits from more than one State agency, DGC will coordinate the review.

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1 For a flow chart of the permitting process, refer to p. 119 of the *Kenai River Comprehensive Management Plan* (ADNR 1986).

2 The "Kenai River Overlay District" encompasses all lands adjacent to the Kenai River within the City of Soldotna. The Overlay District was established to: "...mitigate the impacts of human activity on the river while also providing opportunities for development and uses which will not cause significant erosion, ground or surface water contamination or significant adverse alteration of fish habitat" (City of Soldotna Zoning Code, 17.03.250). A Conditional Use Permit must be obtained from the City Planning and Zoning Commission before developing lands in the Overlay District.

III. UNDERSTANDING THE KENAI RIVER

CHAPTER CONTENTS

A.	**The nature of rivers: systems, parts, and processes**	**2**
	A basic introduction to "systems"	2
	Parts that make up the Kenai River system	5
	Processes and time in the Kenai River system	7
	Watershed processes	7
	River processes	7
	Movement of water and sediments in rivers	8
	Streamflow and sediment data for the Kenai River	14
	The shaping of river channels	21
	Where do meanders come from?	21
	What do meanders mean to Kenai River landowners?	23
	A closer look at the lower Kenai River channel	24
	Kenai River floods	27
	How all this affects riverbanks *(why riverbanks seldom stay put)*	29
	Bank erosion	30
	Bank failure	33
B.	**Human impacts on river systems**	**35**
	How people change watersheds, what impacts human activities may have	35
	How people are impacting fish habitats along the Kenai River	42

III. UNDERSTANDING THE KENAI RIVER

A. THE NATURE OF RIVERS

It's much easier to live with something if you try to understand it. That goes for rivers too. If you know a little about how rivers behave, and why, you can avoid a lot of fruitless head-butting with forces beyond your control. Rivers are so complex, however, that all we can do here is introduce some of their basic features and processes. Section A of this chapter discusses rivers as physical systems. Section B discusses the effects humans often have on rivers. The main points made in Section A can be summarized as follows:

1) Watersheds are complex, "open" systems made up of many interacting parts ("variables"), including a river, its tributaries, and lands that contribute to their flow. As a whole, watersheds are vulnerable to change. To observe particular watershed parts, how they fit together, and how they change, you need to look at them using appropriate scale(s), context(s), and time frames. Your parcel is a small subsystem of the larger watershed system.

2) The "variables" that most define a particular river are: streamflow, sediment load, water quality, and channel features (slope, streambed material, etc.). These are interconnected — change in one usually leads to change in others. It's hard to generalize about river variables because they vary in both space and time (particularly during floods). Kenai River variables have produced a generally "meandering" river. Meanders continually reshape riverbanks. Learning to live with rivers means learning to understand river variables, their interactions, and human impacts on them.

THERE WILL ALWAYS BE ONE MORE RIVER, NOT TO CROSS BUT TO FOLLOW.
— EDWARD ABBEY

A basic introduction to "systems"

Rivers are large freshwater surface streams that flow in channels. It's useful to think of rivers as "systems." A system consists of all parts and processes contained in a defined boundary. Systems can be any size from relatively large (a forest, a city) to relatively small (a tree, your body).

A useful boundary for a "river system" is its watershed divide, which is drawn by connecting the points of highest elevation surrounding the river. Figure 2 in Chapter II shows the Kenai River watershed divide. On the Kenai River side of the divide, tributary streams and overland flows ultimately enter the Kenai River and discharge into Cook Inlet; on the other side, waters flow into other river systems.

The Kenai River watershed is made up of many *parts*[1] (water, land, fish, people, etc.). These parts are affected by many *processes* (erosion, deposition, growth, decay, etc.) that change parts or move them around. Processes can be caused by the interactions of parts themselves, or by external forces like gravity, friction, earth's rotation, solar radiation, etc. Parts and processes, interacting over time, determine what's found in a river system.

The Kenai River watershed boundary is important because it outlines all areas that contribute surface flow to the Kenai River and its tributaries. *Instream flow*, the flow within the river channel, is a river's most critical component. In other ways, however, a watershed divide is an arbitrary boundary: lots of things — air masses, sunlight, human beings

1 The "parts" of a system can also be called "variables," "elements," "components," and other names. All mean something like: "the pieces that make up the whole."

and their practices, trains and trucks, volcanic ash — move or are carried across the watershed divide as if it weren't there.

Systems can be "open" or "closed" and more or less self-regulating. In partially closed systems, like your body or your house, some things enter, but many things are kept out by barriers like your skin, roof and walls, your watchdog. In wide open systems, things move in and out freely because there are few barriers at the system's boundary. Barriers around systems help keep internal conditions stable, which is why you close windows and doors to keep your house warm, or put on a raincoat to stay dry. **A watershed is an open system**; there are few barriers around it.

In addition to barriers, some systems have feedback loops and regulating mechanisms to help keep conditions inside the system stable. In your house, thermostats connected to heaters keep air temperatures relatively constant; in your body, many mechanisms help keep your temperature near 98.6 degrees F. **Watersheds *as a whole*, have few feedback loops and self-regulating mechanisms.**

THE KENAI RIVER, LIKE MANY WIDE OPEN SYSTEMS, IS VERY VULNERABLE TO CHANGE.

Internal stability is important; most systems function best within a narrow range of conditions. For example, you have a hard time functioning when your body temperature varies much from 98.6 degrees, and you experience total "system shut-down" with a high fever or hypothermia. The same is true in watershed systems: as long as variations are within "normal" limits ("normal" rainfall, temperatures, plant cover, seasonal patterns of instream flow, etc.), the system functions "normally." As conditions deviate from norms, "normal" watershed processes start breaking down. As processes change, so do many parts, both physical — like the river channel, or biological — like salmon populations. In particular, living organisms often require a certain range of conditions; exceed the normal range and they start to die.

Because the Kenai River watershed system is open and has few mechanisms for maintaining internal stability, it's very vulnerable to change. It can be altered by changing the kinds of things crossing its boundaries, rates (amount per time) at which things enter and leave, or the processes going on in the river basin. Sections of the Kenai River system are undergoing changes in kinds of elements being added, for example where urban runoff enters drainage networks feeding the river. Sections of the Kenai River are undergoing changes in rates of input, for example where growing numbers of people use stretches of riverbank. In some areas (e.g., urbanizing areas, heavily used riverbanks), processes such as overland flow, erosion, plant succession, fish growth, etc. are changing.

Systems are nested within one or more larger systems. Larger systems determine much of what enters smaller, open systems within them. In other words, the Kenai River watershed is dramatically affected by larger systems beyond its boundaries (none of which are really addressed in this *Guide*). Larger systems enclosing the watershed include:

climate, which determines temperatures, rainfall and snowfall, wind patterns, and events like floods, drought, and ice ages;

geologic and geographic systems, which determine where rivers are located on the planet and what patterns of earth movement — earthquakes, volcanoes, subsidence — affect them. Past geologic processes (for example, high runoff during melting of glaciers) may have determined channel geometries and other river features we see today.

socioeconomic systems, which affect the numbers of people moving into and out of an area, the kinds of industries (timber, mining, etc.) and infrastructure (roads, utilities, etc.) they develop, the numbers of tourists who visit, etc.;

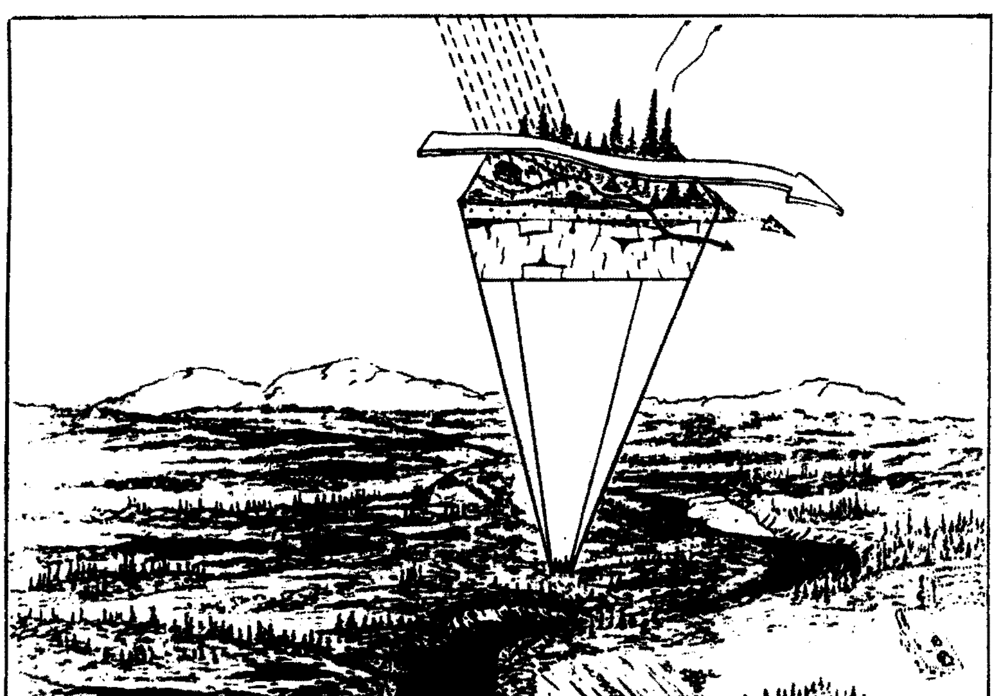
political systems, which affect what and how land uses are promoted, discouraged, regulated, etc.; and

educational systems, which determine what people learn and understand about where they live.

Just as the Kenai River watershed is contained within larger systems that influence it, it contains and influences smaller systems. Some of these *subsystems* are relatively open, some are relatively closed, some have a high degree of self-regulation, some, a low degree. The river itself can be viewed as an open subsystem nested within the watershed, as can each piece of property or stretch of riverbank (see Figure 1). The boundaries of these subsystems (defined by plat maps, landforms, inventory criteria, etc.) are crossed by the same kinds of things that cross the watershed boundaries. **Your property can be viewed as a "parcel subsystem" nested within the watershed system — what happens in the watershed will affect you, and vice versa.** On many parcels, individual buildings represent even smaller, partially closed subsystems with relatively stable internal conditions.

Because most systems nest within larger systems and contain smaller systems, there are many different system "contexts" you can use when looking at river processes and landowner concerns. The context(s) you choose determine what problems and solutions (if any) you see. Unfortunately perhaps, it's human nature to ignore most systems. We tend to focus only on those closest to us (house, family, community, etc.) and those that cause us concern (the "climate system" when bad weather approaches, the "political system" before an election). As a result, we often don't notice or understand how larger processes (flood cycles, political change, recreational trends, population growth, insect epidemics, urbanization) affect systems like the Kenai River until significant problems develop. Smaller systems, like riverbanks or spawning areas, are also easy to ignore until we affect them enough to start noticing that something's changed.

Figure 1. A "parcel subsystem" nested within the Kenai River watershed system. (Note that the parcel exchanges air, groundwater, surface water, etc. with the larger watershed.)



"Context" — the larger and smaller systems you consider — is clearly important. Awareness of larger systems helps you plan for and deal with their processes. Awareness of smaller systems helps you minimize the damage to them that your actions might cause. Sometimes a problem that's hard to understand and solve using one context can be addressed successfully from another. For this *Guide*, our context is usually a "parcel" or the "watershed," although for some things, like regulations, we use state or national contexts. But in reality, **much of what happens to the Kenai River depends on what happens in systems, large and small, not addressed in this *Guide*.**

"Scale" also affects what you see and understand about systems. Scales range from very detailed "micro-scales" (what happens to molecules in nanoseconds) to sweeping "macro-scales" (what happens to landscapes over eons). In this *Guide*, we try to focus on a "landowner-scale" that's neither too small nor too generalized. "Landowner-scale" emphasizes river system parts, processes, and time frames relevant to people living along the river. (The photo scale used during inventory mapping is an example, see Chapter VII.)

A "systems perspective" suggests how complex a river system like the Kenai is, where many parts and processes interact to create a range of conditions that are "normal" over some period of time. It should also be clear that successfully managing systems (watersheds, subdivisions, parcels, etc.) depends on using appropriate context(s), scale(s), and time frames. Using "landowner scale" and "watershed" or "parcel" contexts, we can look a little closer at the parts and processes making up the Kenai River system.

Parts that make up the Kenai River system

As we've said, systems are made up of parts. Any part can affect other parts, and in turn be affected by them, so relationships among parts are as important as the parts themselves. Because the scale you use determines which parts and relationships you see, it's hard to develop a list of parts that's useful at many scales. One way to do this, however, is to classify parts into broad categories that you can subdivide when you need more detail. All parts of the Kenai River system fall into one of six broad categories: 1) water, 2) land, 3) air, 4) living organisms 5) non-living organic matter, and 6) miscellaneous human inputs (like inorganic material manufactured for use or produced as waste). These six parts, plus sunlight, encompass all the elements that interact to create the Kenai River watershed, from its uplands and riparian lands to its riverbanks and channel.

Table 1 lists the six broad watershed parts and subdivides them into smaller categories useful for looking at subsystems like landowner parcels, the river channel, different habitats, and riverbanks. Subcategories shown in Table 1, though useful, are no more "right" than many other possibilities. Also, notice that some parts (flowing water) can turn into others (ice, ponds), and that some parts are combinations of others (soil consists of rock minerals, water, air, organisms, and organic matter). Whenever possible, Table 1 refers you to related discussions elsewhere in the *Guide*, but as you can see, not all watershed elements are covered in this reference.

Table 1 shows how many elements or variables interact in a river system and how hard it is to categorize them. When you think about all the interactions and processes that affect these variables (see next section), the complexity starts to get mind boggling. Still, the more we understand the watershed and its subsystems, the more intelligently we can live with them (hence this *Guide*). **If you want to begin an inventory of all the variables found in your "parcel system," Table 1 can serve as a checklist for gathering information from this *Guide*.**

Table 1. Parts (variables) making up the Kenai River watershed system.

	Variable	Discussed on page
1.	**WATER**	
	ATMOSPHERIC WATER	
	clouds	nd
	precipitation (rainfall, snow, sleet, etc.)	II.7
	SURFACE WATER (can be frozen and unfrozen seasonally)	
	still (non-flowing) water	
	lakes and ponds	nd
	wetlands	IV.58-60
	flowing water (can be further categorized by flow characteristics)	
	instream flow (flow in the channels of streams and rivers)	III.8-29, 31, 36
	overland flow (sheet flow, rills, gullies)	III.31
	snow and ice	nd
	SUBSURFACE WATER: groundwater and vadose water (may freeze seasonally)	III.33, IV.13
	GLACIERS (glacial water may melt seasonally)	II.6, III.24
	WATER QUALITY (good or poor	
	freshwater quality (surface and subsurface)	III.14, 19-20, 36, 41, 45
	estuarine water quality	nd
2.	**LAND**	
	SOILS (subdivided for mapping into "map units" or "polygons")	IV.7-18, VII.maps
	SUBSTRATA AND BEDROCK (geology)	II.5-6, III.24-27
	LANDFORMS (geomorphic features)	III.21-22, 24-27
	upland	III.22, IV.9-11
	floodplain	III.21-22, 26-29, 35-36
	river channel/river banks	III.21-34, IV.100-108
3.	**AIR**	
	QUALITY (good or poor)	nd
	TEMPERATURE (largely a function of solar radiation)	II.7, IV.24-25, 28-29
	MOVEMENT	
	rate (wind speed)	nd
	direction (wind direction)	IV.24-25
4.	**LIVING ORGANISMS (Their *habitats* also consist of combinations of variables)**	
	PLANTS	IV.19-60, VII.maps
	INVERTEBRATES (micro-organisms, worms, insects, etc.)	nd
	FISH	II.8-11, 19, III.12, 42-46, IV.62-65, 73-74
	BIRDS	II.8-10, 13-18, IV.20-21, 59, VII.tbl 5
	MAMMALS (other than humans)	II.8-10, 12, IV.20-21, 59, VII.tbl 5
	HUMANS	II.20-29, also see HUMAN ACTIVITIES
5.	**NON-LIVING ORGANIC MATTER (includes organic wastes)**	III.36, 41, 45
6.	**MISCELLANEOUS HUMAN INPUTS**	
	LAND USES	II.28-29, III.35-46, IV.101-102
	HUMAN ACTIVITIES	II.28-29, III.3-4, 35-46, IV.101-102
	INORGANIC WASTES	III.36, 41, 45

nd = not discussed in this *Guide*

Processes and time in the Kenai River system

What you see in a system also depends on the *time frame* you consider. Landowner time frames tend to range from a few years ("short-timer-scale") through several generations ("homesteader-scale") to periods lasting hundreds of years ("tribal scale"). It's important to acknowledge that *what* you've seen and concluded about the Kenai River depends in part on *when* and *how long* you've looked (as well as on *how*, *where*, and *why*). Sometimes it's important to look at processes that take more time or less time than the time frames we normally consider.

Watershed processes

The Kenai River watershed system exhibits the full gamut of processes from birth to death to taxes. Even if we focused only on natural processes, ignoring those caused by humans, an introduction to watershed processes would be beyond the scope of this *Guide*.

If you'd like an introduction to watershed processes (some of which are listed in Table 2) refer to a good basic ecology text (e.g., *Ecology*, Colinvaux 1986; *Ecology and Field Biology*, Smith 1980, *The Ecology of Running Water*, Hynes 1970). All we can say here is that most watershed processes are related to flows of energy and cycling of materials through the system. There is, however, one process we should look at more closely because it distinguishes river systems from all others: the flow of water in a natural channel.

YOU CAN UNDERSTAND A LOT ABOUT RIVERS IF YOU UNDERSTAND THAT THEY DO THREE MAIN THINGS:
(1) MOVE WATER,
(2) MOVE SEDIMENTS,
(3) SHAPE THEIR CHANNELS.
—
OVER TIME, STREAMFLOW, SEDIMENT, AND CHANNEL FEATURES (especially slope and material) REACH A DYNAMIC BALANCE: CHANGE ONE AND THE OTHERS CHANGE TO RESTORE BALANCE.

Table 2. A list of processes that occur in watersheds.

1. birth
2. growth
3. reproduction
4. death
5. photosynthesis
6. consumption
7. metabolism
8. development of food webs
9. competition
10. predation
11. decomposition
12. immigration and emigration
13. population increase and decrease
14. succession (plant and animal)
15. speciation
16. cycling of elements
17. cycling of water
18. cycling of nutrients
19. cycling of gases
20. soil formation
21. erosion and deposition
22. weather change
23. human settlement
24. human-caused land use change

River processes

A river exists when enough water flows in a natural channel ("channelized" rivers are exceptions). River behavior — what happens when water flows in a natural channel — is very complicated. This is partly because many variables are involved and partly because these variables change in both space and time. Tables 3, 4, and 5 give some indication of the challenge involved in understanding river behavior. Table 3 lists the main variables that *affect* river flows and channel characteristics; Table 4, on the other hand, lists many variables that *characterize* river flows and water-borne sediments (*alluvium*); while Table 5 lists variables that characterize river *channels*. The number of terms in these tables suggests how many factors interact in a river.

Despite this complexity, you can understand a lot about rivers if you understand that:

1. Rivers do three main things: they move water, they move sediments, and they shape their channels; and

2. Over time, streamflow, sediment load, and channel characteristics approach a balanced condition or "dynamic equilibrium." When balance is reached, change in one variable leads to change in others until equilibrium is restored.

The processes underlying these two simple-sounding truths are complex. All we can do here is introduce some basic concepts and then look at conditions in the Kenai River. If you need additional information, contact the U.S. Geological Survey, Water Resources Division; the Alaska Department of Natural Resources, Alaska Hydrologic Survey; the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services Section; or other sources listed in Chapter VI.

Table 3. Variables affecting river flows and channel characteristics.

1. time	9. paleohydrology (geologic discharge of water and alluvium)
2. climate (rain, snow, temperature, evaporation)	10. channel variables (see Table 5)
3. relief (landform)	11. drainage basin, river valley, and floodplain size, shape, slope, etc.
4. drainage net (pattern and density)	12. water storage in lakes, snow, glaciers, aquifers
5. flow variables (see Table 4)	13. human activities, land uses (clearing, development, water use, etc.)
6. sediment load variables (see Table 4)	
7. geology	
8. vegetation (type and density)	

Table 4. River flow variables and sediment (alluvial) variables.

River flow variables	Alluvial variables
1. amount (volume)	1. types of sediment load: dissolved load (solutes) suspended load bedload
2. velocity ("current")	2. maximum size moved ("competence," depends on velocity, discharge)
3. discharge (usually measured as cfs; abbreviated "Q")	3. total amount moved ("capacity," depends on velocity, discharge)
4. dischage per time (day, month, year) discharge per storm; (maximum, instantaneous, bankfull)	4. load moved per time (daily, annual, etc. "alluvial conveyance")
5. depth or height (stage)	5. bed material moved in the geologic past by paleohydrology
6. turbulence	
7. temperature	
8. water surface slope (lengthwise; bank-to bank across the channel)	
9. frequency and duration of specific discharges (determines "bankfull" discharge and "base flow;" also 5-year, 50-year, 100-year floods, etc.)	
10. sources (rain, snow; surface, overland, subsurface flows)	

Movement of water and sediments in rivers

Rivers move water and sediments. As one author put it: "...we have in every river not one stream but two: a stream of water... and a closely accompanying stream of rock debris" (Crickmay 1974:19).

Rock debris carried by a river is called *sediment load* or *entrained alluvium*. Some of it is carried as dissolved *solutes*, some is *suspended* in the flow, and some moves intermittently along the bottom as *bedload*, remaining settled for days, months, or years. Sediments come from many sources. Some come from outside the river, brought in by tributaries, overland flow, subsurface flow, wind, and the wasting of banks; but substantial amounts are picked up or dissolved by the river itself from its bed and banks. This process is aided by the abrasive effect of sediments already carried in the flow. (Mechanical erosion caused by moving rock and

Table 5. Channel variables.

- channel or bed slope (gradient)
- channel width
- channel depth
- channel length
- channel shape
  - cross-sectional shape
    - (width:depth ratio,
    - wetted perimeter, etc.)
  - longitudinal shape (channel profile)
  - plan-view ("bird's eye view") shape, called channel "pattern" (straight, braided, sinuous, meandering, etc.)
- channel roughness
- bed material
- bed form
- riverbank material

water is called *corrasion*. Once particles have been corraded, or ground loose, they can be carried away by the force of flowing water.)

Sediment transport in rivers is complex. "At least 30 variables are locked in the sedimentation processes, and the degree of interdependency between these variables is not fully understood" (Heede 1980:3). The total sediment a river can carry is its theoretical *capacity*. Sediment capacity depends largely on the river's *velocity* and *discharge* (see below). Capacity is also affected by turbulence and water temperature. Very turbulent flows can move and keep suspended more material than less turbulent flows. Cold water can carry more sediment than warmer water. ("As temperature decreases, viscosity increases, and carrying capacity increases" (Heede 1980:4).)

Velocity (the "current" or speed of flowing water, usually measured in feet per second) depends primarily on four things:

1. the slope of the channel — the steeper the channel, the faster the flow;
2. channel *roughness* (resistance of banks and bed to movement of flowing water) — the smoother the channel (low *roughness coefficient*), the faster the flow;
3. channel shape (width to depth ratio, "wetted perimeter," etc., Figure 2) — water moves slower in wide, shallow channels than in narrow, deep channels.
4. where in the channel velocity is measured.

In reality, streamflow velocity changes constantly, both in time and space. You can see this by watching the ever-shifting flow patterns in a stream.

Discharge or *instream flow* (volume of flow per unit time) is a function of two things:

1. the cross-sectional area of the water-filled channel (Figure 2) and
2. water velocity through this channel cross-section. If you multiply channel cross-sectional area (in square feet) times average water velocity (in feet per second), you'll have discharge in cubic feet per second (cfs or f^3/sec). Discharge is abbreviated as "Q". (Sometimes it's reported as gallons per minute, gallons per day, etc., or in metric units.)

You'll notice that the same discharge can reflect different conditions (Figure 3). For example, 3,200 cfs can represent the discharge in:

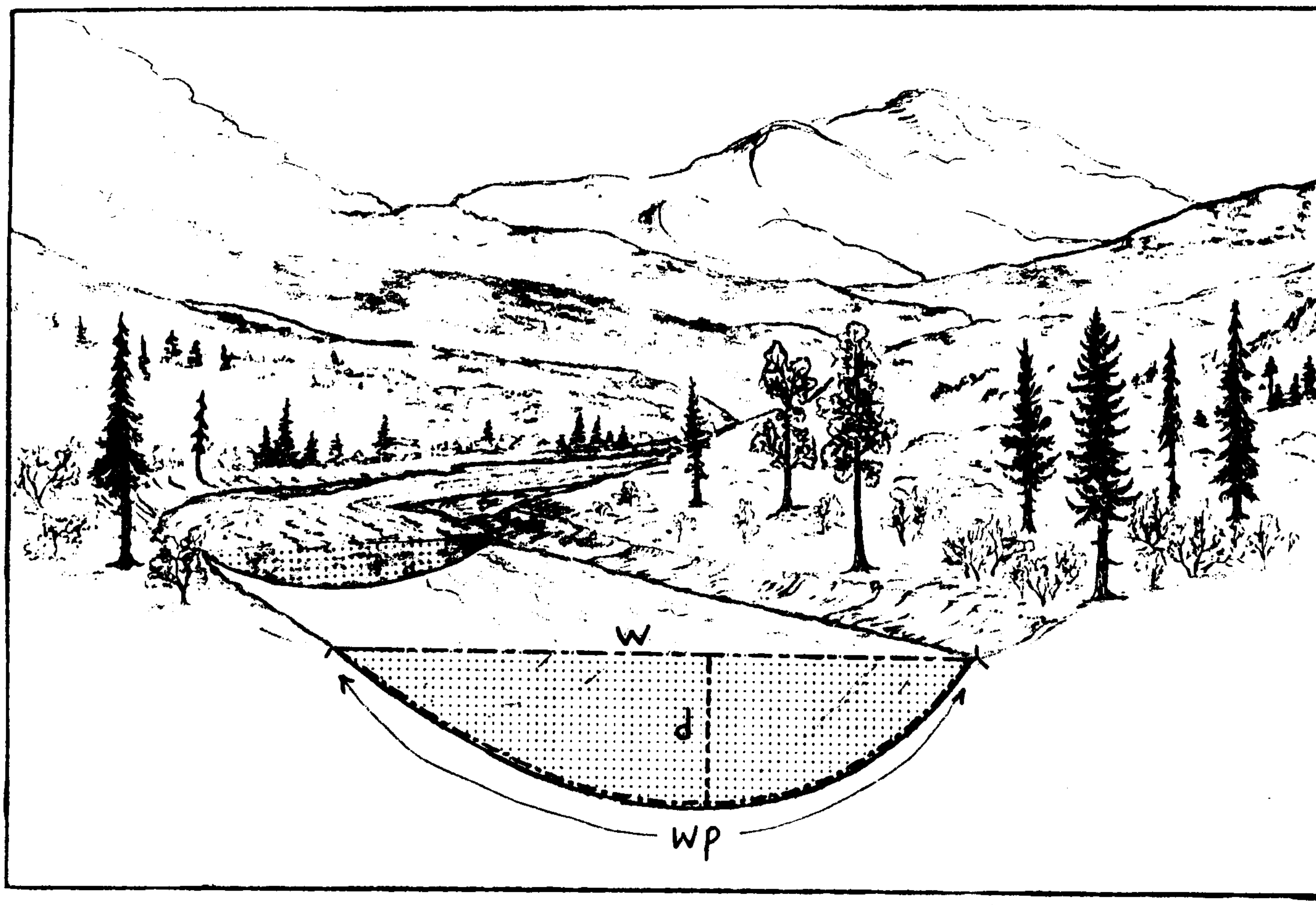
(1) a **small channel** (let's say cross section equals 400 square ft) **that carries water very fast** (8 ft per second: 400 sq ft x 8 ft per sec = 3,200 cubic ft per second), or

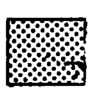
(2) a **larger channel** (let's say 1,600 square ft) **that carries water more slowly** (2 ft per second: 1,600 sq ft x 2 ft per sec = 3,200 cfs).

Although discharge is 3,200 cfs in both cases, one flow is four times faster than the other; and this **difference in velocity is critical**. For one thing, velocity affects capacity — how **much**

Figure 2. Channel cross section (shape and area), width, depth, and wetted perimeter.

(Note, water velocities differ in different locations of the channel cross section. The further away a water "particle" is from the channel wall (wetted perimeter), the less frictional drag it experiences. Generally, therefore, water "particles" move fastest near the surface of the deepest part of the stream and slowest along the channel bed and sides. Local turbulence, however, can disrupt this rule of thumb.)



 channel cross section

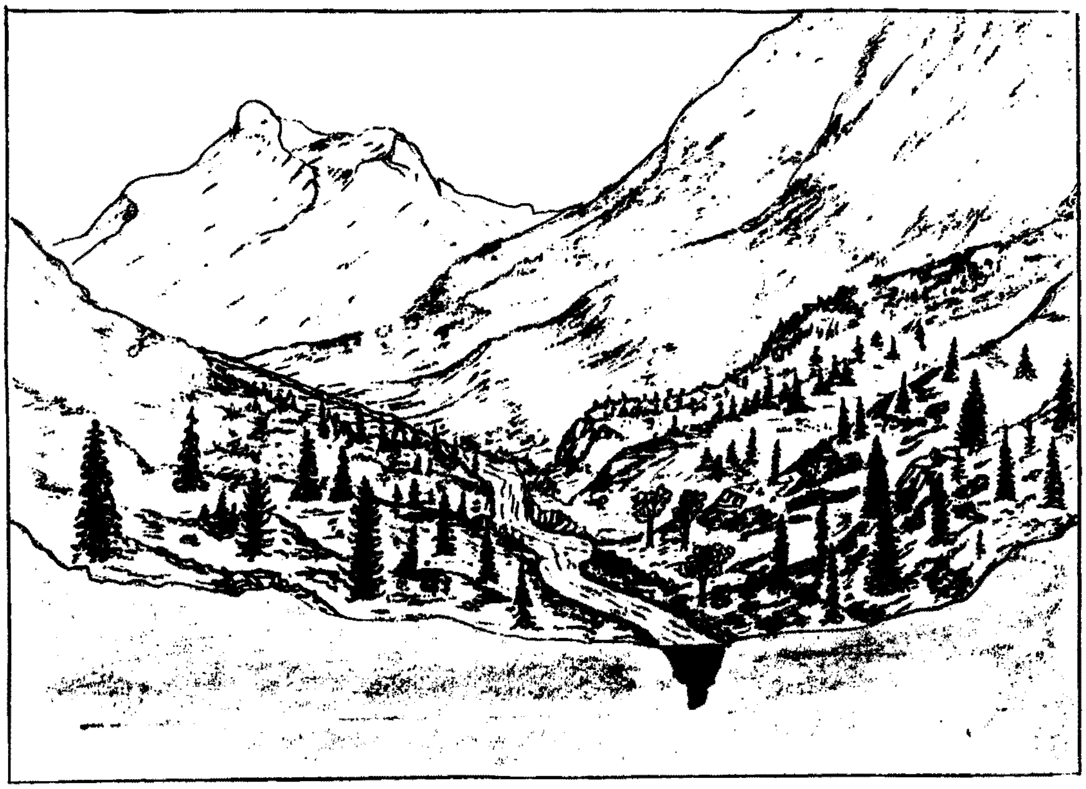
w = width

d = depth

wp = wetted perimeter (the part of the channel surface that is below water level)

Figure 3. Two very different streams can have the same discharge:

The stream on top of the page has a cross-sectional area about one-quarter that of the stream below it, but its flow is 4 times faster. Both streams have the same discharge.



material a stream carries (see above). For another thing, velocity affects how **large a** particle a stream can move (see below). Maybe even more importantly, **velocity is critical to fish**; for example, salmon fry make extended use of areas where currents are slower than 2 ft per second, but not areas where flows are faster (see The relationship between riverbanks and fish, in Chapter IV). (Water depth is also critical to fish use and migrations.)

Clearly, any changes made to channel cross-section may affect stream velocity. At a **given discharge**, decreasing channel cross-sectional area (by putting in a structure, for example) may increase flow velocity. (Decreasing channel *roughness* at the same time by putting in a smooth structure, like a concrete retaining wall, would increase velocity even more.) Conversely increasing channel cross-sectional area decreases flow velocity. (And increasing channel roughness also slows velocities.) It's these kinds of effects that make permitting agencies reluctant to allow landowners to install structures in the river channel — a structure can set in motion all kinds of changes at that cross section, which can translate into other changes upstream and down.)

IF WE COULD SLICE A RIVER CHANNEL INTO A SERIES OF CROSS SECTIONS, WE'D SEE THAT NO TWO CROSS SECTIONS LOOK EXACTLY ALIKE,

—

DIFFERENT CROSS-SECTIONAL SHAPES LEAD TO DIFFERENT CIRCULATION PATTERNS.

Capacity (amount of sediment load) isn't the only alluvial variable related to streamflow; sediment size also relates to flow. The largest piece of alluvium a river can move defines its *competence*[1]. A river's competence is largely determined by flow velocity: as water flows faster, its frictional pull, or *tractive force,* increases, so larger particles can be moved. "All the alluvium well within the competence of the current is readily swept along; that which is close to the margin of competence is moved only now and then, and only for a short distance in each move" (Crickmay 1974:44ff). Sediments are dropped whenever velocity, and with it competence, decrease.

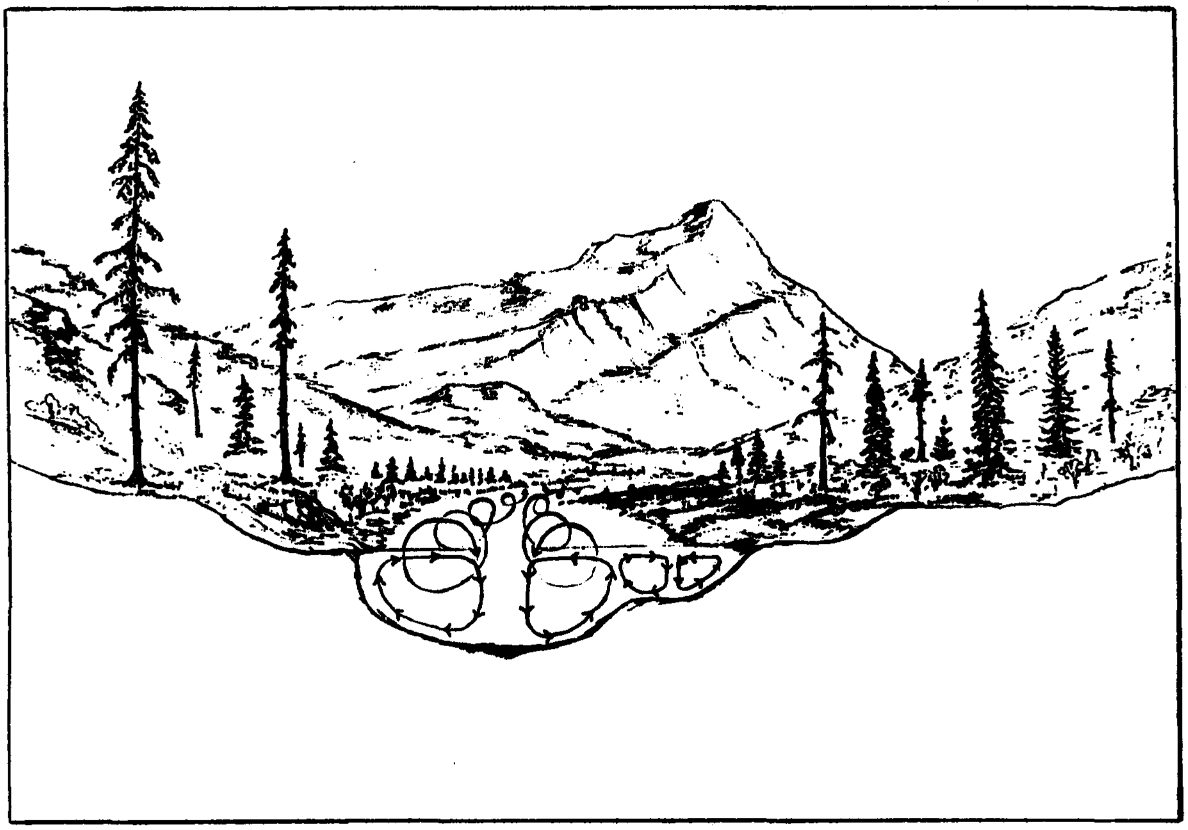
We've already mentioned that velocities differ at different points within a single channel cross section, and also at any single point from second to second. The variation at a single cross section is multiplied up and down the river. If we could slice a river channel into a series of cross sections, like slicing a log into very thin "rounds," we'd see that no two cross sections look exactly alike (Figures 3 and 4). Each channel cross section differs from others upstream and downstream, and each has its own varying patterns of discharge and velocity, turbulence and sediment load.

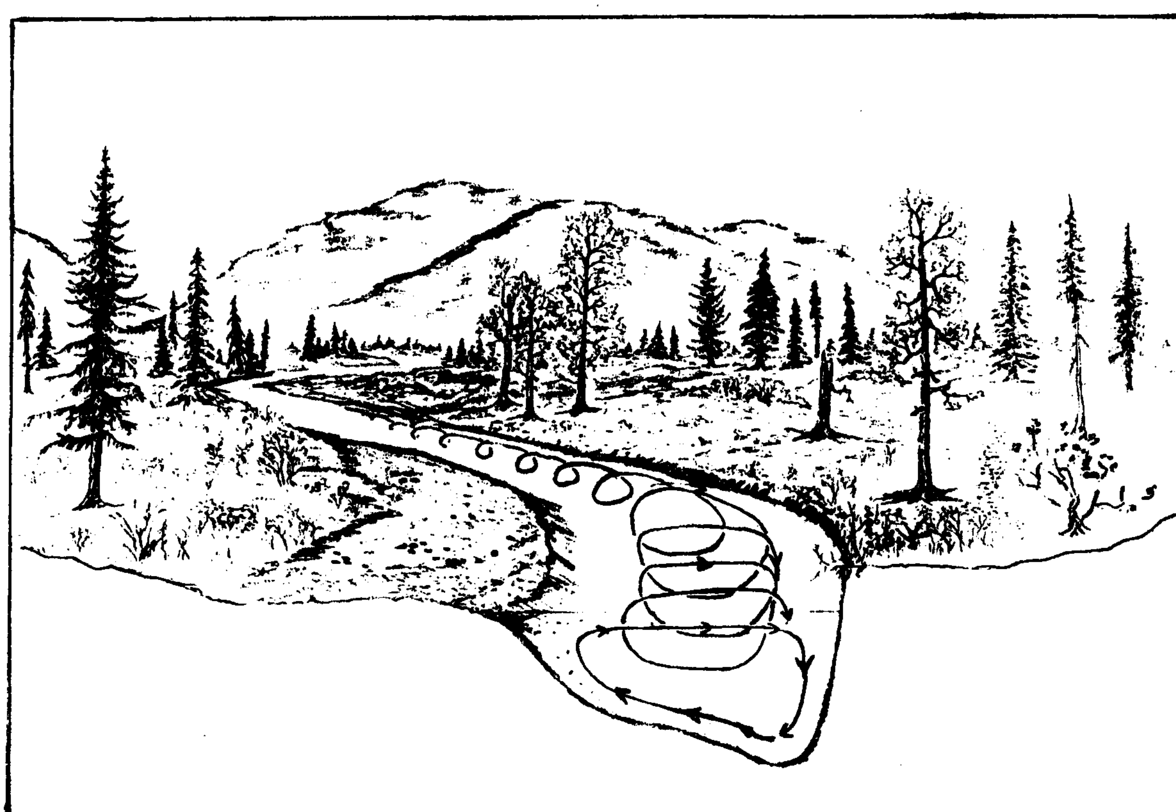
Some variations in velocity are due to water's tendency to flow downstream in a helical, or cork-screw pattern (Figure 4). This sets up *secondary circulation* currents running diagonally *across* the channel. Different cross-sectional shapes lead to different patterns of secondary circulation (Figure 4). These cross currents are critical in the formation of "point bars," "cutbanks," and other channel forms discussed later.

Variations in velocity, turbulence, secondary currents, and other flow variables throughout a river mean that sediments within the competence of existing flows are picked up (eroded) in some parts of the river channel, carried along for varying distances (transported), and dropped (deposited) in other parts of the channel. It also means that it can be misleading to use what's

1 Obviously, competence also depends on specific gravity (mass relative to an equal volume of water). Some minerals have a specific gravity much higher than the average for rock debris of about 2.6; gold has a specific gravity of 19.3, so even small particles of gold remain settled in flows that wash larger rock debris away. That's why gold panning works.

Figure 4. Secondary circulation patterns in different channel cross sections.
(Individual water particles tend to follow screwlike paths as they travel downstream; we have exaggerated this tendency towards *helical flow* to illustrate how it sets in motion secondary circulation patterns in river channels. These circulation patterns shape the channel cross section. The line running downstream through the deepest parts of a channel is called the *thalweg*.)





happening in one channel location as an indication of what's happening in another. And it makes river conditions and behavior notoriously hard to predict from day to day, season to season, or year to year. That's why it's important to involve instream flow specialists trained in river hydraulics and geometry and fisheries biology when considering actions that might modify streamflow or sediment patterns. As you'll see below, as rivers "mature," interactions of streamflow and sediments grow increasingly important in shaping river channels. Before looking at river channels, however, we'll summarize streamflow and sediment load data available for the Kenai River.

Streamflow and sediment data for the Kenai River

ALLUVIUM IS CONSTANTLY PICKED UP IN SOME PARTS OF THE RIVER CHANNEL AND DROPPED IN OTHERS.

—

RIVER BEHAVIOR IS NOTORIOUSLY HARD TO PREDICT.

On the lower Kenai River, streamflow data have been collected since 1965. Table 6 shows average monthly discharges measured by the U. S. Geological Survey at the Soldotna Bridge. Discharges are shown both as monthly averages for each year of record and, in the last row, as average discharges per month for all years combined. Figure 5 is a graph of monthly averages for all years combined and, therefore, shows an average yearly discharge hydrograph for the Kenai River. Figure 6 shows all annual discharge hydrographs from October 1965 through September 1990. (The "water year" used by the USGS runs from October 1 through September 30, but except for Figure 6, we've used calendar years because most landowners think of years that way.)

Table 7 shows how the USGS reports yearly Kenai River streamflow data in their annual publication *Water Resources Data, Alaska* (this page is from *Year 1990*). Discharge data are collected on a daily basis except when river ice prevents this, then data are estimated. (They may also be estimated on other days for various reasons.) Extreme flows for all years of record and for the particular year reported are listed at the top of the page. The total, mean, maximum, and minimum flows for each month are listed at the bottom of each month's column, along with acre-feet (AC-FT) and the cubic feet per second per square mile (CFSM) represented by the total monthly flow. *Acre-feet* is the quantity of water required to cover 1 acre to a depth of 1 foot, and is equivalent to 43,560 cubic feet of water, which is about 326,000 gallons. *Cubic feet per second per square mile* is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that runoff is distributed uniformly in time and area (USGS 1991:24).

You can see from Table 7 that the highest flow so far recorded on the Kenai River at the Soldotna Bridge was 33,700 cfs on September 9, 1977. The highest *stage*, or water level, was 22.62 ft on January 18, 1969, when an ice-dam backed up the river. Normally, Kenai River stage ranges from about 5.2 to 13.5 ft during open water (Bigelow pers. comm.). Backwater from ice can increase this significantly. The lowest flow ever recorded was 770 cfs, April 1-4, 1966.

It's obvious from Table 6 and Figures 5 and 6 that the Kenai River generally flows highest in July or August (sometimes in September) and begins to drop by October. (As you'll see in Human Impacts, high flows usually coincide with the period of maximum bank fishing, which is when banks are wettest and, therefore, most vulnerable to damage from trampling.) Lowest flows generally occur in March and April.

Sediment load in the Kenai River is not measured on a regular basis, but occasional measurements are made. Tables 8 and 9 are from *Water Resources Data, Alaska, Water Year 1980* and show sediment data collected in 1979. As you can see from these tables, sediment

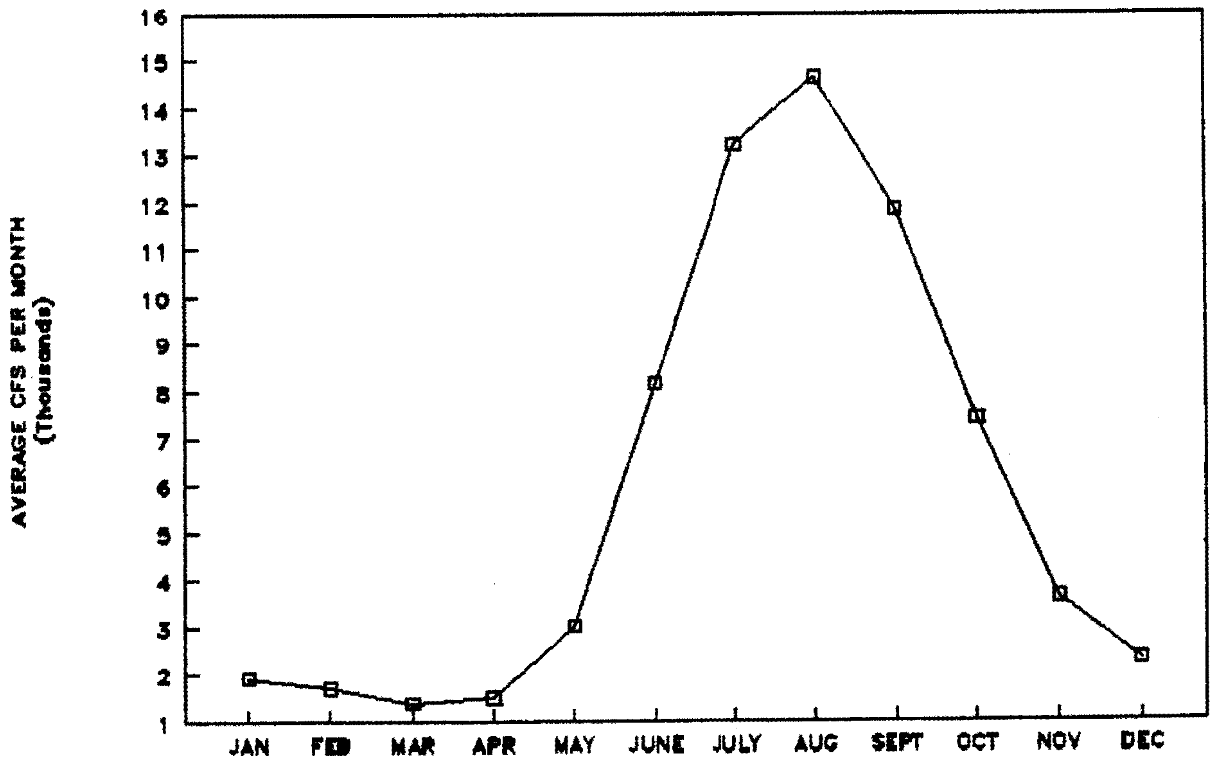
Table 6. Mean monthly discharge (Q) in cubic feet per second, year-by-year and for all years combined USGS data, Kenai River at Soldotna.

year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
'65	*	*	*	*	2630	6535	10780	11440	11540	*	*	*
'66	1200	1000	850	859	1995	6777	10920	18970	17140	6305	2133	1500
'67	1235	1100	1100	1100	2134	8524	13520	18970	20840	8538	2778	1548
'68	1674	1616	1781	1512	3361	8457	11910	13110	6273	7322	2922	2161
'69	2842	2417	1597	1486	2223	10220	13290	8706	5873	2861	1641	1413
'70	2331	1752	1763	1708	2754	7983	11620	13560	9739	14370	4507	2828
'71	1755	1250	1148	1150	1962	6760	15240	17950	13100	4110	4432	2234
'72	1245	969	848	812	2375	4940	11440	14310	11470	4807	2322	1629
'73	1197	954	842	998	1950	5458	9696	10530	7546	4536	2458	1574
'74	1068	913	869	1335	2238	6804	11140	11390	16570	3504	1631	1190
'75	1319	1146	1045	1087	3751	7351	13830	12150	8075	8590	3375	1640
'76	823	822	800	1002	2096	6850	12560	13650	13820	5579	1813	1132
'77	2989	3299	2475	1831	3497	11750	18740	24890	17380	8243	4642	5469
'78	1324	1214	1155	1387	2968	7552	12270	13460	12100	6873	3286	1730
'79	1210	851	859	1545	3182	7338	13550	19130	11930	6451	3248	1916
'80	3250	3788	2143	2836	4681	12570	17780	16820	9219	13990	7335	4840
'81	4290	4575	2696	2166	5093	11360	15920	19240	12170	10310	5444	2100
'82	2413	1957	1477	1437	2093	6581	11780	11690	15500	5683	4855	2937
'83	1672	1387	1055	1474	3128	8948	12760	11590	6038	10940	2636	1842
'84	1942	1859	1795	1882	2982	7397	12530	13450	8270	3607	2431	2141

year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
'85	1565	1567	1134	1187	2221	6482	13010	12290	8824	7839	2553	1624
'86	3414	2279	1827	1471	2902	8173	13390	13390	10670	6055	4815	4161
'87	2878	2166	1330	1680	3143	8236	13160	13660	8904	9921	4415	3531
'88	1545	1286	1302	1994	4277	11370	14930	15150	11770	7952	3974	2076
'89	1871	1554	1406	1593	3446	6547	13390	16340	18450	7559	4447	2148
'90	1861	1604	1471	2209	5645	12330	14780	16490	14030	10150	3581	2217
'91	1200	1050	961	1172	2383	7092	12520	12830	12320	5748	5953	2038
total Q	50,113	44,375	35,729	38,913	81,110	220,385	356,456	395,156	319,561	191,843	93,627	59,619
ave Q per mo for all years combined	1,927	1,706	1,374	1,496	3,004	8,162	13,202	14,635	11,836	7,379	3,601	2,293

* No data available for these months

Figure 5. Average discharge per month (in thousand cfs) for all years of record.



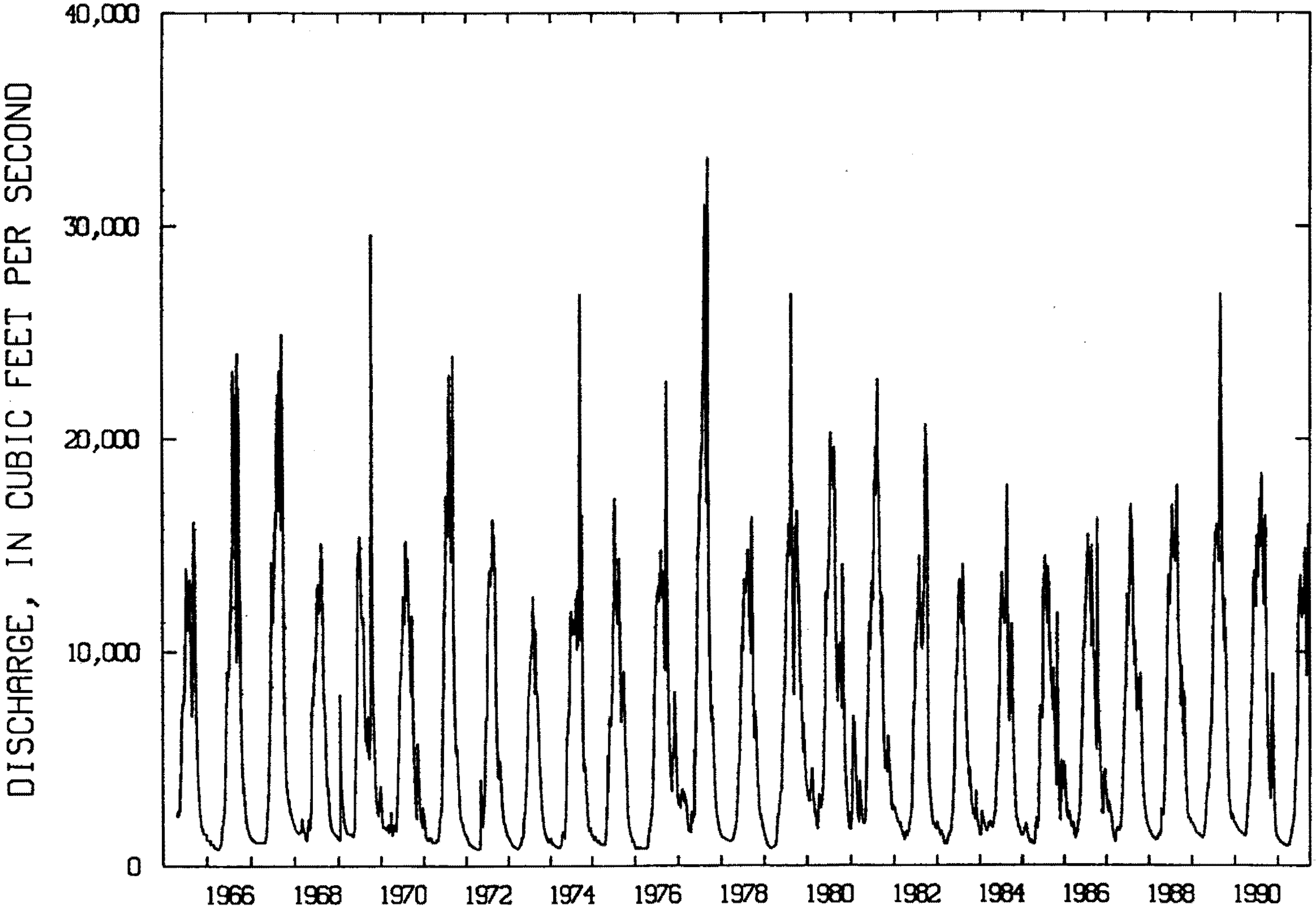


Figure 6. Annual discharge hydrographs for the Kenai River at Soldotna, October 1965 through September 1990 (from USGS).

15266300 KENAI R AT SOLDOTNA AK
MEAN DAILY DISCHARGE (CFS)

Table 7. Kenai River streamflow data measured at the Soldotna Bridge as reported in *Water Resources Data, Alaska, Water Year 1990* (USGS 1991:105).

SOUTH-CENTRAL ALASKA

15266300 KENAI RIVER AT SOLDOTNA

LOCATION.--Lat 60°28'39", long 151°04'46", Kenai Peninsula Borough, Hydrologic Unit 19050002, near center of span on downstream side of bridge on Sterling Highway, 1.0 mi southwest of Soldotna.

DRAINAGE AREA.--2,010 mi^2.

PERIOD OF RECORD.--May 1965 to current year.

GAGE.--Nonrecording gage. Datum of gage is 35.34 ft above National Geodetic Vertical Datum of 1929.

REMARKS.--Records good except for periods of no gage-height record, Dec. 24, Jan. 1 to Apr. 9, and July 29 to Aug. 1 and periods of ice effect, Nov. 13-14, 21-22, 27-29, Dec. 1, and Apr. 10-22, which are poor.

AVERAGE DISCHARGE.--25 years, 5,958 ft^3/s, 40.25 in/yr, 4,317,000 acre-ft/yr.

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 33,700 ft^3/s, Sept. 9, 1977, gage height, 13.45 ft, from graph based on gage readings; maximum gage height, 22.62 ft, Jan. 18, 1969, backwater from ice; minimum daily, 770 ft^3/s, Apr. 1-4, 1966.

EXTREMES FOR CURRENT YEAR.--Maximum discharge, 18,400 ft^3/s, Aug. 20, gage height, 10.70 ft; minimum daily, about 1,400 ft^3/s, Mar. 23 to Apr. 4.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1989 TO SEPTEMBER 1990
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	11700	6010	e2400	e2000	e1700	e1500	e1400	3520	8950	13800	e17000	14500
2	11100	5750	2330	e2000	e1700	e1500	e1400	3520	9380	14200	17200	13600
3	10700	5550	2270	e2000	e1700	e1500	e1400	3520	9820	14200	17100	13200
4	10500	5300	2270	e2000	e1600	e1500	e1400	3580	10100	14700	16800	13100
5	11000	5110	2220	e2000	e1600	e1500	e1500	3650	10600	15000	16400	13200
6	10600	4950	2250	e2000	e1600	e1500	e1500	3650	11100	15300	16300	12900
7	12200	4470	2210	e2000	e1600	e1500	e1500	3790	11800	15400	15900	12700
8	12500	4200	2130	e1900	e1600	e1500	e1600	3880	12400	15500	15600	12200
9	12400	4100	2320	e1900	e1600	e1500	e1700	3910	12800	15400	15100	12600
10	12400	4000	2250	e1900	e1600	e1500	e1700	4120	13100	15100	14900	13200
11	12100	3980	2250	e1900	e1600	e1500	e1800	4440	13300	14800	15000	12900
12	11500	3430	2410	e1900	e1600	e1500	e1900	4660	13100	14700	15300	13200
13	11000	e3400	2380	e1900	e1600	e1500	e2000	4820	13300	14600	15500	13200
14	10600	e3200	2360	e1900	e1600	e1500	e2000	4900	13700	14500	16100	13400
15	10000	3220	2340	e1900	e1600	e1500	e2000	5000	13800	14200	17000	14600
16	10900	3130	2290	e1900	e1600	e1500	e2200	5190	13400	13900	17400	14900
17	11000	3040	2320	e1900	e1600	e1500	e2200	5550	13600	13500	17900	15200
18	11100	2960	2320	e1800	e1600	e1500	e2400	6030	13300	13500	18100	15900
19	11000	2880	2270	e1800	e1600	e1500	e2400	6410	13300	13600	18100	15700
20	10800	2860	2250	e1800	e1600	e1500	e2400	6630	13100	13900	18400	15900
21	10400	e2800	2210	e1800	e1600	e1500	e2600	6870	12900	14500	18300	16400
22	9680	e2800	2200	e1800	e1600	e1500	e2800	7150	12800	14600	17800	16200
23	9530	2760	2180	e1800	e1600	e1400	2860	7250	12600	14700	17200	16300
24	9140	2700	e2200	e1800	e1600	e1400	2920	7380	12800	14700	16600	16000
25	8680	2640	2110	e1800	e1600	e1400	2900	7440	12400	15000	16000	15400
26	7910	2580	e2000	e1800	e1600	e1400	2940	7570	12200	15100	15600	14700
27	7410	e2400	e2000	e1700	e1500	e1400	3000	7670	12200	15400	16200	13600
28	7130	e2400	e2000	e1700	e1500	e1400	3100	7800	12100	15500	15900	13000
29	6880	e2400	e2000	e1700	---	e1400	3300	8100	12700	e16000	15900	12000
30	6600	2400	e2000	e1700	---	e1400	3450	8430	13200	e16000	15500	11200
31	6240	---	e2000	e1700	---	e1400	---	8570	---	e17000	15100	---
TOTAL	314700	107420	68740	57700	44900	45600	66270	175000	369850	458300	511200	420900
MEAN	10150	3581	2217	1861	1604	1471	2209	5645	12330	14780	16490	14030
MAX	12500	6010	2410	2000	1700	1500	3450	8570	13800	17000	18400	16400
MIN	6240	2400	2000	1700	1500	1400	1400	3520	8950	13500	14900	11200
AC-FT	624200	213100	136300	114400	89060	90450	131400	347100	733600	909000	1014000	834900
CFSM	5.05	1.78	1.10	.93	.80	.73	1.10	2.81	6.13	7.36	8.20	6.98
IN.	5.82	1.99	1.27	1.07	.83	.84	1.23	3.24	6.84	8.48	9.46	7.79

CAL YR 1989 TOTAL 2461860 MEAN 6745 MAX 26800 MIN 1300 AC-FT 4883000 CFSM 3.36 IN. 45.56
WTR YR 1990 TOTAL 2640580 MEAN 7234 MAX 18400 MIN 1400 AC-FT 5238000 CFSM 3.60 IN. 48.87

e Estimated

concentrations ranged from a high of 52 milligrams per liter (mg/L) on October 2 to a low of 1 mg/L on September 7, 9, and October 23. Sediment *loads* ranged from 2,120 tons of sediment per day on October 2 to 23 tons per day on September 9. The highest sediment concentration so far recorded on the Kenai River was 151 mg/L on July 14, 1971; the highest load was 9,290 tons per day on September 9, 1977. **Clearly, in the Kenai River, streamflow and sediment load are subject to tremendous fluctuations.**

Table 8. Water quality data (sediment and temperature) for the Kenai River at Soldotna (from USGS 1981).

SOUTH-CENTRAL ALASKA

15266300 KENAI RIVER AT SOLDOTNA--Continued

WATER-QUALITY RECORDS

PERIOD OF RECORD.--Water years 1952-53, 1955-58, 1966-71, 1977, and 1979-80.

PERIOD OF DAILY RECORD.--
SUSPENDED-SEDIMENT DISCHARGE: August to December 1979 (discontinued).

REMARKS.--Once-daily samples were collected by observer.

EXTREMES FOR PERIOD OF DAILY RECORD.--
SEDIMENT CONCENTRATIONS: Maximum daily mean, 52 mg/L Oct. 2, 1979; minimum daily mean, 1 mg/L Sept. 7, 9, and Oct. 23, 1979.
SEDIMENT LOADS: Maximum daily, 2,120 tons (1,920 tonnes) Oct. 2, 1970; minimum daily, 23 tons (21 tonnes) Sept. 9, 1979.

EXTREMES OUTSIDE PERIOD OF DAILY RECORD:
SEDIMENT CONCENTRATIONS: Maximum observed, 151 mg/L July 14, 1971; minimum observed, 1 mg/L Mar. 24, 1971.
SEDIMENT LOADS: Maximum daily observed, 9,290 tons (8,430 tonnes) Sept. 9, 1977; minimum daily observed, 3.1 tons (2.8 tonnes) Mar. 24, 1971.

WATER QUALITY DATA, WATER YEAR OCTOBER 1979 TO SEPTEMBER 1980

DATE	TIME	STREAM WIDTH (FT)	SAMPLE LOC-ATION, CROSS SECTION (FT FM L BANK)	PER-CENT OF TOTAL DEPTH	STREAM-FLOW, INSTAN-TANEOUS (CFS)	TEMPER-ATURE, WATER (DEG C)	SEDI-MENT, SUS-PENDED (MG/L)	SEDI-MENT DIS-CHARGE, SUS-PENDED (T/DAY)
NOV								
14...	1400	--	--	--	8010	3.0	10	216
14...	1530	--	--	--	8010	3.0	10	216
MAR								
13...	1645	--	--	--	2290	.0	10	62
MAY								
09...	1500	--	--	--	3280	--	16	142
JUN								
12...	0900	--	--	--	12500	--	48	1620
JUL								
29...	1330	263	117	20	18400	11.8	33	1640
29...	1331	--	117	80	--	11.8	--	--
29...	1332	--	149	20	--	11.8	--	--
29...	1333	--	149	80	--	11.8	--	--
29...	1334	--	181	20	--	11.8	--	--
29...	1335	--	181	80	--	11.8	--	--
29...	1336	--	218	20	--	11.8	--	--
29...	1337	--	218	80	--	11.8	--	--
29...	1338	--	270	20	--	11.8	--	--
29...	1339	--	270	80	--	11.8	--	--
SEP								
30...	0800	--	--	--	7660	7.5	15	310

Table 9. Sediment data for the Kenai River at Soldotna (from USGS 1981).

SEDIMENT DISCHARGE, SUSPENDED (TONS/DAY), AUGUST TO DECEMBER 1979

DAY	AUGUST MEAN DISCHARGE (CFS)	AUGUST MEAN CONCEN-TRATION (MG/L)	AUGUST SEDIMENT DISCHARGE (TONS/DAY)	SEPTEMBER MEAN DISCHARGE (CFS)	SEPTEMBER MEAN CONCEN-TRATION (MG/L)	SEPTEMBER SEDIMENT DISCHARGE (TONS/DAY)
1	15800	---	---	12900	8	279
2	15200	---	---	12200	8	264
3	15100	---	---	11500	7	217
4	14900	---	---	10900	5	147
5	14700	---	---	10300	5	139
6	14600	---	---	9700	4	105
7	14500	---	---	9140	1	25
8	14800	---	---	8700	2	47
9	14800	---	---	8350	1	23
10	16000	---	---	8140	4	88
11	18800	---	---	8020	2	43
12	20800	---	---	7960	4	86
13	22300	---	---	8140	8	176
14	23000	---	---	8500	13	298
15	24700	---	---	9900	28	748
16	25000	---	---	10900	18	530
17	26500	---	---	11700	12	379
18	26800	---	---	12300	10	332
19	26500	---	---	13000	11	386
20	25700	---	---	13700	9	333
21	24100	---	---	14500	12	470
22	22900	---	---	14800	14	559
23	21600	21	1220	15600	20	842
24	20400	17	936	15900	16	687
25	19200	12	622	15900	12	515
26	18000	10	486	15900	14	601
27	17000	10	459	15500	11	460
28	16100	10	435	15300	12	496
29	15100	12	489	14700	9	357
30	14400	14	544	13900	7	263
31	13600	8	294	---	---	---
TOTAL	592900	---		357950	---	9895

DAY	OCTOBER MEAN DISCHARGE (CFS)	OCTOBER MEAN CONCEN-TRATION (MG/L)	OCTOBER SEDIMENT DISCHARGE (TONS/DAY)	NOVEMBER MEAN DISCHARGE (CFS)	NOVEMBER MEAN CONCEN-TRATION (MG/L)	NOVEMBER SEDIMENT DISCHARGE (TONS/DAY)	DECEMBER MEAN DISCHARGE (CFS)	DECEMBER MEAN CONCEN-TRATION (MG/L)	DECEMBER SEDIMENT DISCHARGE (TONS/DAY)
1	14100	12	457	9700	9	236	6550	12	212
2	15100	52	2120	9580	9	233	6640	10	179
3	15600	41	1730	8980	6	145	6550	10	177
4	15600	19	800	8580	6	139	6550	18	318
5	16600	33	1480	8020	9	195	6460	5	87
6	16600	18	807	7750	4	84	6100	---	---
7	16100	20	869	7960	9	193	5890	---	---
8	15600	9	379	8050	9	196	5800	---	---
9	15800	9	384	7900	14	299	5560	---	---
10	15600	6	253	7900	10	213	5350	---	---
11	15600	6	253	8350	14	316	5350	---	---
12	16200	14	612	8440	10	228	5000	---	---
13	15600	4	168	8350	10	225	5000	---	---
14	14900	5	201	7900	10	213	5000	---	---
15	14700	4	159	7450	10	201	4500	---	---
16	14100	4	152	7600	10	205	4500	---	---
17	14300	9	347	7150	10	193	4500	---	---
18	13700	4	148	6880	6	111	4500	---	---
19	13200	3	107	6760	10	183	4500	---	---
20	12700	2	69	6550	11	195	4000	---	---
21	12300	4	133	6640	4	72	4000	---	---
22	12200	2	66	6580	9	160	4000	---	---
23	12400	1	33	6580	7	124	4000	---	---
24	12900	3	104	5950	5	80	4000	---	---
25	13100	8	283	5620	10	152	3750	---	---
26	12900	11	383	5560	18	270	3750	---	---
27	12500	7	236	5260	14	199	3750	---	---
28	11900	11	353	5350	15	217	3750	---	---
29	11100	6	180	6100	13	214	3750	---	---
30	10500	11	312	6550	15	265	3500	---	---
31	10100	9	245	---	---	---	3500	---	---
TOTAL	433600	---	13823	220040	---	5756	150050	---	

The shaping of river channels

Over time, streamflow interacts with sediment load and valley characteristics (landform, geology, vegetation, etc., see Table 3, earlier) to create river channels, floodplains, and other landforms, or *geomorphic features*, many of which are illustrated in Figure 8. The processes that shape river channels are particularly important to landowners.

River channels can be described as "single-thread" channels (straight, sinuous, or meandering) or "multi-thread" channels (braided, anastomosing, anabranching). A single river can have different channel patterns at different locations, and the pattern at any location can change as water levels rise and fall.

The Kenai River exhibits several channel patterns along its length: meandering, sinuous, and anabranching. (Some short stretches might also be called "straight.") Since relatively little of the Kenai channel is "anabranching," and since the difference between "sinuous" and "meandering" channels is just a matter of degree (a "sinuous" channel has fewer curves per channel length than a meandering channel), we can generally describe the Kenai River as having an "irregular meandering" channel[1].

Because much of the Kenai River meanders, we'll look at how meanders form and what they mean to landowners.

Where do meanders come from?

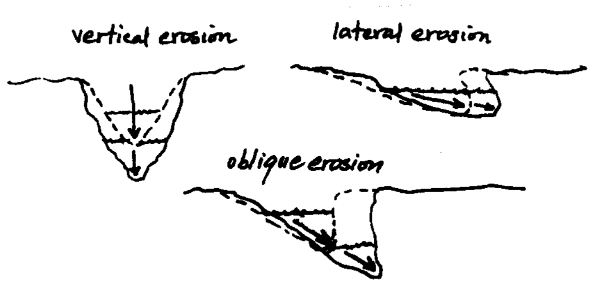
Imagine the river channel as the conduit in which flowing water and shifting sediments sculpt their interactions. Close to the river's headwaters, and in other sections where the river is steep and relatively "young" in geological terms, channels show comparatively little reworking by water and sediments — instead channel shape, slope, and material mostly reflect the geology of surrounding material. But over time, two changes take place:

(1) The river erodes *downwards* in its channel toward some "base level" (a lake, sea, reservoir, or river) that represents the lowest level the channel (or channel section) can theoretically reach. As downcutting begins, river erosion trends vertically downward, except where forced sideways by faults, resistant rocks, or other geological controls (Figure 7). The rapidly downcutting river is said to be *degrading* its channel. Rapidly downcutting rivers generally cut downwards (vertically) too fast to cut very far sideways (laterally), so they tend not to develop large meanders.

(2) Over time, as rivers degrade their channels, channel slope is reduced. (That is, the difference decreases between the elevation of the river channel and that of base level.) With lower channel slope, two things start to happen:

a. The rate of downcutting slows. As downcutting slows, the erosive effects of flowing water and entrained sediments can act longer against channel sides as opposed to channel bottom. Sideways (lateral) erosion gets started wherever these effects are concentrated by existing bends, or where the bank is less resistant to erosion because of geologic material, lack of vegetation, etc. As the river cuts laterally in addition to vertically, it begins eroding *obliquely* downward (Figure 7). Both lateral and oblique erosion encourage meandering.

Figure 7. Vertical, oblique, and lateral erosion.



1 As you'll see later, for much of its length, the lower Kenai River displays a meander geometry created by channel-forming discharges much higher than those of today.

Figue 8. Examples of geomorphic features (landforms) along the Kenai River (definitions from AGI 1976 and SCS 1992b).

C = cutbank: The concave wall of a meandering stream that is maintained as a steep or even overhanging cliff by by the impinging of water at its base.

F = flood plain: The nearly level alluvial plain that borders a stream and is subject to inundation under flood-stage conditions. It is usually a constructional landform built of sediment deposited during overflow and lateral migration of the streams.

M = meander: One of a series of regular freely developing sinuous curves, bends, loops, turns, or windings in the course of a stream.

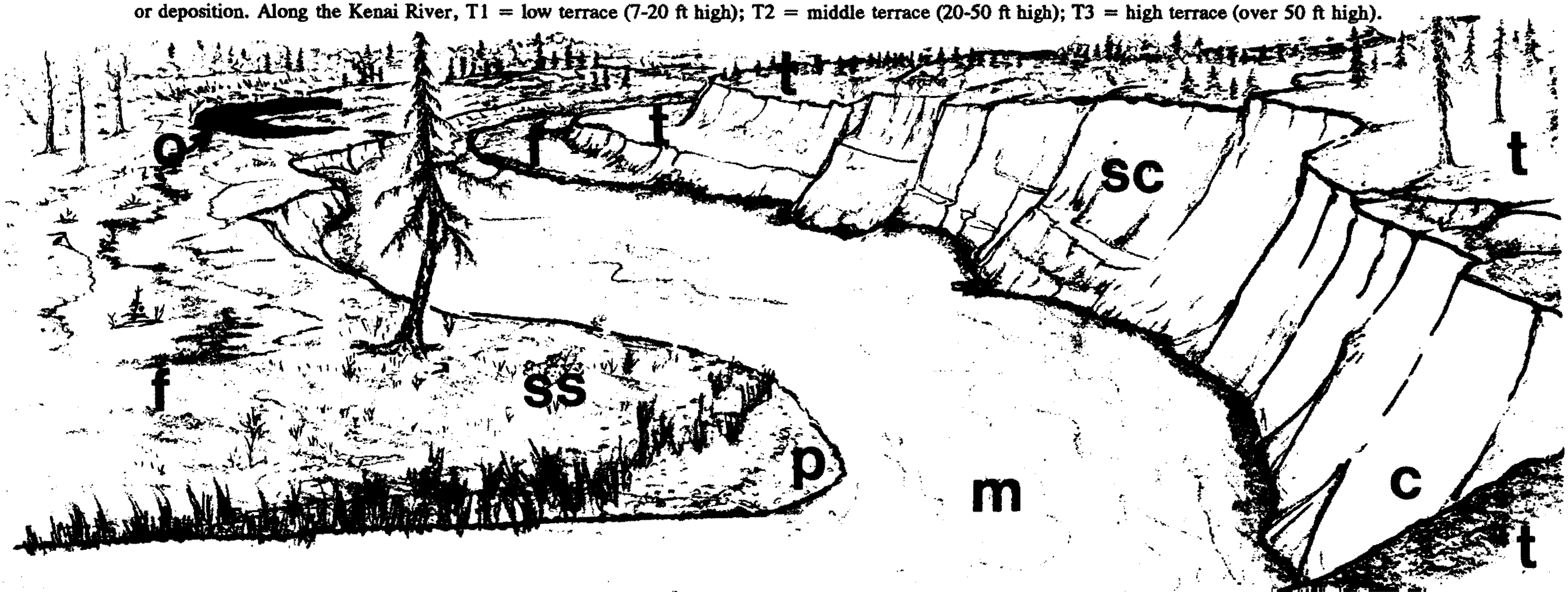
O = oxbow lake: The crescent-shaped, often ephemeral body of standing water situated by the side of a stream in the abandoned channel (oxbow) of a meander after the stream formed a neck cutoff and the ends of the original bend were silted up.

P = point bar: One of a series of low, arcuate ridges of sand and gravel developed on the inside of a growing meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.

SS = slip-off slope: A streamward sloping erosion surface developed along the inner bends of rivers. The surface is the result of the interaction of lateral and downward erosion by the river. (See Figure 7.)

Sc = scarp: An escarpment, cliff, or steep slope of some extent along the margin of a plateau, mesa, terrace, or bench. A scarp may be of any height.

T = stream terrace: One of a series of platforms in a stream valley, flanking and more or less parallel to the stream channel, originally formed near the level of the stream, and representing the dissected remnants of an abandoned flood plain, stream bed, or valley floor produced during a former state of erosion or deposition. Along the Kenai River, T1 = low terrace (7-20 ft high); T2 = middle terrace (20-50 ft high); T3 = high terrace (over 50 ft high).



b. Flow velocity, and therefore stream competence and capacity, begin to decrease. As a result, the stream starts dropping some of its sediments — larger (heavier) sediments first. Where sediments accumulate, the channel begins to build up, or *aggrade*.

This process of aggrading and degrading goes on up and down the river until some stretches reach a point where channel slope and shape, streamflow characteristics, and sediment load are more or less in balance or "dynamic equilbrium." In this condition, as long as each of the balanced variables stays relatively stable, so will the others; but change one variable, and the others also change. "Most of the Kenai River and its tributaries are streams with channels in unconsolidated sediment and most are in dynamic equilibirum" (U.S. Army Corps of Engineers 1978:78ff).

MOST OF THE KENAI RIVER AND ITS TRIBUTARIES ARE... IN DYNAMIC EQUILIBIRUM. — ARMY CORPS OF ENGINEERS (1978)

When this equilibrium is reached along much of a river's length, the river is said to be *graded*. One definition[1] of a graded stream is: "A stream in which, over a period of years, the slope is delicately adjusted to provide, with available discharge and with prevailing channel characteristics, just the velocity required for transportation of the sediment load supplied from the drainage basin" (SCSA 1982:69). As a river approaches grade, more and more of its erosive energy is directed laterally rather than downward; increased meandering is the result.

1 A more precise definition, showing just how delicate and complex is the balance that creates a graded stream, is provided by Crickmay (1974:107): "...graded flow is the simple, balanced condition in the polyphase motion of water and alluvium when the flowing liquid enters into a full reaction with a channel composed of *stream-selected* fragmental solid matter... A graded flow is: a segment of a natural stream running with even and imperceptibly declining gradient in a bed of its own flow-brought alluvium having a full range of grain sizes compatible with the existing flow factors, throughout which the maximum alluvial sizes on the one hand, and the bed slopes on the other have become so adjusted to maximum discharges, seasonal discharge variations, and the effective viscosity of the water, that the mean water level is subject during an indefinitely long period to no more than infinitesimal cumulative variation."

What do meanders mean to Kenai River landowners?

It's risky to generalize about rivers because, as we've seen, they are complex and ever-changing. Still, as long as we're aware of the dangers inherent in generalizing about river behavior, a few "rules-of-thumb" about meanders can be useful to landowners.

1. As explained above, erosion tends to be strongest where flows are deep, fast, turbulent, and cold; these effects are amplified by patterns of secondary circulation. In erosive locations, sand and silt are picked up first, then clays and large particles as flows grow more erosive.[2] **In general, on meandering rivers, erosion is strongest on the outside bank of meander bends**; this is where streamflows tend to be deepest, fastest, and most turbulent, and secondary circulation patterns carry particles from the outside bend toward the inside bend (Figure 4). In addition, particularly at sharp riverbends, streamflow is directed <u>at</u> the riverbank rather than <u>parallel</u> to it, which means more erosive energy is directed at the bank.

2 Among settled alluvium smaller than fine silt, the finer the grain, the greater the velocity needed to start it moving. Whereas settled sand is moved by comparatively low velocities, moving settled clay takes velocities comparable to those that move large cobblestones. This is because clay, although tiny, is very cohesive, and high cohesion, like large size, makes a particle hard to move. This is one reason that fine sediments can "plug" gravels and make them unsuitable for spawning; it takes uncommonly high discharges to flush out these very fine sediments.

2. In calmer areas, alluvium settles out, large particles first, followed by successively smaller particles in the downstream direction as flows grow slower and less turbulent. **On meandering rivers, deposition tends to occur on the inside banks of meander bends**; this is where flows are generally slowest and most shallow, and secondary currents bring in particles that settle out.

3. With some exceptions (discussed below) **erosion and deposition *tend* to be more or less balanced on straight stretches of river between meander bends** (these areas are called *crossovers* or *inflection points*).

THESE GENERALIZATIONS POINT OUT A COMMON SENSE GUIDELINE: DON'T BUILD CLOSE TO AN OUTSIDE MEANDER BEND.

4. As a result of these patterns, **outside meander bends tend to develop "cutbanks" that constantly retreat backwards (and also tend to move slowly down the river valley); inside bends tend to develop "point bars" and "slip-off slopes" that grow outwards into the channel** as sediments accumulate; and **straight reaches tend to stay relatively stationary** — at least in "landowner" time frames. (See Figure 8.)

These generalizations suggest a common sense guideline: don't build close to an outside meander bend (unless the river flows through very resistant rocks, which the Kenai River doesn't). The question for Kenai River landowners on outside meander bends isn't: can I *stop* riverbank erosion? but: how fast is the bank eroding and can I (or should I) *slow* it down?

A closer look at the lower Kenai River channel

The relationships we've just outlined hold true for most rivers in dynamic equilibrium — and given current flow regimes and sediment inputs, the Kenai River is in dynamic equilibrium (discharge and sediment loads fluctuate within relatively determinate seasonal ranges; channel slope and shape remain relatively constant). But the Kenai River is also *underfit*, and in some stretches *entrenched*, and that creates some variations on the patterns we've described. In addition, the Kenai River is subject to several kinds of flooding (although floods are often moderated by the reservoir-like effects of Skilak and Kenai Lakes, which also help maintain winter base flows). The following discussion of the lower Kenai River is based primarily on Scott (1982).

An *underfit* river flows in a river valley (channel plus floodplain) that was shaped by a larger river in the past. The valley landforms (geomorphic features) reflect the actions of this larger river, which carried more water, at least seasonally. A river becomes underfit when some long-term change greatly reduces its flow. For example, streamflow may decline because rainfall decreases, glaciers shrink, plant communities change, temperatures rise, etc. (see variables affecting flows and channel characteristics in Table 3).

The forerunner of the present Kenai River began as a large braided (multi-thread) river fed by meltwater pouring from retreating glaciers. The glaciers that fed this river advanced from the Kenai Mountains out onto the Kenai Lowlands many times over tens of thousands of years, most recently during the "Naptowne" glaciation, dated from about 11,550 B.C. to 3,850 B.C. Moraines left behind by that advance are found downstream as far as river mile 38.9, (creating the Moosehorn or Naptowne rapids). A moraine left by glacial retreat also impounds Skilak Lake.

As glaciers shrank, sediment loads and flow volumes began to decline. Slowly the braided river evolved into a large single-thread meandering flow. This "paleo-Kenai River" had much higher discharges than the current river, possibly as much as ten times higher (Reckendorf and Saele 1991:9). As a result, the "paleochannel" created by river erosion, transportation, and deposition was shaped out of much larger-sized material than would be true today. In addition, the many flow and sediment variables interacting in the paleo-Kenai River produced a particular *meander geometry* (frequency and "sharpness" of meander bends, etc.).

As flows continued decreasing over time, and flow fluctuations were stabilized by the reservoir-like effects of Skilak Lake, large alluvial material began settling out and collecting on the river's bed, while smaller sediments were carried away. As a result, stretches of lower Kenai River channel, particularly between river miles 17.6 and 39.4, became covered with a lining, or *armoring*, of large rocks. Within the City of Soldotna, the median diameter of these rocks, measured by Reckendorf in 1991, ranged from about 5 to 10 inches (making them "cobble" in size).

Smaller material (gravels and smaller sediments within the competence of present-day flows) often overlie the paleochannel bed. These smaller sediments are regularly redistributed by high flows like bankfull discharge and floods. But the paleochannel cobbles are very stable. Reckendorf concluded that even the 100-year flood[3] (currently calculated to have a discharge at Soldotna of approximately 38,400 cfs) probably would not move paleochannel material in significant amounts (1991:9). In other words, stretches of the present-day Kenai River flow in a channel lined with rocks too big for the river to move under normal circumstances.

THE FORERUNNER OF THE PRESENT KENAI RIVER BEGAN AS A LARGE BRAIDED (MULTI-THREAD) RIVER FED BY MELTWATER POURING FROM RETREATING GLACIERS.

Armoring of the paleochannel prevents down-cutting or bed scour given present-day discharges and existing channel gradients. In one way, this helps stabilize the channel: "The streambed acts as a foundation for its banks" (Keown 1983:35), so anything that stabilizes this foundation also stabilizes riverbanks and maintains the existing channel. But armoring theoretically also promotes lateral, rather than vertical, erosion. (Look again at Figure 7; where does erosive energy get directed if vertical downcutting is prevented?) Since present-day "normal" discharges can't erode downwards into the armored bed, erosive energy is directed laterally, especially towards the outside of Kenai River meander bends. If vegetation or some other mechanism doesn't reduce this erosive energy, it can cut into riverbanks, particularly since most Kenai River banks consist largely of unconsolidated material that's relatively easy to erode (Reckendorf 1989, Reckendorf and Saele 1991).

In addition, the immobility of large bed material makes armored sections of the Kenai River particularly susceptible to "plugging" by finer sediments. If rocks lining the channel aren't shifted at least every year or so, the fine sediments that collect between them are never exposed to streamflow erosion, and therefore never get flushed out. As we'll see later in this chapter, this can seriously impair salmon spawning and incubation.

Another consequence of being underfit and armored is that channels may not have typical cross sections. Figure 4, earlier, illustrates two schematic cross sections from a "typical" river (if there is such a thing). As you can see, in a straight stretch, shown in the top drawing, the deepest part of the channel, or *thalweg*, is located in the middle. This tends to create a symmetrical channel cross section. On a meander bend, shown in the bottom drawing, the thalweg tends to be against the outside bank, creating an asymmetrical cross section. This xpattern of thalweg location is typical in meandering rivers. Also, the thalweg is

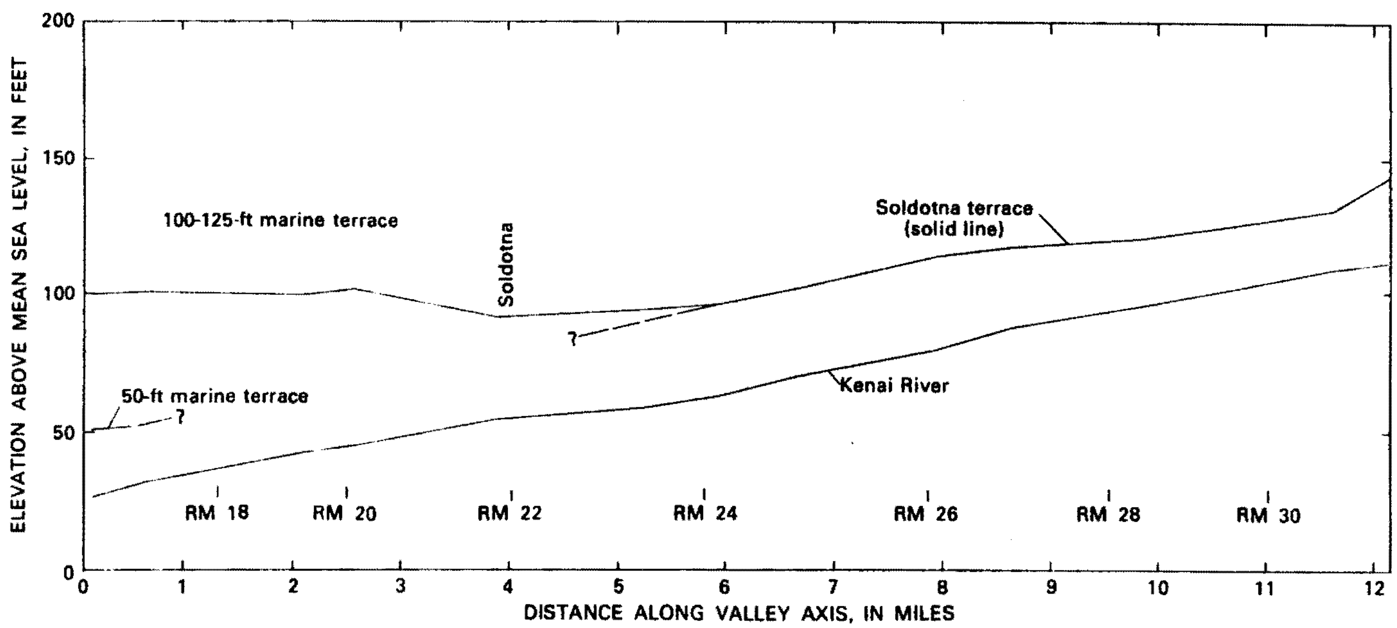
3 The 100-year flood is the peak discharge that has a 1% chance of being equaled or exceeded in any single year, or a 100% chance of being equaled or exceeded in 100 years.

typically *deeper* at meander bends than in adjacent crossover areas.

In an underfit and armored river, flows may be unable to move bed material around to maintain typical patterns of thalweg location and depth. The thalweg may end up next to an inside bend, or exhibit no difference in depth between an outside bend and adjacent crossovers (examples of such abnormal patterns exist in the Kenai River). Since erosion is most severe where fast, deep, turbulent water contacts the channel bank and bed, and this is usually adjacent to the thalweg, if the thalweg isn't where you'd expect it to be, erosion won't be either. This means that our generalizations about meanders and erosion, while generally true, may be modified along the Kenai River by unusual thalweg patterns. The only way to know what's happening at a particular cross section is to survey it.

Parts of the lower Kenai River are also *entrenched* (or eroded below the valley surface in which the channel formed) (Figure 8). Most of the entrenched section cuts through the "Soldotna Terrace," an old mix of floodplain and slip-off slopes formed by the "paleo-Kenai River" towards the end of the Naptowne glaciation. The Soldotna Terrace is about a mile wide, stretches from river mile 13 to 31, and ranges from 30 to 70 ft above the present-day bankfull channel. During riverbank mapping, Reckendorf (1989, 1991) distinguished three terrace surfaces along the Kenai River within the City of Soldotna: terrace 1 (7 to 20 ft high), terrace 2 (20 to 50 ft high), and terrace 3 (over 50 ft high), (see Chapter IV, Section D). Upstream of the Soldotna Terrace, meanders are entrenched in more recent deposits. Below river mile 13, the Soldotna Terrace grades into coastal terraces. Despite the presence of coastal terraces, the Kenai River below river mile 13 is not confined by terrace walls and meanders across a wide floodplain. Its floodplain, however, is still bounded by steep terrace walls.

Figure 9. Location of entrenched sections of the Kenai River (from Scott 1982:9).



Profiles of the Soldotna terrace and the Kenai River (water surface at intermediate flow level) measured along the valley axis. River miles are shown inset. Altitudes were derived photogrammetrically, and absolute values are only accurate within the approximate range of ±10 ft. Relative differences between altitudes of terrace and river at a point are believed accurate to within ±2 ft.

Downcutting into the Soldotna Terrace was probably initiated by terrace uplift. (Uplift steepens channel slope and, therefore, increases river downcutting.) The terrace could have been uplifted by either *isostatic rebound* (upward rebounding of land as the weight of glaciers is removed) or *tectonic uplift* (uplift caused by earthquakes and other movements of the earth's crust) or both. Entrenchment upstream of the Soldotna Terrace is probably due to a lowering of base level.

River entrenchment has two main consequences for Kenai River landowners, one good and one potentially bad. The good consequence is that entrenched sections have only narrow floodplains, meaning there's less flood-prone area available for human settlement and development. Development in floodplains can lead to very high costs in both property damage and loss of life.

ENTRENCHED SECTIONS OF THE KENAI RIVER CAN HAVE VERY HIGH, STEEP BANKS THAT ARE EASY TO DESTABILIZE.

The bad news is that entrenched sections of the Kenai River can have very high, steep riverbanks. These high banks represent terrace *scarps*. (Scarps are cliff or slope faces of terraces, plateaus, or other tablelands; see Figure 8.) Many of these high banks are only "conditionally stable" at best (see Maximizing riverbank stability, Chapter IV), at least where well-vegetated. But their height and their composition of largely unconsolidated material mean they're easy to destabilize. Once disturbed, high entrenched banks can be hard to restabilize, particularly on outside meander bends. Only where high cut banks are fronted by more recent low floodplain deposits, which protect the "toe" of the high, steep slope, is restabilization relatively manageable. Entrenchment also makes river access difficult, and most attempts at creating access down high banks (unless by properly designed stairs) tend to increase bank erosion, failure, or both. Bank erosion and failure are discussed further in How all this affects riverbanks, below.

Kenai River Floods

We've seen how hard it is to generalize about rivers. What makes it even harder is that "normal" patterns can by swept away overnight by a major flood, and there's no real predicting when this might happen. The "100-year flood" statistically happens only once every hundred years, but there's a 1% chance it will happen this year, or next (or it might happen both this year and next). Flood "water surface profiles" and "recurrence intervals" are based on available streamflow data, and the Soldotna gaging station was installed only 27 years ago.

Floods can tear up river channels and put them back together in very different shapes. As water levels rise, discharge, velocity, and turbulence increase[1]. The rising river starts picking up more material and larger material. The thalweg often shortens its course and cuts across point bars and meander necks. "What was bottom begins to be swept away..." (Crickmay 1974:29). Old channels are abandoned and new channels form.

Meanwhile, as the bed and banks are reshaped by powerful, turbulent flows, lands beside the river often undergo renewal. Where flood flows overtop riverbanks, they leave the confinement of the channel and spread out horizontally. As they do, water depth and velocity decrease abruptly, overbank flows lose competence, and large quantities of alluvium are dropped beside the river channel. Large material settles out first, then finer sediments as flows taper off. This process builds horizontal floodplains on the

1 Practically every rule of thumb about rivers has exceptions, here's another one: increasing water levels increase flow velocities and turbulence unless rising water levels also increase the channel cross-sectional area and/or channel roughness by, for example, covering a vegetated gravel bar that at lower flows was an island.

valley floor wherever the river overtops its banks.

The Kenai River is subject to four kinds of flooding:

1. The most common floods are caused by **high storm runoff and/or rapid melting of winter snowpack.** On the Kenai River, snowpack (and glaciers) begin melting in May, and meltwater flows continue to increase throughout the summer (see Table 6 and Figure 5). These flows raise water levels in both Kenai and Skilak Lakes (lake levels drop during winter), and rising flows then discharge into the Kenai River. (The reservoir-like effects of Kenai and Skilak Lakes help keep Kenai River streamflows relatively stable.) From late summer until freezeup in November or December, rainfall runoff also adds to streamflow. Storm runoff rates are generally highest in early fall. The combination of storm runoff and meltwater can cause serious flooding. The highest stormwater flood at Soldotna occurred in the fall of 1969: peak discharge, measured at Soldotna, was 30,000 cfs on October 15, 1969. The 100-year and 500-year flood boundaries delineated by agencies like the U.S. Army Corps of Engineers represent water surface levels caused by this type of flooding.

2. The highest peak discharge ever measured at Soldotna was partially caused by a second kind of flooding: the **sudden release of a glacially dammed lake.** In early September 1977, a glacier-ice dam impounding a lake in the Snow River drainage basin was breeched or broken and the lake poured into the Snow River, which feeds Kenai Lake. The breakout flood in the Snow River peaked September 5 at the head of Kenai Lake at 16,700 cfs. The maximum daily discharge at the outlet of Kenai Lake in Cooper Landing occurred on September 6, reaching 14,900 cfs; over the next several days, streamflow at Cooper Landing gradually decreased. On September 9, discharge measured at the Soldotna Bridge peaked at 33,700 cfs (88% of the calculated 100-year flood flow of 38,400 cfs) and reached a stage (height) of 13.45 feet. The difference in flow between Cooper Landing and Soldotna reflected heavy tributary inflow below Cooper Landing caused by locally heavy precipitation on September 7 and 8.[2]

The glacier-dammed lake above Snow River has caused periodic flooding since 1911, and is one of two such lakes affecting the Kenai River. The other one occurs in the headwaters of the Skilak River and empties into Skilak Lake (see the watershed map in Chapter II). If these lakes burst out in the summer during seasonal high snowmelt flows, or in early fall during high storm runoff, elevated flood discharges can occur. If they break out during winter (as did the Skilak River lake in January 1969), they can fracture Kenai River ice, which in turn can jam and cause ice-jam flooding (see #4 below). Without monitoring of the ice dams that impound these lakes, outburst flooding is unpredictable.

3. A similar kind of flooding occurs during **outbursts of water impounded *beneath* glaciers.** Scott (1982:5) points out that floods entirely from subglacial outbursts have not been recorded on the Kenai River, but that such floods could have gone unnoticed if they'd occurred in uninhabited areas like the Skilak or Killey River drainage basins before streamflow measurements began at Soldotna in 1965.

4. **Ice-jam flooding** also affects the Kenai River. During breakup, or whenever large blocks of ice float downriver, ice chunks can jam up at sharp meander bends, backing up

2 This flood did not produce the highest flows ever recorded at the mouth of Kenai Lake. In September 1974, a similar glacier-ice dam in the Snow River drainage burst. Peak flow at the head of Kenai Lake reached 26,400 cfs on September 20. Because of Kenai Lake's large storage capacity, peak flows from Snow River are usually much reduced by the time they reach the lake's outlet. However, peak volumes from this outburst were augmented by high water from other Kenai Lake tributaries, resulting in a peak discharge at the lake's outlet of 23,100 cfs on September 21 (Lamke, pers. comm.).

streamflow. Jams on the Kenai River are most common near Big Eddy, where the river turns sharply at about river mile 14.3; but they can also occur elsewhere. Just upstream of Big Eddy, in the interior-meander floodplain on which the Big Eddy State Recreation Site is located, ice scars have been found 20 ft up on the trunks of spruce trees. These scars were probably caused during the flood of January 1969, mentioned above. During that flood, ice blocks jammed up at Big Eddy and backed up water to a depth of 22.62 feet on January 18, measured at the Soldotna Bridge gage. (This is over 9 ft higher than the stage reached during the flood of September 9, 1977.) Ice jams at this site increase the possibility of both meander neck cutoffs and chute cutoffs, either of which would radically change channel slope, streamflow velocity, and other Kenai River variables at this site, and indirectly, in areas upstream and down.

The processes outlined above show that rivers are anything but. Rivers are at their most unpredictable and unstable during floods, but equally significant are the more subtle riverbank changes going on all the time. These remain largely unnoticed until some critical balance is disturbed and something dramatic happens, "*...a strip of land as wide as a house caves in at a time.*"

If this *Guide* leaves you with a single impression about riverbanks, it should probably be that **riverbanks never stop changing** (though change may be fast or slow). Riverbank change is a natural effect of river dynamics, and its inevitability means that riverside landowners can spare themselves a lot of anguish by learning how best to live *with* this change. To do this, landowners need to understand riverbank erosion and riverbank failure.

How all this affects riverbanks

On the river-front some of the houses was sticking out over the bank, and they was bowed and bent and about ready to tumble in. The people had moved out of them. The bank was caved away under one corner of some others, and that corner was hanging over. People lived in them yet but it was dangersome, because sometimes a strip of land as wide as a house caves in at a time. Sometimes a belt of land a quarter of a mile deep will start in and cave along and cave along till it all caves into the river in one summer. Such a town as that has to be always moving back, and back, and back, because the river's always gnawing at it.

— Huckleberry Finn

LANDOWNERS CAN SPARE THEMSELVES A LOT OF ANGUISH BY TRYING TO LEARN HOW BEST TO LIVE WITH INEVITABLE RIVERBANK CHANGE.

The main causes of bank erosion and failure are listed and described below and illustrated in Figure 12. You can use this information to try to identify which causes may operate, and dominate, on your parcel. (If you live within the City of Soldotna, your riverbanks were inventoried in 1990 and are discussed in Riverbank data in Chapter IV.) Table 10 indicates where to look in this *Guide* for information on how to reduce human impacts, including impacts that increase riverbank erosion and failure. (Because of the concern for fish shared by most Kenai River landowners, only bank stabilizing methods that do not damage fish habitats are described in this *Guide*.)

The interface where "man meets river" and all the processes we've looked at so far is on the riverbanks. (During floods, "man meets river" on the floodplain as well, usually at considerable property cost.) Even Huckleberry Finn could see that the truce between humans and the riverbanks we settle is an uneasy one. Most of us like to live in environments that are relatively predictable, and even better, relatively stable.

One way to help in identifying processes affecting your riverbanks is to choose and mark permanent photo spots that give you good views of your banks and then take "baseline" photos. Keep these photos for future reference. Try to photograph your banks at both high and low water levels, and also when they're iced up.

You can also get old and recent aerial photographs of your site and compare them to identify changes (see Chapter VI for sources of photography). Talking to neighbors or others who've lived on the Kenai River for years can help give you some historical perspective on riverbank changes, as can looking at old newspaper articles about flooding.

Bank erosion

Erosion is the removal of soil and rock particles by the actions of water, wind, ice, and gravity. These agents of erosion are fundamental in shaping riverbanks, particularly their slopes. Riverbank slopes can be measured in three ways: in degrees, percents, or ratio's. Figure 10 can help you visualize slope definitions and shift from one definition to another.

If the only agent eroding a bare riverbank is gravity (and bank material is dry and poorly compacted), the bank will assume a slope based on the *angle of repose* of its material. The angle of repose represents the slope at which loose cohesionless material will come to rest on a pile of similar material and remain stable (see Figure 11). This angle varies with particle size and shape, and is generally steeper for larger, flatter, and more angular pieces. Despite small particle size, hoever, cohesive material, like silt and clay, can assume steep slopes when compacted.

Gravity, however, is rarely the only agent of erosion operating on riverbanks; banks are also shaped by ice, wind, and most significantly, water. The interactions of these agents lead to many kinds of erosion. Before you can minimize erosion on your bank, you need to know which process(es) you're dealing with. There are nine to consider. These are summarized below and illustrated in Figure 12. (Much of the following discussion is summarized from Keown 1983.)

Figure 10. Comparison of slope definitions.

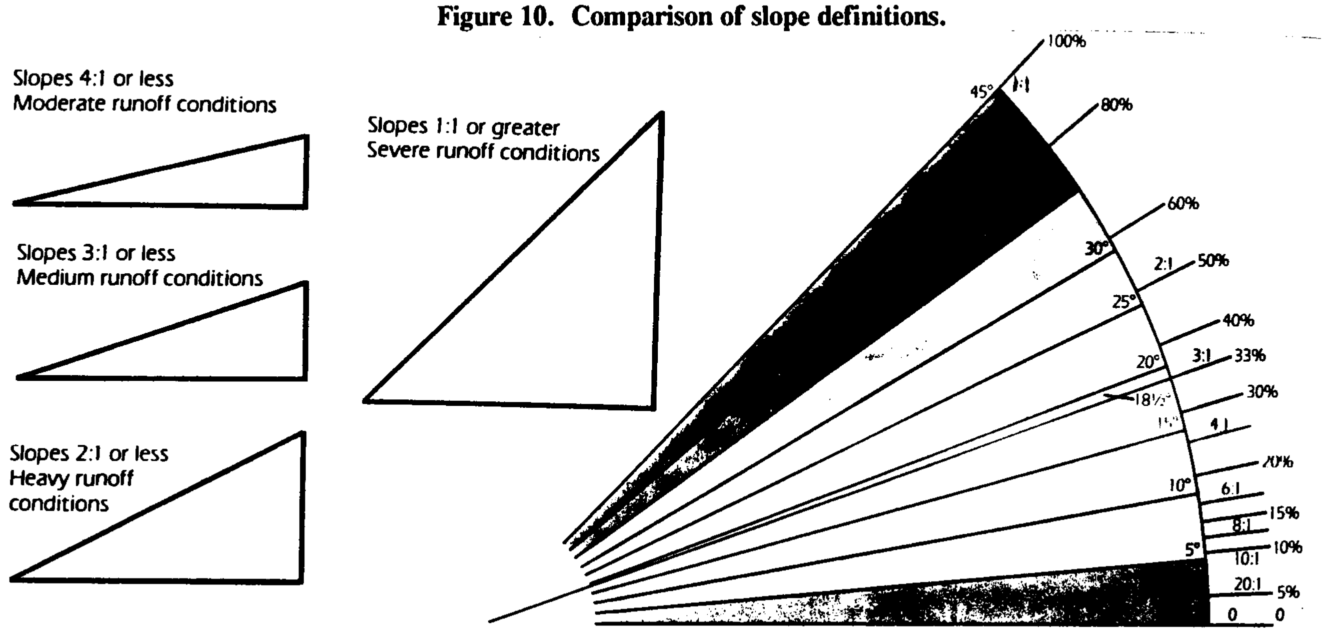
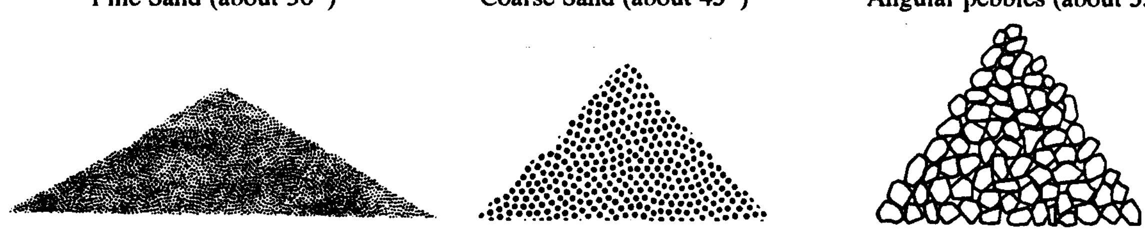


Figure 11. Angles of repose of different materials.

Fine Sand (about 30^0) Coarse Sand (about 45^0) Angular pebbles (about 55^0)



1. **river currents** As discussed earlier, moving water picks up and transports sediments. The faster, deeper, and more turbulent streamflow becomes, the more erosive it gets. As we pointed out, this means that the outside curves of meander bends generally experience the most erosion. But other banks are also prone to erosion by moving water, particularly those that have layers of unstable material.

In general, Kenai River banks consist of unconsolidated material that's relatively erodible (Reckendorf 1989). Except for riverbanks in the City of Soldotna, however, few stretches of Kenai River bank have been inventoried. As a result, the following comments focus on banks within Soldotna. Within city limits, much of the Kenai River is entrenched within the "Soldotna Terrace;" these high banks consist of terrace deposits. Most lower banks within city limits represent more recent floodplain deposits.

Because both terrace and more recent banks developed during changing flow regimes over hundreds or thousands of years, many different layers, or *strata*, developed. SCS field work (Reckendorf and Saele 1991) indicates that the most erodible strata consist of cobbly, poorly graded[1] gravels with a sandy matrix. In Soldotna, these commonly occur near the toe of low terrace, high floodplain, and low floodplain banks. Strata of well graded gravels are also highly erodible, more so than strata of silty sand or well- or poorly graded sands. Some strata, particularly those having large amounts of compacted clay, are relatively resistant to streamflow erosion.

2. **rainfall** The impact of raindrops loosens and spatters soil particles. When soils are saturated, rainfall turns to runoff (overland flow), which, like any other flowing water, can pick up and carry away particles. Overland flow can remove riverbank particles in sheets (*sheet erosion*), in tiny channels (*rill erosion*), and in larger channels (*gully erosion*).

3. **seepage** Rainfall and overland flow sink into (*infiltrate*) permeable soils and underlying substrates, eventually joining groundwater reservoirs or perching on impermeable layers. If subsurface flows seep out through the face of a riverbank, they carry away fine sediments, eroding the bank and weakening its structure. In addition, the pressure of subsurface flows can push bank material outwards, also weakening the bank (see Bank Failure below).

4. **overbank drainage** Irrigation water, drainage from cleared or paved areas, water diversions, etc. can flow down the face of riverbanks, leading to their erosion.

5. **obstacles in the river** Obstacles block and divert streamflows, sometimes redirecting them at banks. Obstacles can also constrict flows, increasing their velocity. Both effects can increase localized erosion. The most common natural obstacles in the Kenai River are large boulders that were probably ice rafted downstream during glacial retreat. In some locations, these divert flows towards banks and cause localized erosion. Manmade obstacles can have similar effects.

6. **wave attack** Wind and boat wakes can set in motion turbulent, erosive waves. Observations indicate that waves caused by boat wakes have increased Kenai River bank erosion (Scott 1982, Reckendorf 1991). Scott reported boat wakes running 3 to 4 ft up riverbanks, and suggested that increased boat use for fishing, beginning about 1974, has led to bank erosion

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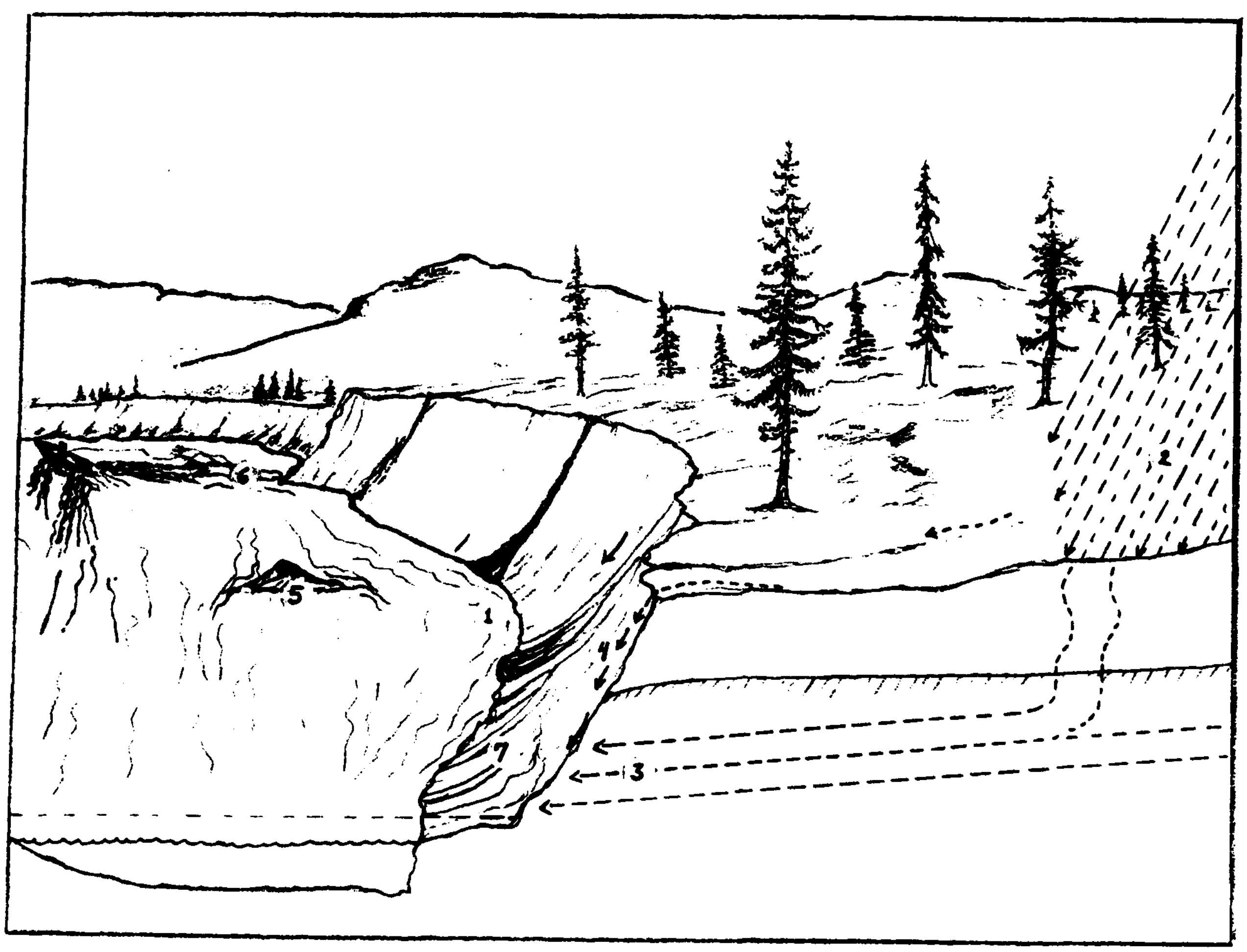
1 Here, *graded* is used in its engineering sense and describes sediments having a particular distribution of particles from small (clays and silts) to large (gravels and cobbles). "Well graded implies more or less uniform distribution from coarse to fine; poorly graded implies uniformity in size or lack of continuous distribution" (AGI 1976:191). *Poorly graded* material can also be called *well sorted* because it consists of sediments that have been sorted into grains of one or just a few size classes. *Well graded* material can be called *poorly sorted* since particles haven't been sorted into a limited number of size classes.

rates greater than the estimated geological rate of about 1 ft per year. Reckendorf emphasized that banks having toes of poorly-graded gravel are especially vulnerable to wave attack "...because as waves wash the fines and sands out of the gravel matrix, the gravel collapses, and everything above sloughs down the slope" (1991:25). Such wave-induced bank undercutting is believed by many to be one of the most serious causes of erosion now affecting the Kenai River.

7. **freeze-thaw and wet-dry cycles** Moist soils expand as they freeze and contract as they thaw. Soils on south-facing riverbanks, where daily temperature fluctuations tend to be more pronounced, are more likely to undergo freeze-thaw cyles than soils on north-facing banks. Soils with high clay contents swell as they get wet and shrink when they dry. Both processes loosen particles and increase their susceptibility to wind and water erosion.

8. **ice and debris** The Kenai River freezes along its banks during most winters. Thick ice may also build up above boulder fields in the river (Reckendorf and Saele 1991:6). In the spring, chunks of bankfast ice may break off or be torn loose, ripping out pieces of bank frozen to them. In addition, floating ice can bang against or grind away (abrade) banks and bank vegetation (as well as boat docks and other structures along the river). (This is less likely to cause erosion if banks are still protected by bankfast ice as floating ice travels down river.) Ice blocks can also jam at riverbends or against obstacles, causing ice dams and upstream flooding. Large floating debris can have effects similar to floating ice.

Figure 12. Illustrated bank erosion processes (numbers refer to processes listed in text).



9. **changes in land use and plant cover** Human activities and developments in watersheds tend to change drainage patterns, reduce the area available for rainfall infiltration, increase surface runoff, disturb soils, and remove plant cover (see Human impacts on river systems below). Unless carefully controlled, these watershed changes **inevitably** increase erosion. (They also tend to increase downstream flooding.) If land use changes alter streamflows, channel shapes, or sediment loads, they can set in motion a host of adjustments within the river, including increased bank erosion. Along the Kenai River, however, the most pronounced effect of human actions so far is the trampling and destruction of riverside plant cover, which leads to increased bank erosion and failure (see Maximizing riverbank stability, Chapter IV).

Bank failure

Bank *failure* is the collapse or slippage of a large mass of bank material. Depending on factors like bank particle size, shape, and size distribution; saturation; load; etc. banks move in different ways (e.g., creep, slide, slump, etc., Figure 13). Failure can occur near the surface or deep within a slope.

Banks fail when the forces that increase stability, or "shear strength," are weaker than the forces that increase instability, or "shear *stress*." **Shear strength** is decreased or **shear stress** is increased by:

1. **swelling of clays** as they absorb water;

2. **increased pressure and lubrication from subsurface water** (either *vadose*[1] water or groundwater). Subsurface water can come from infiltration of rainfall or overbank flow, from flood flows, tidal flows, etc;

3. **soil slippage or creep in response to gravity**. Slippage is indicated by cracks in bank material running generally parallel to the stream;

4. **changes in channel shape**, particularly deepening of the channel adjacent to the bank. As noted earlier, "The streambed acts as a foundation for its banks" (Keown 1983:35): remove the foundation and the bank is likely to fail;

5. bank **erosion that either undercuts or steepens the bank slope**. Outside banks on meander bends are most likely to be undercut by rivers, but waves from boat wakes can undermine banks and initiate failure anywhere that banks aren't protected by vegetation or something else. As mentioned earlier, high steep banks found along entrenched sections of the Kenai River are particularly susceptible to failure because of their height and unconsolidated strata;

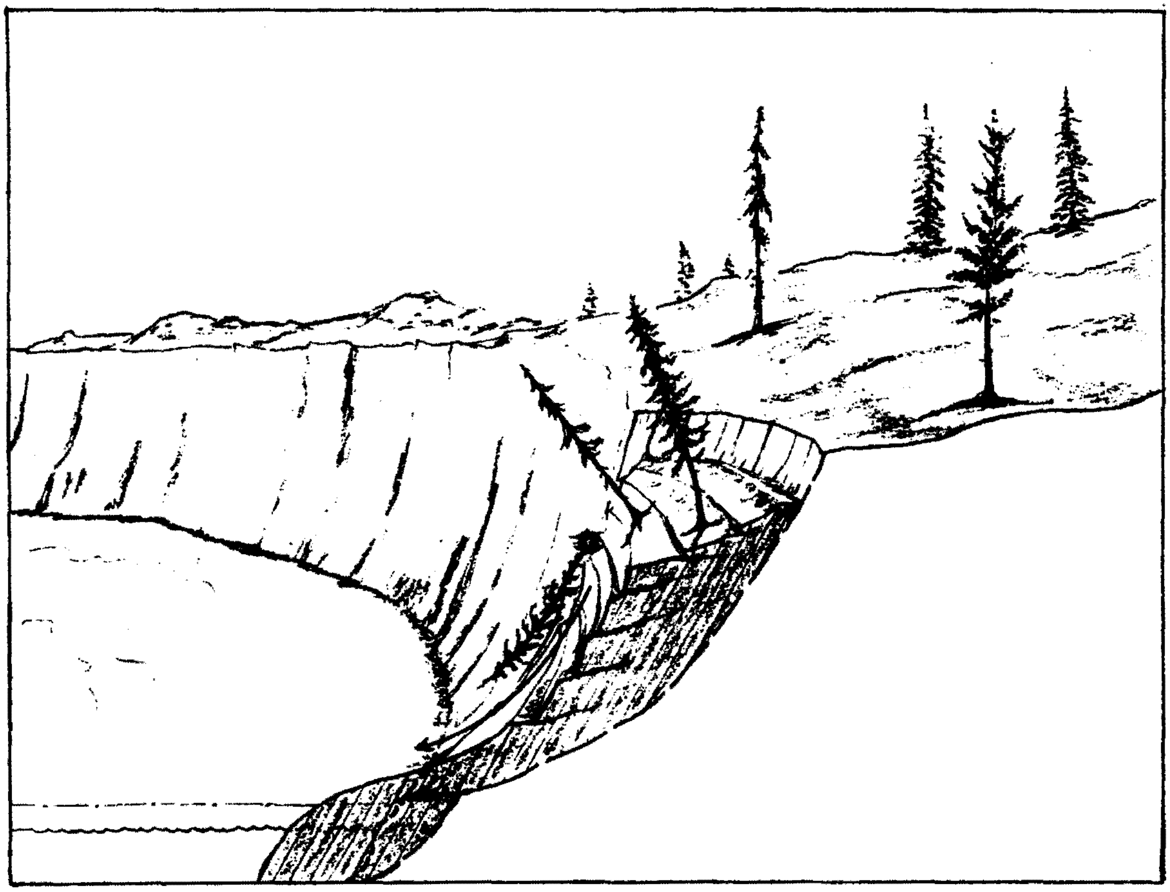
6. **increase in the load (weight)** on top of a riverbank or on its slope face (from buildings, roads, water, etc.);

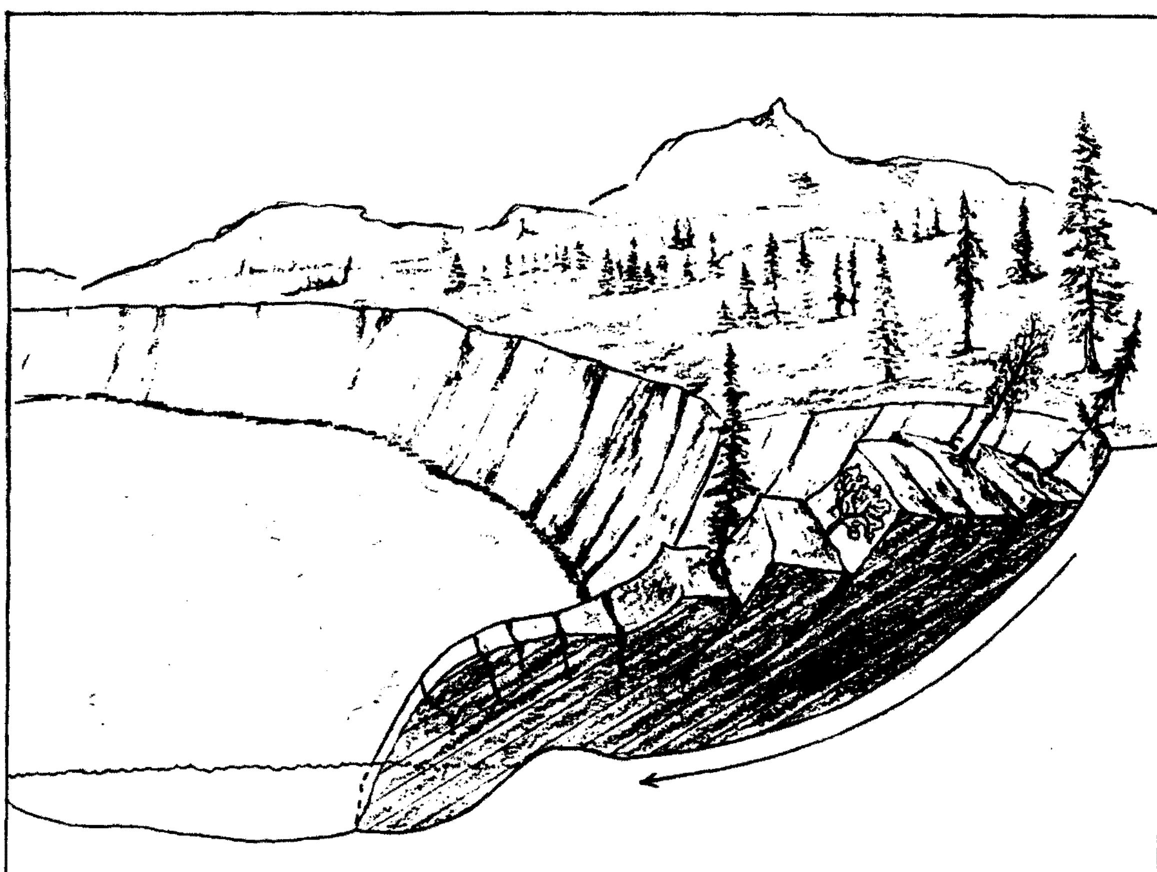
7. **rapid drop of water levels against the bank face**, for example, when floodwaters or tidewaters recede. "When the bank face is covered by water, a pressure balance exists between the water in the channel and the weight of the saturated bank" (Keown 1983:14). Rapid drop of water against the bank face upsets this pressure balance.

Once you have some idea of the forces that are weakening your banks, you can choose bank stabilizing approaches most likely to work in your situation. Many ways of maximizing riverbank stability are described in Chapter IV (Maximizing riverbank stability). In addition, Table 10 can help you find other discussions of ways to prevent bank damage.

1 *Vadose* water is subsurface water located above the *zone of saturation*. In the zone of saturation, basically all the spaces between particles ("interstices") are filled with water under pressure greater than atmospheric pressure (some interstices may be filled with gases or fluids other than water). The top of this saturated zone is the *water table*, and all water within this zone is *groundwater*.

Figure 13. Two illustrations of bank failure.





B. HUMAN IMPACTS ON RIVER SYSTEMS

In the first section of this chapter, we looked at watersheds as "systems." With a "system's view," it's easier to think about how human activities might affect the Kenai River watershed, and the river that defines it. In particular, a "system's awareness" is useful when looking at impacts because it reminds us to look at the "Big Picture" — at long-term cumulative impacts — rather than at the "little pictures" most of us see — the short-term impacts of what we and our neighbors do on our individual parcels.

When we don't use a system's perspective, and instead look only at our own activities, the impacts we see generally aren't very significant. **But what happens to the Kenai River is determined not just by what you do, but by thousands of actions being taken by thousands of people on lands throughout the watershed.** The phrase "destruction by insignificant increments" was coined to describe the almost invisible process by which resources can be damaged by many small actions that are individually insignificant but cumulatively profound. (It's the same process illustrated in the Introduction by Terry Bendock's metaphor of the removal of rivets from an airplane's wing. Each rivet is individually insignificant — but at what point have so many been removed that the wing falls off?) It takes a system's perspective to see this kind of long-term, incremental, cumulative change.

THE FIRST THING PEOPLE GENERALLY DO WHEN THEY MOVE INTO A WATERSHED IS SETTLE ALONG ITS MAJOR RIVERS.

The bottomline is that people *do* change watersheds in many ways. (This is, of course, much truer now than it was for pre-agricultural/industrial man, but even prehistoric cultures often caused profound and widespread watershed change, principally through their use of fire.) Although watersheds differ from one another, the general process by which humans change watersheds often follows the same steps and leads to similar impacts. These steps are briefly described below, along with the impacts they bring. Table 10 summarizes this information and lists simple practices landowners can follow to minimize the negative impacts their activities may have on the Kenai River.

How people change watersheds, what impacts human activities may have on rivers

Historically, the first thing people did when they moved into a watershed was settle along its major rivers. (Actually, this reflects the human tendency to settle where needed resources are concentrated; useful resources may be more highly concentrated along rivers than anywhere else — with the possible exception of some bays, estuaries, and coastlines.) Until recently, settlement along rivers was as characteristic of modern agricultural/industrial man as it was for his ancestors; in fact, Kenai River lands have been prime "residential real estate" for the last 10,000 years or so (see Chapter II, Section C). For "automotive man," however, roads have become as attractive a magnet for settlement as rivers once were.

There are many advantages to settling along rivers: easy access to water, readily available fish and wildlife for food and fur, transportation corridors — by boat and barge in summer, by skis, sleds, and snowmachines in winter. Riverside lands also provide recreation, convenient removal of wastes, and attractive settings. (Also, human beings, like many other creatures, tend to like "edges," places where water meets land, mountain meets plain, or grassland meets forest.) In addition, floodplain soils are particularly fertile because overbank flows deposit sediments and organic nutrients during floods (as described earlier in this chapter; we've seen, however, that the lower

Kenai River has a relatively narrow active floodplain). As a result, floodplains provide ideal areas for agriculture and forestry. These kinds of conditions attracted both aboriginal inhabitants of the Kenai Peninsula and more recent arrivals like the homesteaders of the 1940's and 50's. (About a dozen unsubdivided or partially subdivided homesteads still exist along the Kenai River.)

Settlement along rivers leads to "making a living" along rivers. The first settlers in an area are generally forced to be relatively self-sufficient and subsistence oriented. They grow or hunt their own food, harvest their own building materials, and make what they need from local resources. But as more people settle an area, roads and other "infrastructure" develop, and with them commercial and industrial developments. As this happens, "making a living" comes to include more and more kinds of activities.

Through this point in watershed development, most human activities remain concentrated near rivers, so impacts are also focused there. Riverside settlement and development can lead to the following kinds of impacts:

- **banks may be disturbed** as riverside lands are trampled; grazed; or cleared for developments such as buildings, roads, river access, trails, views, etc. They may also be modified in attempts to control bank erosion and failure.

- **"instream flows" may be reduced as water is withdrawn or diverted** for drinking and other personal uses, for irrigation and industrial processing, or for other "consumptive" purposes. Instream flows are critical for sustaining fish and wildlife, recreation, navigation, water quality, and stream channel attributes.[1]

- **wastes and sediments may be added to rivers**, intentionally or unintentionally. **Such inputs can degrade water quality.** Common unintentional pollutants include seepage from faulty septic systems and landfills, as well as runoff from roads, construction sites, storage areas, agricultural lands, etc. These kinds of wastes are commonly lumped together as "nonpoint source pollution" because no single point can be identified as the source. Nonpoint source pollution is usually addressed by "best management practices," which lay out specific do's and don'ts for activities like road construction, logging, agriculture, land clearing, and other land uses highly likely to generate nonpoint source pollution. For example, Table 11 lists best management practices the Alaska Department of Transportation follows during road construction. Many of these can apply to other kinds of activities, including homesite development.

Wastes discharged intentionally include outflow from city sewage treatment plants; processing byproducts (for example fish processing wastes); and processing or cooling waters withdrawn, used, and then returned to the river channel. Any wastes discharged through a pipe or ditch are called "point sources" of pollution. Intentional discharge of wastes into waters requires a permit from the Alaska Department of Environmental Conservation. Both nonpoint and point sources of sediments and wastes can degrade water quality.

- **native plant communities may be destroyed** by land clearing and development or replaced by plants used for agriculture, landscaping, etc.

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1 In order to protect Kenai River instream flows, the Alaska Department of Fish and Game has submitted two applications to the Alaska Department of Natural Resources (ADNR) to acquire instream flow water rights in the Kenai River to sustain fish production. The applications are pending ADNR "adjudication," the administrative determination of the validity and amount of a water right, including settlement of conflicting claims among interests competing for water appropriations (Estes 1992).

Table 10. **Human activities, their effects, and simple ways to avoid problems and prevent negative impacts.**

human actions or land uses	**may have the following negative impacts on the Kenai River**	**some simple ways to avoid problems and prevent negative impacts (use these practices along both the Kenai River and its tributaries)**	**also see page(s)**
A. clearing, settlement, and development on riverbanks	1. destroys bank-edge and riparian vegetation, as well as "natural" river corridor aesthetics	a. minimize clearing and disturbance of vegetated areas	
		b. leave vegetated "buffer strips" between developments and the river (The width of your buffer strip will depend on what riparian and bank-edge values you want to protect. If you want to provide a useful wildlife corridor along the river and maintain a "natural" aesthetic river environment, leave as wide a buffer as possible — 30 ft, 40 ft, 50 ft, or more — whatever you can accommodate. If your only concern is bank-edge fish habitat, leave a buffer wide enough to protect sensitive bank-edge and adjacent instream environments; see "filter strips," for example, under A4.)	
		c. replant adapted vegetation along riverbanks and in other riparian areas after clearing or disturbance	IV.28-48, IV.71-74
		d. replant vegetation preferred by desirable wildlife species	II.8-18, IV.20-21
A. (continued)	2. increases bank erosion and failure	a. determine the probable causes of your bank erosion and/or failure	III.30-34, IV.66-69 and 100-108
		b. see practices under A1	
		c. maintain, protect, and restore natural bank conditions and processes	IV.71-74
		d. use "spruce tree revetments" or "floating fascine breakwaters" to protect banks from boat wakes and to improve conditions for immature salmon and other aquatic organisms	IV.65, 78, 80
		e. divert surface flows away from the river and into appropriate non-erosive areas (for example, into filter strips, grassed waterways, settling ponds, or wetlands)	IV.58-60, 71

human actions or land uses	may have the following negative impacts on the Kenai River	some simple ways to avoid problems and prevent negative impacts (use these practices along both the Kenai River and its tributaries)	also see page(s)
A. (continued)	2. (continued)	f. install appropriate "soil bioengineering" practices	IV.75-87
		g. avoid increasing weight on banks (e.g., with structures, heavy equipment, impounded water, etc.)	IV.70
A. (continued)	3. reduces infiltration of rain and snow into soil (This tends to decrease groundwater recharge and increase surface runoff; river "base flows" decline if groundwater inflows to river channels drop as a result of decreased recharge.)	a. minimize clearing and disturbance of vegetated areas	
		b. minimize paved areas and soil compaction	
		c. divert surface runoff into areas where flows can infiltrate soils and recharge groundwater reservoirs (for example, into vegetative filter strips, grassed waterways, settling ponds, or wetlands)	IV.58-60, 71
		d. protect wetlands that are contiguous with (directly connected to) the Kenai River and its tributaries (maintain their hydrologic functions)	IV.58-60
A. (continued)	4. reduces water quality as increased sediments and pollutants (chemical and biological) are washed into the river by surface and subsurface flows	a. leave well-vegetated "filter strips" adjacent to the river Filter strip width depends on site-specific factors such as slope, soils, and land use. Long, steep slopes with permeable and/or erodible soils need relatively wide filter strips to protect Kenai River water quality. (In a typical study, on a sandy loam with a 4% slope, a 12-m (39-ft) vegetated buffer zone removed an average of 82% of manure-contributed nutrients; a 36-m (118-ft) buffer zone removed an average of 97% (Loehr et al. 1979:155). Appendix B in the *Final Report of the River/Fisheries Committee* (KRSMA Advisory Board 1985) discusses factors relevant in determining buffer strip width.)	IV.23
		b. replant "filter strips" adjacent to the river after land clearing or disturbance	IV.28-48
		c. divert surface runoff into areas where flows can infiltrate soils and be filtered (for example, into vegetative filter strips, grassed waterways, settling ponds, or wetlands)	IV.58-60, 71
		d. locate leach fields, community waste water and solid waste disposal systems and other potentially polluting land uses on appropriate sites and soils	IV.13-18

human actions or land uses	may have the following negative impacts on the Kenai River	some simple ways to avoid problems and prevent negative impacts (use these practices along both the Kenai River and its tributaries)	also see page(s)
A. (continued)	4. (continued)	e. design, install, and maintain properly functioning septic systems and community waste water disposal systems (Contact Alaska Department of Environmental Conservation for septic system design requirements, e.g., required minimum distance between wells and septic systems, required minimum depth to water table, etc.; see Chapter VI.)	IV.4, V.10ff (RDA)
		f. follow manufacturer's instructions and proper procedures during use, storage, and disposal of chemicals, fertilizers, wastes, and other potential pollutants (for example, don't pour oily wastes, paints, detergents, etc. onto the ground; don't store livestock wastes, road salts, etc. near the river)	
		g. test well water annually	
		h. protect wetlands that are contiguous with (directly connected to) the Kenai River and its tributaries (maintain their water quality/filtration functions)	IV.58-60
		i. follow appropriate "Best Management Practices" (BMP's) during development.	III.40ff (for example)
		j. promote water quality monitoring, public education, and public stewardship	V.2-14
A. (continued)	5. increases water withdrawals from groundwater and surface sources for use in homes, businesses, industries, agriculture, etc. (Water withdrawals can reduce instream flows.)	a. avoid significant water withdrawals from surface and groundwater sources that feed the Kenai River and its tributaries	
		b. protect Kenai River instream flows and seasonal flow patterns	V.13
		c. conserve water to reduce water withdrawals that could affect Kenai River instream flows	

human actions or land uses	may have the following negative impacts on the Kenai River	some simple ways to avoid problems and prevent negative impacts (use these practices along both the Kenai River and its tributaries)	also see page(s)
A. (continued)	6. degrades or destroys instream, bank-edge, and riparian habitats needed by aquatic and/or terrestrial organisms	a. see practices under A1 through A5	
		b. protect wetlands that are contiguous with (directly connected to) the Kenai River and its tributaries (maintain their biologic functions)	IV.58-60
		c. install rootwads or other large woody debris adjacent to banks above and below ordinary high water	IV.64, 65, and 71-74
		d. restore damaged riparian, bank-edge, and instream habitats	IV.64, 65, and 71-74
B. development of access to the river, recreation on riverbanks	1. degrades or destroys instream, bank-edge, and riparian habitats needed by aquatic and/or terrestrial organisms	a. see practices under A6	
		b. consolidate access to a single non-erosive trail	IV.89-93
		c. install stairs for access down sloping riverbanks	IV.94, 96-99
		d. install permanent or seasonal boardwalks (preferably that allow plant growth underneath) for bank fishing, river access, and other bank uses	IV.89-93
		e. consolidate use areas (e.g., develop a single boat launch or fishing area) and leave other areas undisturbed and protected	IV.89-95
		f. install floating boat dock(s).	IV.94-95
		g. "rotate" recreational activities between two or more sites (use one site one year, an alternate site in alternate years)	
		h. install a low-impact fence around undeveloped vegetated banks to protect them from disturbance	
		i. use "spruce tree revetments" or "floating fascine breakwaters" to protect banks from boat wakes and to improve conditions for immature salmon and other aquatic organisms	IV.65, 78-80

human actions or land uses	may have the following negative impacts on the Kenai River	some simple ways to avoid problems and prevent negative impacts (use these practices along both the Kenai River and its tributaries)	also see page(s)
B. (continued)	2. increases bank erosion and failure	a. see practices under A2 and B1	
B. (continued)	3. reduces water quality	a. see practices under A4 b. dispose of recreation-related garbage and human wastes properly	

Table 11. "Best Management Practices" used by the Alaska Department of Transportation and Public Facilities. Many can apply to other development activities. (From ADOT&PF and Federal Highway Administration 1992.)

1. Construction camps shall be located at upland sites whenever practical.

2. Materials stored for use in the construction project shall be stored at an upland site and out of floodplains.

3. Excavated materials shall be disposed of at upland sites unless otherwise approved.

4. Existing access trail, natural corridors, pipeline rights-of-way, and ditches shall be utilized whenever possible.

5. "Dry" dredging, leaving a dike or earth plug between open water and dredge area, is required.

6. Drainage of an area that is hydrologically linked with, or in close proximity to, other wetland areas shall be avoided if out of permitted area.

7. Diverted or construction-related water shall not be directed into receiving waters unless sediment retention structures and water quality control devices are used prior to discharge.

8. Channelization shall be restricted to existing stream channels or to existing drainage ditches unless otherwise shown on the plans.

9. Culverts shall be installed such that they do not create a barrier to fish in designated fish waters under all flow conditions.

10. The duration and area of exposed soil shall be minimized to reduce erosion potential.

11. Existing drainage patterns shall be retained by installing culverts or other drainage features.

12. Soils or fill shall not be placed near streambanks where it may be transported into the watercourse.

13. Where feasible, tracked vehicles shall be used rather than wheeled vehicles to reduce the impact on soils.

14. For projects within the Municipality of Anchorage, vegetation shall be retained along the shorelines of all waterbodies and ephemeral drainages per AMC 21.45.210. Hand clearing is recommended whenever possible to minimize loss of natural vegetation.

15. Runoff from the site after project completion shall have the same water quality as would have occurred following rainfall under preconstruction conditions.

16. Erosion and sedimentation control devices shall be installed between the construction area and water bodies, watercourses, and wetlands prior to grading, cutting, or filling.

17. Land cleared for development and upon which construction has not commenced shall be protected from erosion by appropriate techniques designed to stabilize soils and revegetate the area.

18. Limit equipment encroachment within the floodplain of any watercourse to that necessary to complete the project.

19. Do not service construction equipment within floodplains or runoff zones.

20. Do not wash equipment in water bodies or in floodplains.

21. Permanent and temporary storage of petroleum products shall be kept a minimum of 100 feet from wetlands or waterbodies. Spill containment and cleanup supplies shall be stored within a 15-minute transport time to spill sites.

22. Permanent and temporary storage of excavated or fill materials must be placed at least 25 feet from wetlands or waterbodies unless otherwise stipulated in the contract.

23. Stream crossings that require channel diversions shall use the culvert "flume" technique as developed by ADF&G, unless otherwise approved by the Engineer. Flumes will be armored at inlet and outlet with rock or sandbags and will include a culvert(s) large enough to pass peak normal flows. Stream channel restoration includes regrading banks, gravel lined channels, and revegetating banks (25 fee per side) with native materials. Erodible materials shall not be exposed to flowing water during construction.

24. Vegetation removal in wetlands, for the purpose of clearing only, should be accomplished by hand clearing rather than hydroaxing.

- **fish and wildlife may be displaced or eliminated from settled/developed riparian lands.** This can happen through direct interaction with people and pets (wildlife may be hunted or fenced out, killed by dogs or cats, etc.) or indirectly (wildlife species leave an area as their local habitats are destroyed). Fish may be displaced by changes in bank or instream habitats, water quality, water flows, etc. (Impacts on fish are discussed in greater detail at the end of this section.)

Back to our process of watershed development: eventually, all prime riverfront lands are spoken for (lands with good access and close to settlements and commercial areas). When this happens, **settlement and development spread outward from river corridors into other watershed lands.** This process is accelerated wherever access is developed. (Nothing speeds up settlement and development of an area like a good access road.)

As more areas of a watershed are settled and developed, additional kinds of impacts are added to those listed above. The types of impacts, and their severity, will depend on what kinds of land uses dominate and whether or not major resource harvesting (e.g., forestry) or extraction (e.g., mining) begins. In general, as settlement and development affect larger portions of a watershed, the following changes take place:

- **the amount of area where rainfall and snowmelt can infiltrate into soils declines.** Pavement and buildings prevent infiltration completely; soil compaction around structures and disturbed sites reduces infiltration significantly. **Reduced infiltration leads to increased surface runoff and decreased groundwater recharge.** This can affect rivers in several ways. In particular, (a) rivers tend to receive more runoff during storms, which causes higher flood flows, and (b) rivers tend to receive less inflow during dry periods, which causes lower "base flows." (During dry periods, a river is maintained primarily by groundwater inflow. If groundwater levels drop, this "base flow" also drops.)

- removal of vegetation and disturbance of soils during construction and other development activities lead to **increased erosion.** Increased erosion means that **more sediments are carried to streams and rivers.** As we saw earlier in this chapter, adding more sediments to rivers can change channel configurations and streambed characteristics. These changes affect fish and aquatic wildlife habitats.

In addition, if riverbanks erode and/or fail faster than is considered acceptable, **attempts may be made to stabilize banks.** Bank stabilizing efforts can be as bad for fish and other aquatic resources as erosion itself. (We've all seen car bodies dumped along banks, but smooth retaining walls of wood or concrete can be just as damaging to habitat.) As we saw in the preceding section, it's the nature of riverbanks to erode to some extent almost constantly; and these *natural* rates of erosion *contribute* to the "normal" functioning of watershed systems.

- **water quality deteriorates as runoff from developing areas picks up organic and inorganic pollutants.** Products and wastes associated with development — paints, cleaning agents, solvents, gas and oil, fertilizers, sewage, household and commercial garbage, industrial wastes and byproducts, etc. — generally degrade water quality. The amount of these pollutants in the watershed system tends to increase with increasing levels of development. Both surface and subsurface flows can carry these pollutants to rivers, lakes, and streams, as well as into groundwater reservoirs.

- **water quality may also be altered by manmade changes to instream temperatures and sediment concentrations.** Water temperatures can be changed by removing streamside vegetation (which shades water surfaces on hot days and may reduce heat loss from water surfaces during cold periods). In addition, reducing instream flows can change water temperatures and concentrations of sediments (or pollutants) in the channel.

As more and more watershed lands are developed, additional impacts tend to reflect changes in degree rather than kind — that is, more of the same kinds of impacts occur, both along the mainstem of the river and along its tributaries. One significant exception to this rule is dams. As more developments line the river and spread into surrounding lands, higher flood flows (caused by higher surface runoff) lead to more severe and costly floods. This provides a strong incentive to build flood control structures, such as dams, on the mainstem river or its tributaries. Other justifications for damming a river (or its tributaries) may come into play, such as the need to generate power or increase water supplies.

Awareness of the general pattern of watershed development helps us see where we are in the process. Doing that can help us anticipate problems and head them off before they develop. The Kenai River is still in the early stages of the pattern outlined above: All riverside lands have been "spoken for." Currently, lower Kenai River lands include more than 4,000 platted parcels *adjacent to* the river, and probably three to four times that many parcels within 1/4 mile of the river (i.e. 12,000 to 16,000 parcels). Development is still concentrated in discontinuous patches along the river (and major roads), particularly in and around Kenai and Soldotna (Figure 14). *Extensive* changes to the watershed have not yet occurred (with the exception of changes to watershed forests caused by spruce bark beetles).

EXPERIENCE IN OTHER STATES SUGGESTS THAT HUMANS ARE GENERALLY NOT SUCCESSFUL AT PROTECTING SALMON IN DEVELOPING AREAS.

To all appearances, the Kenai River remains in relatively good condition. But over time, lands along the river will come to support thousands of new homes and businesses and miles of new roads and other developments. The question facing us is: how can we protect the salmon-producing qualities of the Kenai River, along with other river values, as development occurs? Experience in other states suggests that human beings have generally been ***unsuccessful*** at protecting salmon in developing areas. In many areas, "the great fish runs seem to have gone the way of the buffalo" (Jack Hemingway about the Snake River salmon). Look, for example, at what's happened to salmon stocks in the Sacramento River, the Columbia River, or the Snake River. "A recent news release issued by the American Fisheries Society lists 101 West Coast populations of salmon and steelhead that are at 'high risk of extinction,' 58 'at moderate risk,' and 54 'of special concern.' Already, there are 106 populations of salmon, steelhead, or sea-run cutthroat trout that are extinct" (Bendock 1992). Even in Alaska, fish runs have been lost: "Most of Anchorage's waterways no longer support the fish populations of even 10 years ago. Rapid urban development has been the primary cause of this loss. Wetlands have been filled, streams have been channeled and culverted and waterways in general have been loaded with pollutants" (Landry 1991:11).

How people are impacting fish habitats along the Kenai River

As you can see, we haven't *yet* demonstrated that we can do better on the Kenai River than others have done in more developed states. It's still too early in the watershed-development process outlined above to know just how the pattern will play itself out along the Kenai River. But if we look closely at how humans are so far impacting Kenai River fish, we'll see the following patterns emerging:

- **bank habitats are being degraded**. Chapter IV includes a discussion on <u>The relationship between riverbanks and fish</u>. That discussion points out how important bank

Figure 14. Development patterns along the lower Kenai River: comparison of photographs from 1963 (top) and 1992 (bottom). (These photographs have been reduced to approximately 1/2 the size of originals. This and other photography is available from AeroMap US, Inc., listed in Chapter VI.)

(Note cutoff and abandoned meander loops.)

"cover" is to young fish. The most important kind of cover is vegetation growing in or hanging down into the water. In addition, small "cave-like" indentations found along well-vegetated banks also provide good cover — that is, places where fish can get out of the current to rest, feed, or hide from predators. Any activity that reduces plant growth along the water's edge eliminates cover. So far, clearing, trampling, development of boat ramps, and a number of other activities are having this effect.

ANY ACTIVITY THAT REDUCES PLANT GROWTH ALONG THE WATER'S EDGE ELIMINATES COVER, AND COVER IS ESSENTIAL FOR YOUNG FISH.

In particular, trampling by anglers who are bank fishing for sockeyes is having serious effects on bank cover. Sockeyes run in late June-early July and then again in mid-July-early August. As you can see from streamflow data earlier in this chapter, Kenai River water levels are highest from late June to early September. High water levels mean saturated banks, and saturated banks mean banks that are most vulnerable to removal of vegetation and damage from foot traffic. In other words, **at the same time large numbers of anglers are bank fishing for Kenai River sockeyes (and trampling riverbank vegetation in the process), banks are most vulnerable to trampling, and are likely to turn into structureless, erodible muck** (see Figure 27, Chapter IV). In addition to eliminating cover, this also increases bank erosion into the Kenai River (see below).

- **bank erosion is increasing.** On the Kenai River, the two main human-related causes of streambank erosion are: (1) removal of bank vegetation and (2) attack on banks by waves caused by boat wakes (Reckendorf and Saele 1991:7). Removal of bank vegetation was discussed above. The erosive effects of boat wakes was discussed earlier in this chapter. There's one additional comment about boat wakes we should make here: Although the 35 horsepower boat-motor limit imposed on the Kenai River undoubtedly helped reduce boat wakes somewhat, many factors besides horsepower influence wake size. The wake a boat generates is affected, for example, by boat size, hull design and displacement, how the boat is loaded, its load capacity, speed of travel, whether or not the boat is operated "on step," how close to shore it travels, how the operator throttles the motor upon landing, orientation of boat to shore, water levels at time of operation, etc. (Reckendorf and Saele 1991:7). Anyone who watches a bare riverbank getting slapped by waves after a boat passes by can see for himself the kinds of effects boat wakes can have.

Increased bank erosion hurts fish in a number of ways. To begin with, eroding banks rarely provide good plant cover for young fish. Furthermore, bank erosion makes *re-establishment* of plants more difficult. As a result, once plant cover is lost and banks start eroding, a damaging feedback loop is often set in motion: erosion caused by plant loss makes it harder for plants to re-establish, which leads to more erosion, which makes it even harder for plants to re-establish, and so on.

Bank erosion also adds more sediment to the river. Depending on the location and intensity of bank erosion, these sediments can settle into spawning gravels, plugging them with silt. As we saw earlier in this chapter, large stretches of the Kenai River channel are "armored" with rocks that are too large to be moved by present-day seasonal high flows. If rocks lining the riverbed aren't shifted at least every few years (and in armored stretches, they aren't), silts plugging up the spaces between rocks are never flushed out. Sediments that plug the spaces in spawning gravels prevent water-dissolved oxygen from reaching salmon eggs. This can lead to suffocation of developing eggs and *alevins* (young salmon that have hatched from their eggs but still have a yolk sac attached; alevins remain in their spawning gravels till "swim up" in spring). In the language of science: "There is strong positive correlation between intragravel water flow and egg survival. Deposition of silt in the redd, reducing water flow, may result in heavy mortality of the eggs. Oxygen consumption by the alevins in the nest is considerably higher than by eggs, further increasing the need for adequate flow" (Morrow 1980:76).

Bank erosion also causes banks to retreat back from the river like a receding hairline (see Figure 15). What this means is that it takes higher and higher instream water levels before the river reaches the edge of the eroding bank and whatever cover it still offers. Banks that once provided cover during low flows in spring and early summer now provide cover only during high flows, from late June to late August. But salmon fry emerge from spawning gravels in spring, when water levels are low; and this is when fry need cover most — when they're smallest, weakest, and most vulnerable to predation. Banks that have receded too far back from the active channel provide no cover at this critical time of year. In addition, salmon that overwinter in Skilak Lake travel upstream during fall when water levels are dropping. Without hiding cover, they run a gauntlet of hungry predators on their journey to the lake.

SOME NEGATIVE HUMAN IMPACTS ARE ALREADY OCCURRING ALONG THE KENAI RIVER. THE CHALLENGE IS TO MINIMIZE THESE IMPACTS SO THAT THEY NEVER REACH "CRITICAL MASS."

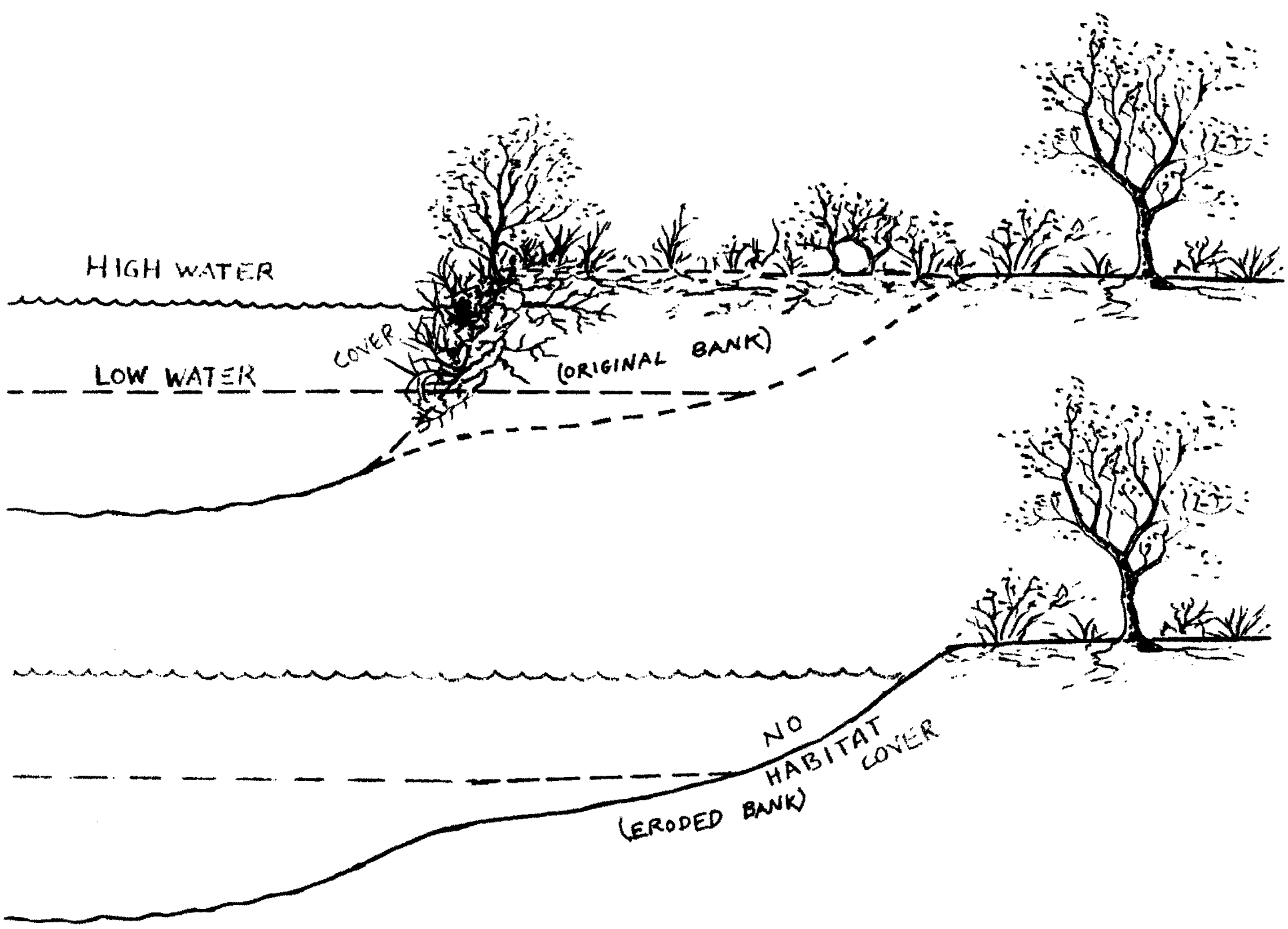
- **local water quality problems are beginning to develop.** Water quality is not yet a general problem in the Kenai River, and fortunately, water quality research has begun. Baseline studies and ongoing monitoring are critical if we want to spot problems as soon as they develop. Given current lack of funding, water quality monitoring may depend on citizen volunteers. (Look up "monitoring programs carried out by citizens" in Chapter VI for names of organizations that coordintate such programs.)

Despite generally good water quality in the Kenai River, localized water quality problems have been documented. In a 2-year baseline study performed by the Alaska Department of Fish and Game, water quality differences "...were observed between the more rural upper river and the more urbanized lower river..." (Litchfield and Kyle 1992:37). In particular, in the lower river, researchers noted: "Hydrocarbons were present in the lower river at concentrations within EPA standards; however, the presence of oil sheens at the two storm drain outfalls warrant further investigation. Fecal coliform bacteria counts [bacteria associated with sewage] below the Soldotna Bridge were elevated compared to upper river locations, and some individual samples were found approaching State of Alaska criteria for secondary water recreation use. Finally, benthic [bottom-dwelling] invertebrate populations differed between the upper and lower river, indicating differential impacts or habitats..." (Litchfield and Kyle 1992:38).

- **Other modifications harmful to fish have occurred along the river.** In particular, boat basins and canals have been excavated in some areas. If not properly designed, excavated basins and channels don't drain completely at low water. As a result, fish may enter at high flows and then get trapped as water levels drop. In addition, a number of structures and erosion-control projects have been installed along the Kenai River. Some of these increase adjacent flow velocities to the point that small fish have difficulty swimming against the locally increased current. Others eliminate bank-edge cover and other habitat features. The Alaska Department of Fish and Game has begun an inventory of all structures along the river (ADF&G 1992). They are continuing research on the impacts that different kinds of structures may have on fish.

As you can see, some negative human impacts are already occurring along the Kenai River. The challenge is to minimze these impacts so that they never reach a "critical mass," that is, become so widespread and serious that they cause significant damage to fish and other river resources. With good data and guidelines, effective educational outreach, community involvement, appropriate habitat protection and enhancement efforts, and high levels of concern for the Kenai River, the chances are good that impacts can be kept below "critical mass;" that we won't remove so many rivets from the airplane's wing that it finally falls off. Table 10 summarizes ways individual landowners can prevent or minimize the negative impacts their activities might have on the river. In addition, Chapter V lists a number of programs designed to give landowners "positive incentives" for taking actions that protect the river and its fish. Kenai River landowners may want to use existing programs or promote new ones that could help protect the Kenai River's long-term health, beauty, and productivity.

Figure 15. How bank "recession" affects the relationship between fish cover and river water levels.



IV. LIVING WITH THE KENAI RIVER

CHAPTER CONTENTS

A. Introduction to "do-it-yourself" resource planning and action
The seven steps of "do-it-yourself planning" 3

B. Using <u>soil</u> information 7
Introduction to soils 7
What are soils? 7
Why are soils important? 8
Soils and landscapes 9
Parent material 9
Soil forming processes 10
Soil properties and land uses 11
Distribution of soil properties 13
Land use interpretations 13
Using soils information on your land 16

C. Using <u>plant</u> information 19
Using plants to improve your property
(*Twelve ways to use plants to your advantage*) 19
Selecting, obtaining, planting, and caring for plants 28
Selecting plants 28
Obtaining plants 37
Commercial outlets 37
Alaska Forest Regeneration Center 37
Tranplanted material 37
Propagating plants yourself 39
Planting 45
Planting grasses and herbaceous plants 45
Planting shrubs and trees 45
Caring for plants 47
Introduction to plant communities 49
Plant communities along the lower Kenai River 53
Overstory plant communities 53
Coniferous forests 53
Deciduous forests 54
Mixed coniferous-deciduous forests 55
Tall shrub communities 56
Low shrub communities 56
Herbaceous communities 57
Understory plant communities 57
Upland plant communities 57
Wetland plant communities 58

D. Using riverbank information 61
Introduction to riverbank management 61
The relationship between riverbanks and fish 62
Maximizing riverbank stability 66
The relationship between plants and riverbanks 66
How plants reduce bank erosion 66
How plants reduce bank failure 67
Practical ways to promote bank stability 69
Conventional plantings 71
Soil bioengineering 75
Structures (boardwalks, floating docks, access stairs) 88
Riverbank data 100
(currently available only for banks in the City of Soldotna)
What riverbank information was collected 100
Using collected information to assess riverbank stability 100

IV. LIVING WITH THE KENAI RIVER

A. INTRODUCTION TO DO-IT-YOURSELF RESOURCE PLANNING AND ACTION

Planning is a process that helps you get from "A" to "B" in a logical manner. In landowner terms, "A" is your property now; "B" is what you want your property to be like in the future. Getting from "A" to "B" involves *making* and *implementing* decisions about the use and treatment of resources you control, and this in turn involves learning about those resources. Planning is a continuing process, not an end in itself; it has value only if it leads to good decisions and appropriate actions.

Land use planning, like any process, can be broken down into steps (see Table 1). If you follow the steps conscientiously, you'll be much more likely to end up where you want to go ("B") than if you don't. The basic steps involved in planning are described below.

The seven steps of "do-it-yourself planning"[1]

Step 1. Obviously, if you want to get from "A" to "B," you need to define "B" as completely as possible; so the first step in planning is **determine your objectives**. This should be fun: All you have to do is envision the ideal conditions and amenities you want on your property. You may not be able to achieve your vision completely, but the more detailed it is, and the more familiar with it you are, the closer you'll get. (And it's highly unlikely you'll get what you want if you don't know what it is.)

1 These steps are based on the "10 elements in the planning and implementation process" outlined in the *National Conservation Planning Manual* (SCS 1984).

Step 2. To get from "A" to "B," you also need to know where you're starting from; so after you've envisioned objectives, it's time for a "reality check," a serious look at the conditions and processes that characterize your property now. The second step in planning, therefore, is: **collect relevant resource data.** Get the best information available about your property, particularly information that describes conditions relevant to your objectives. We've tried to help you do this by compiling a lot of that information in this *Guide*. (See, for example, Table 1, Chapter III.)

Step 3. With the best available information in hand, you're ready for step three: **analyze and interpret collected data.** This means making sense of what the data tell you about meeting your objectives given your resource conditions. A good way to do this is to identify the conditions on your property that will either help you or hinder you in meeting your objectives. "Helpful" conditions (more properly called "potentials") offer opportunities you can take advantage of. "Hindering" conditions (more properly called "limitations") present problems you'll have to overcome. For example, if one of your objectives is "install a properly functioning septic system drain field," conditions like "high water table" and "steep slopes" present problems or site limitations you'll have to overcome, while "level terrain" and "deep, well-drained soils" represent opportunities to reach your objective with relative ease.

As you look through relevant resource information, try to identify and list all limitations/problems and potentials/opportunities that affect meeting your objectives. One way to do this is to list your objectives across the top of a page, with two columns under each objective.

In one column, list all conditions that interfere with meeting that objective (your site limitations). In the other column, list conditions that can help meet that objective (site potentials). A comprehensive list will give you a good basic picture of what you're up against in trying to achieve your objectives. The list will also help as you brainstorm possible alternatives (Step 4).

Once you've made a list, learn as much about each "site limitation" and "site potential" as possible. Most site limitations can be overcome in a number of ways for various costs. You'll need to know enough about your site limitations to evaluate how well different possible solutions might work on your land. Site potentials, on the other hand, offer you opportunities to do things without running into major obstacles or costs. The more you know about them, the more effectively you can use them to your advantage.

This *Guide* includes many interpretations that indicate what various resource conditions mean in terms of different land use objectives. With a little thought, you can also come up with other interpretations related to objectives not addressed here. The Soil Conservation Service and other agencies can help you develop these additional interpretations.

SOMETIMES, AN ALTERNATIVE THAT WOULD BE TOO EXPENSIVE FOR ONE LANDOWNER CAN BE AFFORDABLE IF A GROUP OF LANDOWNERS WORKS TOGETHER.

In Step 4, you **develop and then evaluate alternative schemes or methods for getting from "A" to "B."** Alternatives should be based on information collected and analyzed in Steps 2 and 3. In fact, as you go through Steps 2 and 3, jot down any ideas about specific ways to overcome site limitations, etc. These ideas represent the beginnings of possible alternatives, and can be built on during Step 4 as you obtain more information. Ideas for alternatives can also come from seeing what others have done on their property, from looking at demonstration sites (see Soil bioengineering, in Section D of this chapter), from reading (see example references listed under Twelve ways to use plants to your advantage), and from discussions with other resource managers and landowners, including professionals listed in Chapter VI.

Talking to neighbors can give you more than just ideas. Sometimes, an alternative that would be too expensive for one landowner can be affordable if a group of landowners works together. For example, where a number of adjoining lots need mounded septic systems because of high groundwater levels, a subdivision septic system might be cheaper for affected landowners. Working with other landowners can also help protect river resources, as when a single neighborhood boat launch serves a whole subdivision and allows individual landowners to protect fish habitats and reduce bank erosion. Also, a group of landowners may be able to get cost share funds not available to a single landowner because of minimum acreage or other requirements. State and federal programs like the Stewardship Incentive Program, Rural Development Administration programs, and "319 projects" under the Clean Water Act can sometimes help pay for activities that benefit groups of landowners while protecting river resources (see Chapter V).

Be creative as you brainstorm alternatives; you may come up with ideas that will work for others in similar situations. But as you brainstorm, ask yourself:

(1) What can I realistically accomplish given my time, budget, tools, skills, available help, etc? No matter how effective an alternative might be, it won't work if it's too expensive or difficult to implement.

(2) What effects is each alternative likely to have on other resources, both on my property and on neighboring lands and waters? Table 2 is an "environmental evaluation checklist" that the Soil Conservation Service uses during planning. If you use this checklist to assess alternatives,

it's unlikely you'll accidentally do something that causes damage or leads to unpleasant surprises as far as effects are concerned. The SCS can help you work through this checklist as you develop a plan for your property.

Step 5. Once you have a complete, well-thought-out list of alternatives (whose effects you've assessed), and you've considered what you can realistically accomplish with your personal resources (time, money, equipment, etc.), you're ready to **make decisions.** At a minimum, **decisions should lay out the what, where, when, and how of specific actions you intend to take** (along with "who" if someone other than you will be doing the work). It's very important to **document your decisions** completely and clearly in writing (with maps and drawings, if needed) so you can stay on track and monitor your progress. If you follow steps 1 through 4 conscientiously, the decisions you make should move you towards your goals with a minimum of wasted effort and misadventure.

Step 6. Obviously, planning decisions aren't worth much unless they lead to actions that move you towards your goals, so step 6 is **implement your decisions**. Implementation should be relatively easy and straightforward if you've followed all the steps so far.

Step 7. As we've emphasized many times already, river environments are very dynamic and can change dramatically over time. In addition, your objectives evolve as your needs, desires, knowledge, personal resources, and other life situations change. And the technology available to you also evolves, sometimes quite rapidly. As a result, planning is not a one-shot deal. On a regular basis, it's important to look over where you are on your journey from "A" to "B" and consider whether your goals or your methods need changing. This leads to step 7, **reevaluate and update your plan as needed.**

Table 1. The seven steps of do-it-yourself planning: a logical process for getting from "A" (what you have) to "B" (what you want to have).

Step 1.	**Determine your objectives** (define "B"). What conditions and amenities do you want on your property?
Step 2.	**Collect relevant data** (describe "A"). What conditions and processes exist on your property now? Get the best resource information available. Focus on information that describes resource conditions relevant to your objectives.
Step 3.	**Analyze and interpret collected data.** What "site limitations" (problems) and "site potentials" (opportunities) does your property present in terms of achieving your objectives? Identify and list all conditions and processes that may help you or hinder you in getting from "A" to "B."
Step 4.	**Develop and evaluate alternative schemes or methods** for getting from "A" to "B." Focus on ways to overcome site limitations and ways to take advantage of site potentials. Brainstorm possibilities, but keep in mind (1) what you can realistically accomplish given your personal resources and (2) what effects different alternatives will have on other onsite and offsite conditions.
Step 5.	**Make decisions** (choose alternatives). Decisions should **address the what, where, when, how, and (if necessary) who** of specific actions you intend to take. **Document decisions in writing.**
Step 6.	**Implement decisions.** Put into action the choices you've made.
Step 7.	**Reevaluate and update your plan as needed.**

Table 2. Environmental evaluation (EE) checklist for conservation planning - individuals and groups[1] (from SCS 1989)

Cooperator or Project Name ______________________________ Date ______________
Location ______________________ Conservationist/Technician ______________
Field Office or SCD ___________________ Planning Purpose ______________
Land Treatment Practice(s) or Project Alternative ______________________

Will proposed alternatives adversely affect the following concerns? For harmful effects, refer to SCS policy in parenthesis (where applicable). Planner should offer alternatives for practices or project measures that have significant adverse environmental effects.

EVT Elements + = Beneficial Effects and Codes - = Harmful Effects	NO EFFECTS	EFFECTS2/ Short-Term	Long-Term	Needs further Study3/
Erosion & sedimentation				
Watertable alterations				
Change in streamflow regime (190 GM, Part 410.27)				
Change in air quality, i.e. dust & smoke				
Change in land use				
Upland wildlife habitat				
Riparian Habitat - flora & fauna				
Migration routes, i.e. big game and waterfowl				
Stream fisheries				
Wetlands Policy: (190 GM, Part 410.26)				
Threatened or endangered plants and/or animals (190 GM, Part 410.22)				
Perennial streams, i.e. dewatering, sediment				
Intermittent streams				
Archaeological - Historical resources (420 GM, Part 401)				
Water quantity				
Water quality, inc. receiving waters				
Appearance of the landscape (190 GM, Part 410.23 - 410.24)				
Floodplain management (190 GM, Part 410.25)				
Prime farmland (310 GM, Parts 401-403)				
Other (list)				

1/ Environmental evaluations and assessments are described in Section 190, part 410, of the SCS General Manual. Environmental considerations are addressed in Parts 506.17(h) through 506.17(1), pages 506-16 through 506-20 of the NCPH.

2/ Short term is considered to be the installation period. Long term is considered to be after the installation period to the end of the project (practice) life. A long term harmful effect will occur when mitigation is not adequate or if mitigation is not desired by the landowner. Mitigation includes:

a. Avoiding the impact altogether by not taking a certain action or parts of an action.

b. Minimizing impacts by limiting the degree of magnitude of the action and its implementation.

c. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.

d. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

e. Compensating for the impact by replacing or providing substitute resources or environments.

Long term effects significantly harmful to the environment should be described and brought to the attention of the State Resource Conservationist. "Significantly" is defined in 190 GM, Part 410.4(k).

3/ Contact and schedule appropriate specialist.

B. USING SOIL INFORMATION

Douglas J. Van Patten
SCS Soil Scientist

TO THE WISE MAN THE WHOLE WORLD'S A SOIL.
— BEN JOHNSON (1573-1637)

This section is comprised of two parts. The first part, Introduction to soils, covers basic information on soils, the nature of local soils and landscapes, and general background on the use and management of soils. The second part, Using soils information on your land, explains how to use soil information available for your land. If you're interested in background information on soils, start with the first section. If you have some understanding of soils and are mainly interested in information related to your parcel, turn to the second section.

(1) Introduction to soils

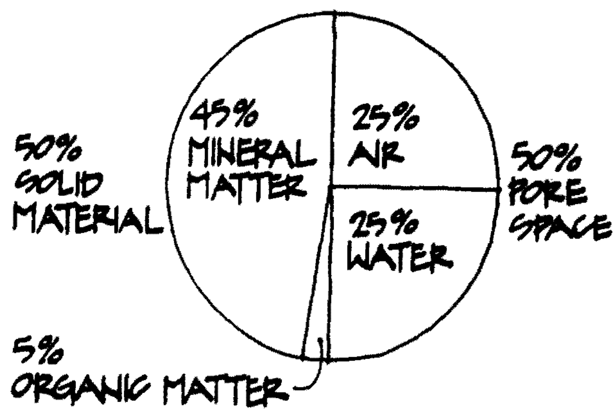
What are soils?

Soil is commonly defined as the natural medium for plant growth. When you think about the importance of plant growth to all life on earth, and the importance of soils to plant growth, you begin to understand how critically we depend on soils.

Soils are composed of varying mixtures of (1) mineral material, (2) organic matter, (3) air, and (4) water. In terms of plant growth, an ideal soil is about 50 percent solids (mineral and organic matter) and 50 percent pore space (voids between the solids) (Figure 1). The organic portion consists of plant residues (*humus*) and the remains of animals and other organisms. For optimum plant growth, about half the pore space should be filled with water, the remainder, with air.

The relative amounts of mineral material, organic matter, air, and water determine *soil composition*. Many inferences about soil behavior and soil suitability can be made if soil composition is known. For example, a very gravelly coarse textured soil may be suitable for engineering purposes like road construction because of low organic matter, large pore spaces, and large particle size. But the same soil would make a poor medium for plant growth for the same reasons. This same soil would readily transmit fluids in a septic system leachfield, but it wouldn't provide the filtering capacity needed to clean wastes from septic system flows before they reached groundwater aquifers, rivers, or other water bodies.

Figure 1. Soil composition good for plant growth (from Johnson et al. 1990).



Mineral soil particles come from various sources, such as weathering of bedrock, volcanic ash, alluvium, glacial till, and marine sediments. Three sizes of soil particles have been defined. These are the soil *separates* of *sand, silt,* and *clay*. Figure 2 illustrates the relative size of these particles as defined by the Soil Conservation Service. The size classes shown relate to functional properties of particles (e.g., water-holding capacity, ability to transmit water, erodibility, etc.) and chemical properties (e.g., cation exchange capacity, capacity to hold available nutrients, etc.).

The relative proportion of sand, silt, and clay particles in a soil determines its *texture* (Figure 2). To determine soil texture precisely, soil separates are sorted in a laboratory and weighed so that their relative percents can be measured. Since it would be impractical and expensive to have all soil samples "textured" in a laboratory, field estimates are made instead. Soil scientists have "calibrated" their fingers through years of texturing soil samples of known composition.

Engineers commonly use the "Unified Soil Classification System," while transportation departments use another system, referred to as the AASHTO Soil Classification System (American Association of State Highway and Transportation Officials). When considering a particular textured soil, be sure to determine which textural system was used; the nomenclature and size criteria differ among classes. For example, a *sandy loam* in the USDA system is a *silty sand* in the Unified System.

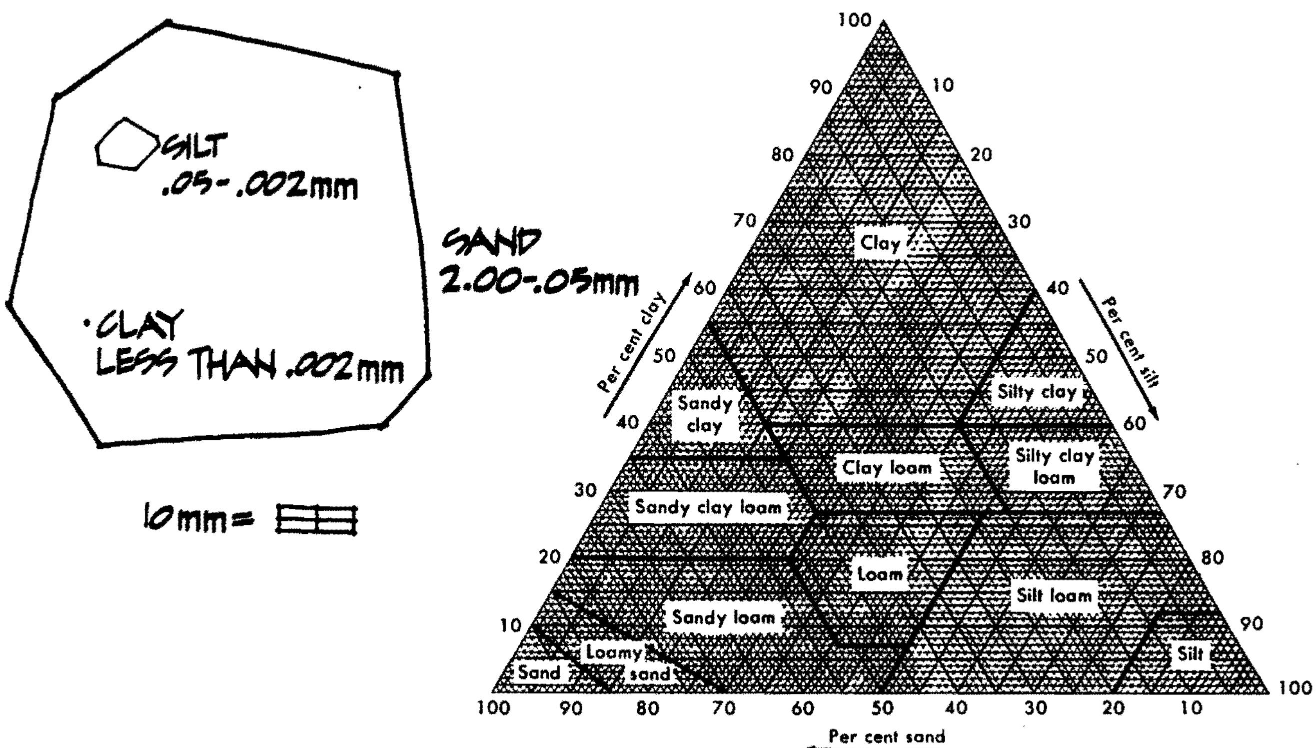
Why are soils important?

As we've suggested already, one critical reason that soils are important is that they, in combination with air, water, and sunlight, support plant growth; and plants sustain all higher forms of life on this planet, including us. Soils are very important in determining what kinds of plants can grow in an area and how productive they'll be.

Because of their importance to plants, soils are also critical to wildlife, which depend on plants for food, cover, and other habitat elements (see Chapter II, Section B). In addition, soils provide habitats for burrowing animals and those that build dens.

For humans, soils are also very important in determining what kinds of developments can be located in particular areas. They provide, quite literally, the foundation for most of our structures and transportation networks. They act as the earth's kidneys, cleaning and purifying our water. And soil properties determine what design criteria should be followed to prevent soils-related failures during development.

Figure 2. Relative sizes of sand, silt, and clay; the USDA soil textural triangle.



Perhaps because soils are everywhere, most of us take them for granted. An analogy is the autonomic nervous system of the human body. We don't have to think about breathing because the autonomic system takes care of it for us. But if the system malfunctions, we're likely to experience major respiratory problems, which can be fatal. In the same way, if we ignore the "soil system" and overlook soil limitations, we may cause malfunctions (cracked foundations, failed crops, clogged septic systems) with serious consequences for both us and the environment. Consider the cost of replacing a failed septic system, and the effects of raw sewage and household chemicals leaching into the Kenai River or contaminating your own or a neighboring well. The intent of this soil investigation is to provide you with the soils knowledge you need to avoid mistakes that are costly to you or the environment.

Soils and landscapes

WE KNOW MORE ABOUT THE MOVEMENT OF CELESTIAL BODIES THAN ABOUT THE SOIL UNDERFOOT.
— LEONARDO DA VINCI (1452-1519)

Five factors interact to create soils: (1) **climate**, (2) **living organisms**, (3) **parent material** (bedrock, surface sediments, etc.), (4) **relief** (landform and topography), and (5) **time**. The interactions of these *soil*-forming factors also create particular *landscapes*. In fact, landscapes and soils are correlated in consistent ways, so that "...the more similar two *landscape units* are [areas with similar slope, aspect, plant communities, etc.], the more similar their associated soils tend to be" (Hudson 1992:838). Soil scientists know this, and as they map, they watch for changes in landscape features like relief (e.g., slope and aspect), plant communities, parent material, etc.[1] When they see a change in landscape features, they know that soils have probably changed too. They confirm this by digging a pit and examining the soil. This correlation between landscape units and soils allows trained soil scientists to "...delineate bodies of soil accurately on the landscape by directly examining less than one-thousandth of the soil below the surface" (Hudson 1992:837).

Parent material

On the geologic time scale, lands along the lower Kenai River are relatively young. As a result, parent material is probably the most important soil factor in the study area. Soils along the lower Kenai River have developed in three kinds of geologically recent materials: (1) *loess*, which is **wind**-deposited material, (2) *alluvium*, which is **water**-deposited material, and (3) *glacial till*, which is **glacial ice**-deposited material. Obviously, these materials can be deposited in both vertically and horizontally complex patterns depending on how wind, water, and ice interact.

Loess tends to be comprised of silt-size particles. The entire Kenai River study area has at various times been mantled by loess derived from volcanic ash or glacial silt. This mantle has been redistributed by wind and water, creating surface layers of variable thickness.

Alluvium is deposited by water and can range from very fine to very coarse material. Coarse material is associated with high velocity flows; fine material with low velocity flows (see Chapter III). Flowing water creates a number of landforms, from nearly-level *floodplains* and gradual *slip-off slopes*, to steep *cutbanks* (*terrace scarps*) and *entrenched channels* (see Figure 8 in Chapter III). Flows that vary over time tend to create *stratified* deposits, that is, deposits with many thin layers of contrasting textures. Slack or slow water in oxbows, sloughs, and near the mouth of rivers deposit fine sediments.

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1 Methods used during soil mapping along the Kenai River will be discussed in detail in the "Technical Report" of the Kenai River Cooperative River Basin Study, due in Spring 1993.

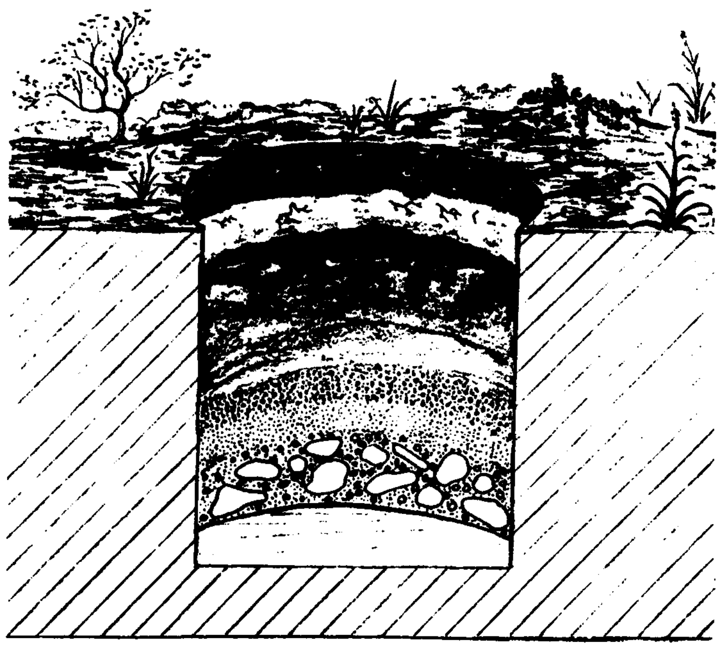
The most common **glacial till** deposits in the Kenai River lowlands are *moraines*, hummocky mounds of unsorted, unstratified material dropped by glaciers. Along the Kenai River, morainal deposits are typically overlain by *proglacial* lake sediments (proglacial lakes occupy the basins in front of glaciers). Proglacial lake deposits are of variable thickness and texture, and are mantled by more recent loess. In general, these deposits are coarser grained near moraines of Naptowne age (close to melt-water sources) and progressively finer grained towards Cook Inlet. For example, soils underlying the loess mantle on moraines near Naptowne Rapids have coarse textures, while those between Big Eddy and the Spurr Highway have fine textures.

Soil forming processes

Differences in the five soil-forming factors lead to different soil forming processes, which in turn create distinctive layers in the upper few feet of soil. These layers are called soil *horizons* (Figure 3). The series of horizons that characterizes a soil is called a soil *profile.* Different horizons have different physical and chemical properties, and give particular soils their identity. During soil mapping, horizons are exposed by digging soil pits. Information is then recorded about the observed horizons.[2]

On well-drained high river terraces, outwash plains, and glacial moraines, the loess mantle and typical plant communities give rise to soils with very colorful horizons. These horizons are formed by a process called ***podzolization***. In soils formed by this process (*spodosols*), iron and aluminum form complexes with organic carbon. These complexes are leached from the surface horizon and accumulate in a subsurface horizon. The leached horizon is light gray; the depositional horizon is reddish brown.

Figure 3. A soil pit showing soil horizons.



Spodosol horizons are visible in many roadcuts in the study area. They generally indicate well-drained soils. Such soils have a low pH (are acidic) and are naturally infertile; however, their physical properties make them easy to prepare for lawns and gardens, and they respond to lime and fertilizer. On steep slopes, these soils should be protected from erosion. (And runoff carrying fertilizer should not be allowed to drain into the river.)

Low river terraces, floodplains, and abandoned channels often have poorly drained mineral or organic soils. When mineral soils are saturated by water for more than a week or two during the growing season, organic material builds up at the surface and forms a mat. Plants and micro-organisms in the underlying soil use up soil oxygen, creating an *anaerobic* (oxygen-deprived) condition. Over time, this soil turns bluish gray

2 When you conceptually extend the soil profile, with its horizons, outwards horizontally into surrounding material, you create a 3-dimensional soil unit called a *pedon*. A soil pedon is "...the smallest volume that can be called 'a soil.' It has three dimensions: it extends downward to the depth of plant roots or to the lower limit of the genetic soil horizons; its lateral cross section... ranges from from 1 to 10 square meters in size depending on the variability in the horizons" (SCSA 1982:120).

through a process called ***gleization***. Soil color reflects duration of soil saturation and anaerobic conditions. If these soils are oxygenated for some period, iron oxides become segregated, creating a mottled appearance (small areas of reddish material surrounded by a matrix of gray). As periods of saturation increase, the *gleyed* soil exhibits increasingly uniform gray and bluish colors.

During wet periods, poorly drained soils are easy to locate: dig a hole and it fills with water. During dry periods, mottled appearance or dull gray and bluish colors indicate that the soil is saturated during the growing season. If saturated horizons are close to the surface, these soils are classified as wetlands. If saturated horizons are lower in the soil profile, they may not be classified as wetlands, but drainage may still be poor enough to affect some kinds of development.

SOIL PROPERTIES DETERMINE SOIL BEHAVIOR. SOIL BEHAVIOR DETERMINES WHAT HAPPENS WHEN YOU USE SOILS IN PARTICULAR WAYS.

Organic soils (soils that, like peat, are very high in dead, undecomposed plant material) occur throughout the area. Organic soils develop through a process called ***paludification***. Organic debris accumulates in upland areas with restricted permeability, in water-holding depressions, and in areas with seeps. These soils can also develop under water, for example in cutoff stream channels and oxbows. In these cold, wet areas, organic material builds up faster than it decomposes. Eventually, undecomposed material creates a thick, water-holding mat, and plants that can't tolerate wetness die. With time these areas generally become muskegs. Obviously, these soils are not suitable for most land uses.

Soil properties and land uses

Soil properties determine soil behavior. Soil behavior, in turn, affects how you can use or manage a parcel of land, and what costs you'll incur in doing so. For example, the soil property "texture" affects a number of soil behaviors, including "permeability" (ability to transmit fluids through the soil) and "water holding capacity" (ability to retain water in the soil). These in turn influence other soil behaviors, such as "susceptibility to frost heave."

Soil behaviors like "permeability" or "susceptibility to frost heave" affect how soils behave when used for specific purposes. A soil with low permeability will not have adequate "percolation" for a septic system drain field. A soil that is highly permeable, on the other hand, may not filter out septic system effluents. A soil with a high susceptibility to frost heave may crack foundations or make roads impassable. The soil property "texture" can itself affect soil suitability for some uses; for example, suitability as a source of gravel.

Soil properties that present obstacles to development are called soil *limitations*. We've already illustrated a few of these: "permeability" that's too low or too high for septic system drainfields; "susceptibility to frost heave" that's too high for foundations or road beds. Another common soil limitation in the study area is the high "erodibility" of the silty sediments that mantle lands along much of the river. Highly erodible soils should be used in ways that prevent erosion. (One reason to be concerned about erosion of silty material into the river is that it can cause siltation of salmon spawning gravels.) Figure 4 shows the relationship between soil texture and erodibility by wind and water.

Some soil properties, such as texture, are measured directly; others are inferred from those that are measured. In Table 3, we list the most significant soil properties examined during the Kenai River study, along with the soil behaviors that can be determined from measured soil properties.

Figure 4. Relationship between soil texture and erodibility.

water erodibility	sand	loamy sand	clay	sandy loam, silty clay	sandy clay, clay loam, sandy clay loam	loam, silty clay loam	silt loam	silt
LOW →								HIGH
wind erodibility	wet soils, rocky soils	silt	clay loam, silt loam	loam, sandy clay, sandy clay loam	clay, silty clay, silty clay loam	sandy loam	loamy sand	sand

Table 3. Soil properties examined in the Kenai River study corridor and the soil behaviors they influence.

Soil property	Soil behavior/limitation
Surface texture and rock fragments	-- erodibility -- surface requirements for recreational activities -- water holding capacity
Subsurface texture and rock fragments	-- subsidence and bearing capacity -- caving of cutbanks -- excavation difficulty -- frost action -- permeability rates (too slow, too fast)
Depth to watertable	-- anaerobic conditions -- equipment limitations -- wetness -- plant limitations -- recreational limitations
Slope	-- equipment limitations -- recreation limitations -- engineering design requirements -- erosion

Flooding is a major site limitation for all land uses. Flood-prone areas have not yet been identified accurately enough to include on maps as detailed as those presented in Chapter VII. If you want to know whether or not your parcel is in the "regulatory floodplain" (the 100-year floodplain), contact the Kenai Peninsula Borough Planning Department (see Chapter VI).

Distribution of soil properties

Certain soil properties are fairly easy to measure and predict over uniform landforms, for example, texture and thickness of the surface layer, amount and size of coarse fragments in the underlying material, and soil reaction (pH). Other soil properties are difficult to measure in the field or can't be depicted accurately on maps because of complex distribution patterns, fluctuations over time, or random occurrence. For example, strata and texture of alluvial deposits can vary greatly over short vertical and horizontal distances. In addition, more recent alluvium on the surface often conceals clues to the composition and variability of underlying material.

NOT EVERY SOIL CAN BEAR ALL THINGS.
— VIRGIL
(70 - 19 BC)

Watertables on floodplains and low river terraces may also be hard to map: they often fluctuate as nearby river levels rise and fall. Sometimes watertables can be observed directly; sometimes they can be inferred by indicators such as mottles in fine textured material. Unfortunately, many Kenai River soils have coarse textured substrates, and indicators of saturated conditions (presence of the watertable) are not present. And of course, soil scientists visit relatively few places during the actual occurrence of seasonal high water.

Another soil feature whose distribution is hard to map in the Kenai River study area is a layer cemented by iron and manganese. Most often this layer is 1 to 2 feet thick and several feet below soil depths normally observed during mapping. It generally occurs where groundwater seeps through low river terraces that occupy positions in front of high terraces or glacial moraines. Muskegs or areas of wet soil commonly occur on these low terraces. This cemented layer may reflect past or present watertable fluctuations. Whatever its cause, this layer may present development problems because it could be difficult to excavate and is relatively impermeable. Its presence or absence should be determined if these limitations may cause problems. For example, effluent from septic systems would not permeate this cemented layer, but would instead move horizontally. In several areas along the river, however, this cemented layer provides some degree of resistance to streambank erosion.

Land use interpretations

During the Kenai River soil investigation, boundaries of individual soils were drawn on aerial photos (like the one on the back cover) and later transferred to a computerized geographic information system (GIS) base map. Areas outlined on soil maps (see Chapter VII) are called *map units* or *soil polygons*. Some map units are made up of one kind of soil, others are made up of two or more kinds of soil. Areas mapped as gravel pits or "madeland" are considered miscellaneous land types. Soil properties relevant to use and management of soils were determined and recorded (see Table 3). In addition, other information, such as soil color and diagnostic horizons, was noted so that soils mapped during this investigation could be correlated with the national system of soil taxonomy at a later date.

Soils data collected in the field were supplemented with information on soil-vegetation relationships, operation of septic systems, and other background knowledge that could indicate how a particular soil might behave when used or managed in a specific way.

A classification system was developed to group together soils that have similar physical and chemical characteristics and, therefore, respond in much the same way to similar land uses and management. These soil groupings were then *interpreted* and rated in terms of their *limitations* and/or *suitability* for particular land uses (see Table 4). Interpretations were made for ten land uses likely to occur along the Kenai River. These are:

1. septic tank absorption fields
2. shallow excavations
3. dwellings without basements
4. dwellings with basements
5. small commercial buildings
6. local roads and streets
7. lawns and landscaping
8. grassed waterways
9. camping areas
10. paths and trails

Interpretations are based on national Soil Conservation Service guidelines (SCS 1983), but they can be modified in the future if local conditions and experience warrant. In addition, other land use interpretations can be developed in the future with the soils data base now available.

Table 5 shows soil properties, behaviors, and site conditions relevant in interpreting soils for particular land uses. The table is divided into engineering uses of soils (covering land uses 1 through 8 above) and recreational uses (land uses 9 and 10). Engineering uses are further subdivided into: building site development, sanitary facilities development, and water management.

MANKIND, IN SPITE OF HIS SOPHISTICATION AND HIS ACCOMPLISHMENTS, THE ARTS AND SCIENCES, OWES HIS VERY EXISTENCE TO A SIX INCH LAYER OF TOPSOIL AND THE FACT THAT IT RAINS.
— AUTHOR UNKNOWN

Table 4. Soil "limitation ratings," "suitability ratings," and their defintions (from SCS 1992b).

Limitation ratings	Suitability ratings
Slight: This rating is given to soils that have properties favorable for the use. The degree of limitation is minor and can be overcome easily. Good performance and low maintenance can be expected.	**Good or Well Suited:** The soil has properties favorable for the use. There are no soil limitations. Good performance and low maintenance can be expected. Vegetation or other attributes can easily be maintained, improved, or established.
Moderate: This rating is given to soils that have properties moderately favorable for the use. This degree of limitation can be overcome or modified by special planning, design, or maintenance. The expected performance of the structure or other planned use is somewhat less desirable than for soils rated "slight."	**Fair or Suited:** The soil is moderately favorable for the use. One or more soil properties make these soils less desirable than those rated "good" or "well suited." Vegetation or other attributes can be maintained, improved, or established, but a more intensive management effort is needed to maintain the resource base.
Severe: This rating is given to soils that have one or more properties unfavorable for the rated use. This degree of limitation generally requires major soil reclamation, special design, or intensive maintenance. Some of these soils, however, can be improved by reducing or removing the soil feature that limits use, but in most situations, it is difficult and costly to alter the soil or to design a structure so as to compensate for a severe degree of limitation.	**Poor or Poorly Suited:** The soil has one or more properties unfavorable for the use. Overcoming the unfavorable property requires special design, extra maintenance, or costly alteration. Vegetation or other attributes are difficult to establish or maintain with the results being questionable.
Very Severe: States have an option to use "very severe" ratings within a survey area. "Very severe" is a subdivision of the "severe" rating... A soil rated "very severe" has one or more features so unfavorable for the rated use that the limitation is very difficult and expensive to overcome... An example would be use of soil with bedrock at less than 20 inches for a septic tank filter field.	**Unsuited:** The expected performance of the soil is unacceptable for the use, or extreme measures are needed to overcome the undesirable properties or qualities.

Table 5. Soil properties, behaviors, and site conditions related to the suitability of different areas for particular land uses.

	Soil uses	Soil properties related to suitability for rated use.	Soil behaviors and site conditions related to suitability for rated use.
	ENGINEERING USES		
Building site development	Shallow excavations for: pipelines, sewerlines, utility lines, basements, and open ditches	-- texture -- dense soil layers or large stones	-- high water table -- sloughing -- slope -- flooding
	Dwellings with or without basements	-- texture -- engineering properties	-- high water table -- slope -- flooding -- frost action
	Local roads and streets	-- texure -- dense soil layers or large stones -- engineering properties	-- high water table -- slope -- flooding -- frost action
	Lawns and landscaping	-- texture -- large stones -- soil reaction (pH)	-- high water table -- slope -- flooding -- available water holding capacity
Sanitary facilities	Septic tank absorption fields (soils rated to 6 ft depth)	-- texture -- large stones -- impermeable layers	-- high water table -- slope -- flooding -- permeability
Water management	Grassed waterways	-- texture	-- high water table -- slope -- permeability -- erodibility -- suitability for permanent vegetation
	RECREATION USES		
	Camp areas	-- texture -- large stones	-- high water table -- slope -- flooding
	Paths and trails	-- texture -- large stones	-- high water table -- slope -- flooding -- erodibility

(2) Using soils information on your land

The soils investigation conducted during the Kenai River Cooperative River Basin Study was tailored specifically for lands along the Kenai River and the residential and recreational developments most likely to occur. **Soils data were collected that could help Kenai River landowners: (1) identify what areas are best suited for particular land uses, and (2) understand what kinds of soil limitations they might find when trying to develop different areas.**

If you want to learn about the soils on your property, take a moment to look up your area on one of the soil maps in Chapter VII. Outlined areas are *soil map units* (also commonly called *soil polygons*). Each has a numbered code, such as 1126B; this is a *map unit symbol*. Table 6 provides a map legend you can use to find out what a particular map symbol means. There may also be another code (e.g., 90/DV/129/02) in smaller print in your map unit; this is a *soil profile identifier*. It tells you that a soil pit was dug at that location by the soil scientist so he could observe and describe the soil profile there (illustrated in Figure 3).

Collected soils data were used to rate the suitability of soils for ten land uses common along the Kenai River (listed above and referenced in Table 5). As explained above, soil suitability ratings and limitation ratings are based on measured soil properties and on inferences about soil behavior derived from known soil properties.

How do you determine how your soils rate for a particular land use? Unfortunately, we don't have room in this *Guide* to list how the hundreds of mapped soil codes were rated for each of the ten assessed land uses. That information will be presented in the "Technical Report" of the Kenai River Study (due in Spring 1993). When the "Technical Report" is completed, reference copies will be distributed to a number of agencies and libraries, including:

Soil Conservation Service, Anchorage and Homer
Cooperative Extension Service, Soldotna
Kenai Peninsula Borough, Soldotna
City of Soldotna
City of Kenai
Soldotna Public Library
Kenai Public Library
Homer Public Library
Bureau of Land Management Library, Anchorage
Loussac Library, Anchorage.

You will then be able to use the "Technical Report" yourself to look up particular soil interpretations. In the meantime, if you'd like to know how a soil is rated for one of the land uses so far considered, you can do the following:

Locate your areas of interest on the index map in Chapter VII; then turn to indicated map sheet(s). Note map unit symbol(s) — e.g., 1216B — that apply to your areas. Jot these down and call the SCS Homer Field Office (907-235-8177). We have a software program that allows us to enter a soil symbol and find out how that soil is rated for any of the ten land uses.

Soils can be rated using: (1) *limitation* ratings or (2) *suitability* ratings (see Table 4). "Limitation ratings" identify the type and degree of limitation that affects the use of a site for a specific purpose. These ratings range from "slight" (essentially no soil limitations) to "severe" (limitations that make a particular soil unfavorable for a rated use). "Suitability ratings" identify the degree that a soil is favorable for a given use. These ratings range from "good" or "well suited" for the use to "unsuited" for the use. Soils are rated in their "natural" state; that is, not modified in unusual ways.

Engineers and others can often modify limiting features, or they can adjust designs to compensate for limitations. Such modifications, however, are often costly. You may be willing to accept a few soil limitations, provided they don't lead to violations of local or state codes or regulations. The final choice of a site for a particular land use is personal and involves weighing costs of site preparation and maintenance against benefits of location.

Table 6. Soil connotative legend (a key for interpreting soil *map unit symbols*).

Surface texture	(PSC) 1/ (10-60")	Texture 3/ (24-60")	Watertable	Slope %
1 = SIL, VFSL	1 = <15% cos frags >3" by vol	1 = S, FS, LS, LFS	0 = 0-1'	A = 0-4
2 = COS, S, FS	2 = 15-35% cos frags >3"	2 = SL, FSL	1 = 1-2'	B = 4-8
3 = SIC, C, SC	3 = >35% cos frags >3"	3 = L, SIL, SCL, VSFL	2 = 2-4'	C = 8-15
4 = ALL others (FSL, SL, etc.)	4 = high shrink-swell	4 = SICL, SC, SIC,C	4 = 4-6'	D = 15-25
5 = Pt (>8")	5 = OL, OH, Pt 2/	5 = Pt	6 = >6'	E = >25
6 = Gravelly (15-35% by vol)			7 = ponded 4/	
7 = Very gravelly (35-50%) by vol			8 = perched 4/	
8 = >50% coarse fragments				

Map unit examples:

1210A = Silt loam surface, cobbly PSC, sandy (rapid permeability), watertable 0-1', 0-4% slope.

2326B = Sandy surface, very cobbly PSC, sandy loam (moderately rapid permeability), 4-8% slope.

Texture terms: (USDA)

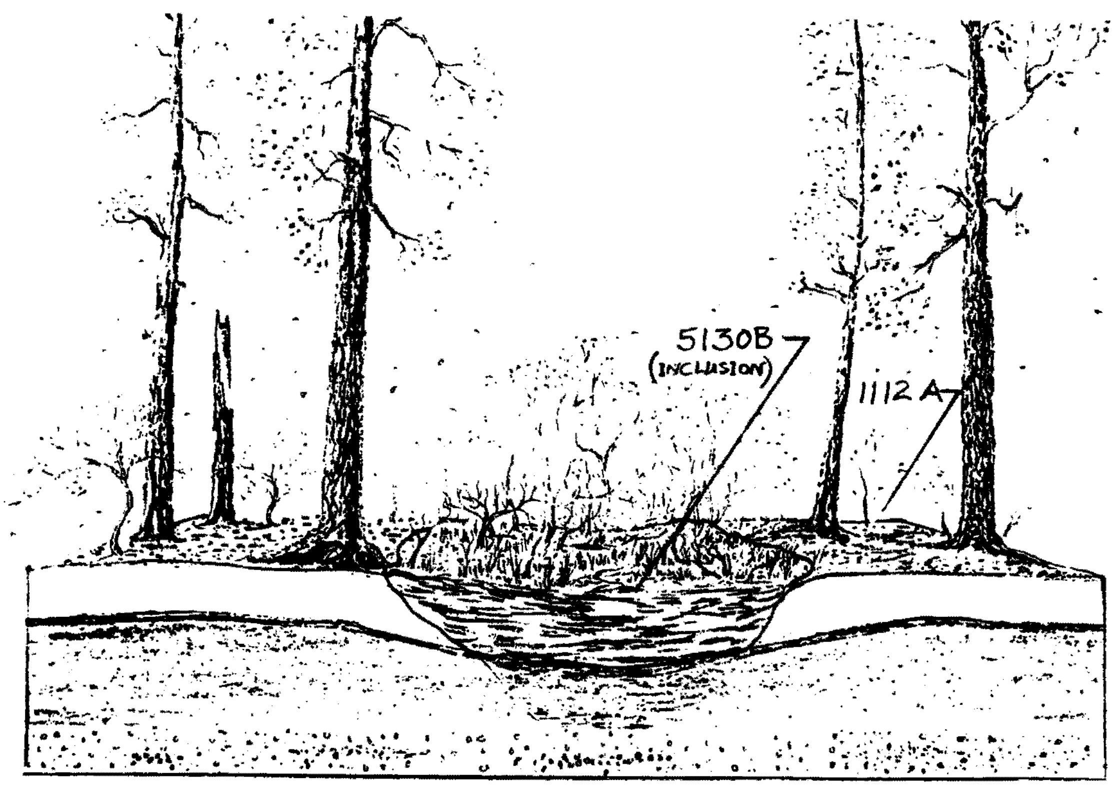
COS	Coarse sand	VFSL	Very fine sandy loam
S	Sand	L	Loam
FS	Fine sand	SIL	Silt loam
VFS	Very fine sand	SI	Silt
LCOS	Loamy coarse sand	SCL	Sandy clay loam
LS	Loamy sand	CL	Clay loam
LFS	Loamy fine sand	SICL	Silty clay loam
LVFS	Loamy very fine sand	SC	Sandy clay
COSL	Coarse sandy loam	SIC	Silty clay
SL	Sandy loam	C	Clay
FSL	Fine sandy loam	Pt	Peat
<	less than (e.g., 1<2)	>	greater than (e.g., 2>1)

Footnotes:

1/ Particle size control section; "cos frags" = coarse fragments
2/ Restrictive feature (O = organic): subsidence and/or low strength
3/ For permeability determination
4/ Ratings same as 0-1' watertable group (not used throughout survey)

It's important to understand the limitations of soils information presented here and in the "Technical Report." Soil maps and tables provide generalized information about the soils in an area. SCS maps are designed to answer certain kinds of questions at a certain scale (see Chapter VII). What soils maps are very *good* at showing is the *likelihood* or *probability* that particular conditions will be found in a particular soil map unit. The probability is generally about 85% that you will find soils similar to those indicated by the map unit symbol at any specific location in the map unit. That means that there's a 15% chance that *at any spot* in that map unit, you will find completely *different* conditions. These *inclusions* of contrasting conditions, too small to map, are unavoidable unless you map square yard by square yard across your property (and even then, you might have contrasting inclusions of a square foot or so within your square yard mapping unit). Figure 5 provides an example of what an unmapped soil inclusion looks like. What this means is that, **useful as soil maps are for planning purposes, they DO NOT eliminate the need for onsite investigations** when you're deciding exactly where to locate a particular development. (Map scale and its implications are discussed in greater detail at the beginning of Chapter VII.)

Figure 5. A "contrasting inclusion" too small to map in a soil map unit. (The world is full of "contrasting inclusions" no matter what scale you map at.)



C. USING PLANT INFORMATION

Using plants to improve your property

If your parcel is well-covered with mature trees and shrubs, as are most parcels along the Kenai River, you have a head start on enjoying the benefits plants provide landowners. You need only decide how to maximize benefits from your plants, and then take care of them (see Selecting, obtaining, planting, and caring for plants). If your lot is cleared, you can start planting even if you aren't sure what developments will go where. Just plant in areas where development is least likely. Plantings can produce rewards surprisingly quickly once they're in the ground.

Below, we outline twelve ways to use plants to improve your property. This list is just a start. We don't consider how to use plants for a variety of personal uses, including: cottage industries and crafts, food, medicines, cosmetics, teas, liqueurs, syrups, etc. Information on these uses is found in *Tanaina Plantlore* (Kari 1987), *The Forgotten Crafts* (Seymour 1984), *Discovering Wild Plants* (Schofield 1989), and other publications.

Plants also provide the best ways to protect riverbanks from erosion and to protect and improve river edge habitats for salmon and other aquatic life. Their uses for these purposes are discussed in more detail in: Using riverbank information (Section D of this chapter).

TWLEVE WAYS TO USE PLANTS TO YOUR ADVANTAGE.

(1) Use plants to protect your privacy. Even along the Kenai River, privacy can be an issue. In some ways, living on the river is not unlike living on a road, only the traffic consists of boats. On a busy Saturday during a strong king salmon run, hundreds of boats use the lower river, and most of them make several trips up and downstream during the day.

In addition, Kenai River landowners encounter the same kinds of intrusions as landowners elsewhere, including disturbances from neighbors, roads, nearby businesses, etc. For most river landowners, disturbances are likely to increase in the future because typically only a few lots have been developed in most Kenai River subdivisions. As a result, most landowners are surrounded by less development now than they will be in the future. Some landowners have purchased "buffer" lots next to the parcel they plan to develop in order to guarantee more space and privacy. But for many landowners, the most cost-effective way to ensure long-term privacy will be through plantings that screen them from neighboring lots. *Landscape Plant Materials for Alaska* (CES 1980)[1] provides information that can help you choose plants that will be effective and attractive screens.

As you plan your property, think ahead into the future as far as possible before deciding to cut any mature trees or shrubs. Whatever you cut now can take years to replace. Think about where development may occur around you and how you might want to be screened from it.

It can help you envision the future somewhat to look at your subdivision plat map (and maps of adjoining subdivisions) and read any covenants that apply. Covenants define what kinds of activities are allowed in a particular subdivision and are enforceable by surrounding landowners. Check with the Land Assessment office of the Kenai Peninsula Borough or with local realtors for information on plat maps and subdivision covenants.

If you're in a city that has a general plan or a zoning code, you can find maps that show what land uses are permitted in your area. The City

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1 Chapter VIII, References, suggests how to get books mentioned in this *Guide*.

of Soldotna, for example, zones different areas for different land uses. In addition, it has established a "Kenai River Overlay District" along the river. Most developments within the Overlay District must be approved in advance by the city's planning and zoning commission (see Chapter II). Check with the planning director of the city you're in for further information on land use guidelines.

If your area isn't covered by covenants, zoning, or any other kind of land use plan, there are few or no restrictions on what kinds of developments can occur nearby (that is, the Borough does not specify which areas will be residential, recreational, commercial, industrial, etc., so any land use can be located almost anywhere. The *Kenai River Comprehensive Management Plan* (Alaska Department of Natural Resources 1986) lists developments considered compatible with the biological functions of lands along the Kenai River, but the list is advisory except on state-owned lands.

A KEY TO EFFECTIVE PLANNING IS PREDICTING WHAT MAY HAPPEN IN YOUR AREA IN THE FUTURE SO YOU CAN ACT ACCORDINGLY.

Despite the difficulty, it's worth trying to predict what may happen on surrounding lands. A key to effective planning is anticipating what your area will look like in the future so you can act accordingly. This is certainly true when it comes to planning where to use trees and shrubs to maintain long-term privacy.

(2) Use plants to improve habitat conditions for fish and wildlife. If you landscape or garden or mow your lawn or never give your plants more than a passing glance, you manage wildlife. In fact, **if you own land in Alaska, you manage wildlife.** And if you own property along a river or lake, you also manage fish. Whatever action (or inaction) you take makes things better or worse for particular species. As a result, it makes sense to think about the fish or wildlife management program you're intentionally or unintenionally conducting. That way you can focus on benefiting animals you value and discouraging animals you don't. The following discussion focuses on how to manage your property for particular birds or mammals. The relationship between riverbanks and fish later in this chapter focuses on how to manage your property to improve fish habitat.

Tables 5 and 6 in Chapter II list birds and mammals that use the Kenai River corridor; these are the species you may be able to attract to your property. The tables also indicate the general kinds of habitats each species prefers. To use these tables, it helps to know which kinds of habitats your property does or could support. You can use plant maps in Chapter VII to identify which plant communities are found on your property. The section: Plant communities along the lower Kenai River, later in this chapter, can help you fit mapped plant communities into broad habitat types used in Tables 5 and 6. (Call the Soil Conservation Service, U. S. Fish and Wildlife Service, or Alaska Department of Fish and Game if you have questions about what habitats your plant communities represent.) Once you know which habitat types occur on your lands (or could, with proper management), you can use Tables 5 and 6 to find out which birds or mammals you might attract with habitat improvements.

Plants offer the best means to improve habitat conditions on your property. For most animals, plants determine whether or not an area is suitable for feeding, hiding, displaying to potential mates, nesting, or raising young. Plants themselves provide food, shelter, nesting sites, song or hunting perches, or other habitat requirements. For predators like fox, owls, weasels, and hawks, plants harbor the insects and small animals on which they feed, as well as providing shelter and concealment while hunting. (Some animals, however, also need non-plant habitat features, like boulders or cliffs or certain kinds of open water.)

To attract particular species to your land, you need to make sure that your property provides the habitat features they need. Field guides and other natural history publications can help you identify these features. In addition, some publications suggest how to improve your property for particular species or for wildlife in general. A few of these are listed below. Figure 6 illustrates a bare lot that has been transformed into a landscape designed to attract wildlife.

The Backyard Naturalist (Tufts 1988)
Enhancement of wildlife habitat on private lands (Decker and Kelley no date)
Gardening with wildlife kit (NWF no date)
Landscaping for wildlife in Alaska and *Winter bird-feeding in Alaska* (ADF&G Nongame Wildlife Program 1982)
Managing small woodlands for wildlife (Gutierrez et al. no date)
Wildlife and timber from private lands: a landowner's guide to planning (Decker et al. no date)

TO ATTRACT PARTICULAR WILDLIFE SPECIES TO YOUR LAND, YOU NEED TO MAKE SURE THAT YOUR PROPERTY PROVIDES THE HABITAT FEATURES THEY NEED.

You can get help from the Alaska Department of Fish and Game (particularly the Nongame Section in the Division of Wildlife Conservation), the U.S. Fish and Wildlife Service, and the Soil Conservation Service in selecting plantings for particular wildlife species. (See Chapter VI for addresses and phone numbers.) If you want to encourage bald eagles to use your property, you'll want to get a copy of the free publication: *Bald Eagle Basics — Alaska* (USFWS 1992).

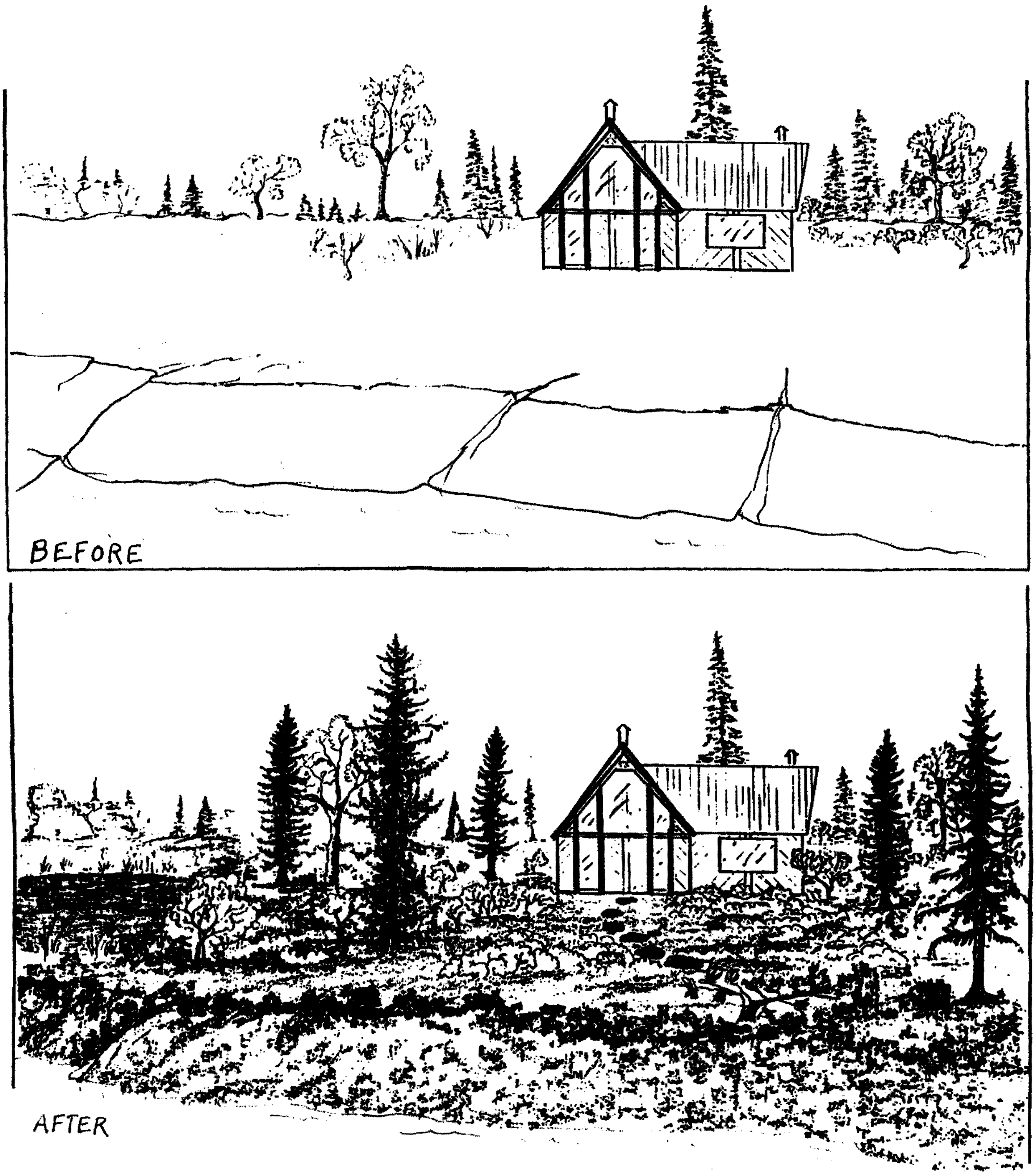
(3) Use plants to improve aesthetics. Plants are the primary resource you can easily modify to improve the aesthetics, or attractiveness, of your property. They can be used to enhance aesthetics in numerous ways. Many excellent books and magazines suggest ways to improve your property through landscaping. *Landscape Plant Materials for Alaska* (CES 1980) is a good place to start. A quick look at it or any other reference will stimulate ideas.

If you have a cleared or weedy lot and want to re-create a natural setting, walks through nearby undisturbed plant communities will suggest many possibilities. (And with the landowner's permission, possible sources of material to transplant to your property.) If you want to know which plants make up particular plant communities along the Kenai River, refer to plant information in this chapter and Chapter VII. Soil maps in Chapter VII can be used to identify what kinds of soils specific plant communities grow on. You can compare soils in your area with soils that support plant communities of interest to see if your property seems suitable for particular kinds of plants.

As you collect ideas, think about what you want to emphasize or camouflage on your property and what plant characteristics (flowers, fruits, form, color, texture, height) would be effective in different locations. Trees and shrubs can be used to frame or enhance views, to create a sense of sanctuary, to enhance perspective, to conceal eyesores, to visually unify an area, and to reduce reflections or glare from surfaces like water or snow.

If your landscaping ideas involve removing large trees or shrubs, consider how this might affect riverbank stability or adjacent fish habitats (see Riverbanks later in this chapter). Often pruning the lower branches from trees or the tops off shrubs can open up views or let in sunlight just as well as removing entire plants (see Figure 8). Also, topping shrubs often stimulates stump sprouting, which can make shrubs more effective as bank stabilizers, as hedges, and as wildlife food and cover.

Figure 6. A landscape designed to encourage birds and mammals.



(4) Use plants to protect water quality.[1] Plants protect water quality in a number of ways. The principal way is by providing ground cover that minimizes soil erosion. Ground cover slows overland flows of runoff water. Slow flows can't carry as much sediment as fast flows, so less sediment is picked up and washed into nearby water bodies. Plants that cover the ground also physically protect underlying soils from runoff flows, which also protects them from erosion. When lack of adequate ground cover leads to increased erosion into streams, sediments can plug spawning gravels, suffocate salmon eggs, and bury aquatic plants and insects that provide food for fish.

Ground cover such as grasses and forbs can also be used to remove excess nutrients and pesticides that are often carried into streams and lakes with soil particles. Agricultural lands, gardens, lawns, and road ditches are all sources of excess nutrients, pesticides, and other kinds of runoff that can degrade water quality.

IF MANY KENAI RIVER LANDOWNERS IMPROVE BANK-EDGE AND INSTREAM HABITATS, THEIR EFFORTS CAN HAVE A CUMULATIVELY LARGE POSITIVE EFFECT ON FISHERIES. THE REVERSE IS ALSO TRUE.

Soil erosion can be controlled best by matching appropriate plant species with particular site conditions and needs. Sod-forming grasses, for example, can be used as effective surface filter systems, while the root systems of trees and shrubs can be used to anchor streambanks (see Maximizing riverbank stability). Root systems also increase soil porosity and tilth, thus increasing water infiltration into groundwater recharge areas. Stored groundwater enters rivers and streams more slowly than surface flows; this delayed discharge is critical in maintaining streamflow levels during dry periods and winter months. In addition, as more water infiltrates during storms, less enters stream channels as floodwaters.

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1 This section was written by Dan LaPlant, SCS State Biologist.

Water quality also includes water temperatures. Plants bordering the river shade bankside areas and moderate temperatures there during summer months. In many areas of the Kenai River, small temperature differences caused by grasses, shrubs, and trees overhanging shallow stream-edge areas can mean the difference between environments that are suitable for survival and growth of salmon fry and environments that aren't.

(5) Use plants to improve recreation (including fishing). Plants significantly affect the quality of recreational experiences: Just compare fishing at the Homer Spit "Fishing Hole" with fishing on the tree-lined Kenai River. If you use your property for recreational enjoyment, think about how you can manage your plants to enhance your experiences. The preceding discussions on privacy and aesthetics and the following comments on windbreaks should give you some ideas.

In addition, The relationship between riverbanks and fish later in this chapter discusses how bank-edge vegetation benefits fish, and suggests ways you can protect and improve fish habitat with plantings. If many Kenai River landowners improve bank-edge and instream habitats, their efforts can have a cumulatively large positive effect on fisheries (just as, if many river landowners damage fish habitats, their actions can have a cumulatively large negative effect). Protecting and improving fish habitat quantity and quality can mean more fish all along the river and well into the future.

(6) Use plants to improve air quality. Plants absorb carbon dioxide and release oxygen; this process slows the build-up of atmospheric carbon dioxide, thus slowing development of the "Greenhouse Effect." In addition, large areas of leaf surface trap airborne particulates such as dust and pollen; and some green plants remove pollutants such as sulfur dioxide, carbon monoxide, nitrogen oxides, and other airborne chemicals.

(7) Use plants to increase property values. If you've ever tried purchasing large trees or shrubs for landscaping, you know how valuable plants can be. Real estate ads often cite "mature landscaping" in their promotional descriptions because realtors know how much buyers value this amenity, particularly in recreational areas where buyers are looking for attractive places where they can "get away."

Landscape Plant Materials for Alaska (CES 1980) describes a method for calculating the landscape value of particular trees. Using this method, we calculated the landscape value of several hypothetical trees to give you some idea of what their replacement costs would be. (The value of trees for firewood and building materials is discussed under (9) below.)

For a birch tree in good condition, with good form, located on a Kenai River subdivision lot, and having a diameter of 12 inches (in the method used here, 5-12 inch diameters are measured 1 ft above the ground): value = $1454; for a similar birch on the same lot, with a diameter of 3 inches (2-4 inch diameters are measured 6 inches above the ground): value = $165.

For a cottonwood in fair condition, with fair form, and having a diameter of 18 inches (diameters over 12 inches are measured 4.5 ft above the ground), located on a residential lot on the Kenai River: value = $1090.

For a white spruce in excellent condition, with excellent form, and having a diameter of 15 inches (measured 4.5 ft above the ground), located in the front yard of a Kenai River lot: value = $1717; for the same tree located in a dense forest on a 10-acre parcel: value = $382.

Big trees are like money in the bank. The following section on plant propagation and care provides guidelines on how to protect your growing assets. If you don't have "mature landscaping," the sooner you start planting, the sooner you will.

(8) Use plants to reduce energy costs. Energy savings can be realized by using trees to keep a site warmer or cooler than it would otherwise be. A useful rule of thumb in this regard is to plant deciduous trees on the south and west sides of your home and evergreens on the north and east sides. The deciduous trees will block the hot summer sun, but let in winter sun after leaf fall; the evergreens will block cold northern winds.

"Precision landscaping" can get much more sophisticated than this. Figure 7 illustrates a parcel that has been "precision landscaped" to gain a number of benefits (from Johnson et al 1990).

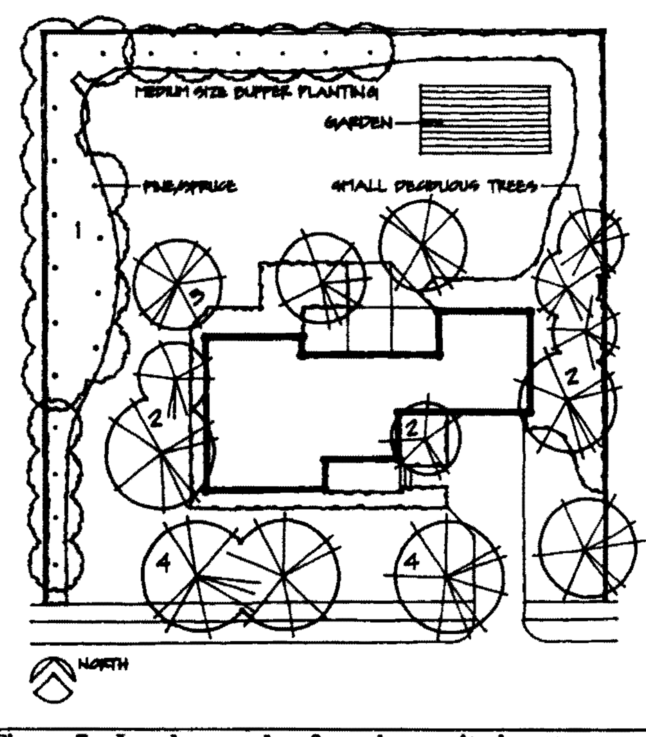


Figure 7. Landscape plan for a home site in a temperate portion of the country with prevailing winter winds from the northwest and summer breezes from a southerly direction (from Johnson et al. 1990:21).

The following benefits are gained by the landscaping shown in Figure 7.

1. Coniferous windbreaks block winter winds.
2. Trees on east and west sides provide summer shade.
3. This tree provides shade as the sun sets in midsummer. [In Alaska, summer sun can set even farther north.]
4. Trees on the south side should be species that grow tall enough for lower branches to be pruned to let in winter sun (see Figure 8).

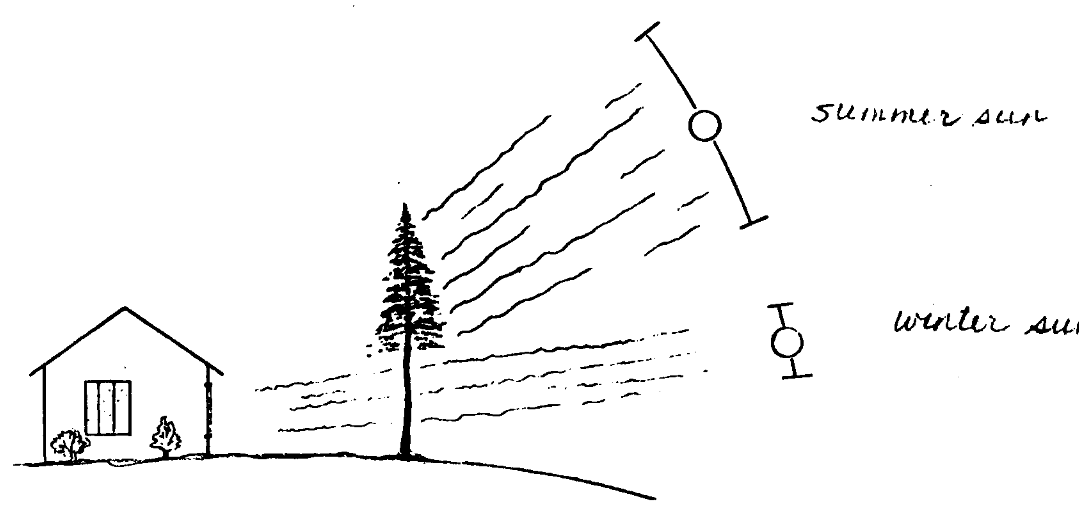
The year-round effect of foundation plantings seems never to have been measured, but they would be expected to also be energy savers if they do not shade windows in the winter.

Although most of the Kenai River corridor is still a well-forested environment, and thus largely protected from strong winds, some areas may still benefit from windbreaks. Windbreaks can reduce your energy costs up to 10-25% if wind blowing against your buildings significantly increases air-exchange rates (Wight and Clifton 1988). Also you may benefit by sheltering outdoor areas where you work, play, or grow food. (Yields from gardens and fruit trees protected by windbreaks are higher than from those in unprotected sites.)

If you want to plant a windbreak, you'll need to consider a number of factors in your design. These include: windbreak height, length, orientation, continuity, density, number of rows, row spacing, as well as plant species adapted to the site and the direction of winds you want to block (both prevailing winds and those that are intermittent but troublesome). An additional critical factor is distance of windbreaks from areas being protected. (If protection from wind is the goal, the tallest row of windbreak plants is generally located 2 to 5 times the row's height (2H to 5H) from leeward areas being sheltered. If snow capture is critical, the most windward row of the windbreak is generally located 90 to 180 feet upwind from areas you want to keep free of snow.)

Careful windbreak design is important. An incorrectly designed or installed windbreak won't provide the protection you want. In addition, it can cause problems such as snow drifts where you don't want them (on your driveway, for example) or increased airflow through unintentional gaps. (On the other hand, accelerating wind speed with carefully located plantings can sometimes keep roads blown free of snow (Younker et al 1990).) The Soil Conservation Service can help you design a windbreak that fits your site conditions and meets your objectives.

Figure 8. Trees can provide summer cooling without blocking winter sun. Also, removing low branches increases views without cutting down trees.

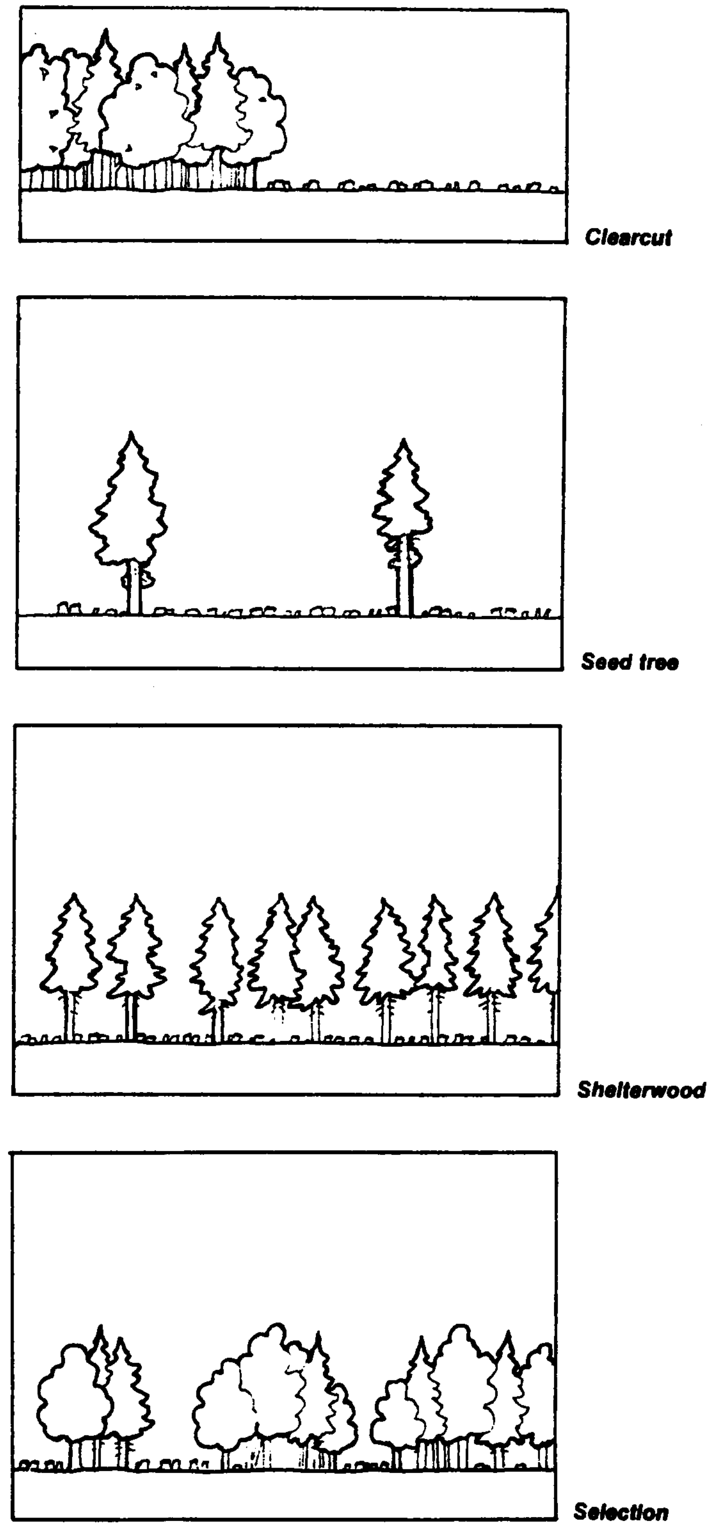


(9) Use plants as a renewable source of fuel and building material.[1] If you have forested land, you probably have opportunities to produce some wood products. Of course, great care must be taken in deciding how to manage the forest adjacent to the river to prevent contributing to bank erosion and damage to fish habitats. The Alaska Forest Practices Act requires that any commercial timber harvest that occurs on private land within 100 feet of the shore or bank of the Kenai River be sited and designed primarily to protect fish habitat and surface water quality from significant adverse effects. In addition, if 40 acres or more are involved in a forestry operation, the provisions of the Forest Practices Act apply and should be studied before proceeding.

Much of the forest along the lower Kenai River has reached mature age (see Overstory Plant Communities, later in this section). Mature trees can be harvested and young trees established to replace them by several different *silvicultural systems* (Figure 9). (Silvicultural options that remove all or most trees are not recommended adjacent to the Kenai River, even in small areas, because of potential damage to water quality, bank stability, etc.) Once a tree passes maturity, its health and vigor decline and it becomes more susceptible to insects (like spruce bark beetles) and disease (like heart rot decay). Along the lower Kenai River, most trees reach maturity when they are about 8 to 10 inches in diameter (about 25 to 30 inches in circumference at breast height; *breast height* is 4.5 ft above the ground).

If you have younger trees, for example less than 8 inches in *diameter at breast height* (dbh), you may have opportunities for thinning. By thinning a dense stand of trees, more room is given to those trees the landowner considers most valuable. Tree vigor is increased by reducing competition for limited light and soil resources. Without thinning, competition in crowded stands can weaken trees and make them more susceptible to insects and disease.

Figure 9. Various "silvicultural systems" (those that involve removing all or most trees are NOT recommended along the Kenai River) (from Richberger and Howard no date).



1 This section was written by Tom Ward, SCS State Forester.

Whether you harvest and regenerate part of your forestland or thin it, the trees that are cut can provide valuable fuel or building materials. The average mature white spruce stand on the Kenai Peninsula contains about 2,500 cubic feet of usable wood per acre, which is equivalent to about 25 cords of firewood. The average birch stand contains about 17 cords per acre, and the average mixed stand, probably about 20 cords. (Mixed stands are the most common type along the Kenai River. Pure birch or spruce are relatively uncommon.) This average applies to well-stocked, mature stands; if your forest is rather open or somewhat immature or both, you probably have less wood volume. By thinning just 1 out of every 5 trees in the average mixed spruce-birch forest, it may be possible to obtain 2 to 4 cords of firewood per acre. "Firewood thinning" is a good way to clean up the dead, dying, injured, and crooked trees in your forest. Gradually the quality of timber is improved as the poorest trees are removed and more room is given to the best quality trees, decreasing competition and increasing their growth rates.

If you happen to be blessed with a well-stocked stand of high quality mature spruce, you have a ready source of building materials. The same "average" 2,500 cubic foot per acre spruce stand described above should contain about 7,000 to 8,000 board feet of timber (a board foot equals a piece of wood 1 ft by 1 ft by 1 inch). The average 2,000 square foot single family home contains about 15,800 board feet of lumber. If the square foot-to-board foot ratio holds for smaller homes, a 1,000 square foot home would contain about 7,900 board feet, or about the volume of the acre we've been considering. Local sawmills can mill your lumber, or it's possible to mill your own lumber with the variety of portable sawmills and chainsaw attachments on the market. While you may not want to obtain all the lumber to build your home from your own woodlot, you may be able to economically obtain some of the larger dimension boards or timbers that would be very expensive or unavailable at a lumber yard. It may also be feasible to mill enough lumber yourself for smaller projects, such as a garage, barn, or storage shed.

Another popular option for building materials is logs. Everything from a garage or small cabin to a home or commercial lodge can be built from logs. The average 16 by 18 foot cabin will require 50 to 55 logs 20 to 24 feet long and at least 9 inches dbh. In the spruce stand we've been discussing, there might be 100 such trees per acre; perhaps 30 to 50 in a good mixed spruce-birch stand. It may take several acres of mature forest to obtain these logs, or you may want to obtain only a portion of the needed logs from your property. Dead standing trees or beetle infested trees often make good house logs if they haven't been dead too long. Usually lumber can be obtained for 1 to 2 years after the tree has died, while needles remain on the branches or shortly after they've fallen. Trees dead 5 years or more may still be useful as houselogs if heart rot decay hasn't proceeded too far. Usually most of the bark and small branches are gone from a tree that has been dead 5 years or more.

Regenerating your forestland to replace trees that have been cut should be a priority regardless of which method you use to manage your forest. If you plan to rely on natural regeneration from the seeds of nearby trees, a seedbed will have to be prepared. This "site preparation" involves breaking up the groundcover to expose some mineral soil. This can be done mechanically or by burning. *A Revegetative Guide for Conservation Use in Alaska* (CES 1991) provides details for site preparation, some of which are included in the following section on Planting. Tree seedlings can be planted with or without site preparation. Competing vegetation, especially bluejoint reedgrass, will probably have to be controlled to allow tree seedlings to establish themselves.

The harvest of trees can be compatible with other uses, such as wildlife habitat enhancement, recreation, and improving the appearance of your forestland. For example, careful thinning or selection harvesting can improve views of the river, provide recreational access, and increase plants preferred by wildlife. In addition, moose are much more likely to travel through and take shelter in somewhat open forest stands than in those that are so densely stocked that movement between trees is difficult. Openings in forests can create diversity for wildlife and people alike. In addition, selective removal of beetle-infested trees in stands that are largely uninfested may prolong the lives of hundreds of surrounding trees, and thus prolong the benefits these trees provide to humans, wildlife, and the river system. (Assistance is available to plan and carry our forest management on private lands; see forest-related categories in Chapter VI.)

(10) Use plants to reduce noise levels. Although plants are more effective as visual screens than as sound barriers, they can reduce noise levels to some extent. Research indicates that one or two rows of dense shrubs with one or two rows of taller trees behind them can reduce noise from suburban traffic up to 20% (Wight and Clifton 1988). To reduce noise appreciably, plantings should be wide (at least 16 ft, if possible), tall, dense, and planted parallel and as close to the source of noise as possible.

(11) Use plants to direct foot traffic. Plantings are an ideal way to control traffic flow on your property. This is particularly important if you're trying to keep family and friends from scrambling down banks to reach the river. Scrambling down a bank is a good way to make it erosion-prone. Instead, identify a single suitable access route to the water's edge (e.g., a route that's dry, not too steep, and surfaced to prevent erosion) and block other routes with shrubs or trees. If you want to protect your banks more, install a walkway down to and along the river as described in <u>Practical ways to promote riverbank stability</u>.

(12) Use plants to prevent soil erosion. Water quality benefits gained by preventing erosion were discussed under (4) above. Preventing erosion is also critical in maintaining long-term soil productivity. Topsoil forms slowly, and if yours washes away, it becomes much harder to grow plants for any of the beneficial purposes discussed in this *Guide*. How plants prevent erosion, and how to maximize their erosion-control effectiveness, are discussed under <u>Maximizing riverbank stability</u>.

Selecting, obtaining, planting, and caring for plants

(1) Selecting plants

Your first goal when selecting plants is plant survival. Are the plants you're choosing adapted to the conditions they'll encounter once they're planted? Site conditions include climate and microclimate (particularly temperature, moisture, and growing degree days), aspect (which affects microclimate), depth to water table, and a number of soil conditions (including texture, depth, drainage, and pH). Chapter II provides information on Kenai Peninsula climates; soil sections in this chapter, as well as soil maps in Chapter VII, provide information on soil conditions along the lower Kenai River.

You can add to your knowledge of local site conditions by your own observations. For example, you can set up your own small weather station(s) with a minimum-maximum thermometer, a precipitation gauge, and maybe a small wind gauge or anemometer to measure wind speed and/or wind direction. By taking weather measurements in two spots simultaneously, you can compare the two and learn which spot is relatively colder, windier, or wetter. Relative differences tend to be consistent, and the contrast between areas can be striking.

Air of different temperatures separates rapidly, especially on windless nights, with warm air rising and cool air settling into depressions and into pockets upslope of barriers like buildings or hedges. Warmest microclimates tend to be areas protected from the wind, partway up sunny south-facing hillsides. Downhill flow of air from these sites should not be blocked, or cold air can't drain away. Another warm microclimate is found against south-facing walls of structures, protected from wind, but with full exposure to sun all day. Being near a large body of water also moderates temperatures. In your warmest microclimates, you can often grow plants that would not survive elsewhere on your property; such sites are good places for fruit trees, gardens, and flowering ornamentals.

To learn more about your soils, you can dig a few soil holes and compare the soil profiles you find with information in this *Guide* and with soil series descriptions in the *Kenai-Kasilof Area Soil Survey* (SCS 1962). To find out how much nitrogen (N), phosphorus (P), and potassium (K) your soil contains, as well as its pH, you can send a sample to the Cooperative Extension Service (see insert 1).

Once you're familiar with local conditions, several publications can help you choose plants adapted to your site and microclimates. Examples include:

Landscape Plant Materials for Alaska (CES 1980),
A Revegetative Guide for Conservation Use in Alaska (CES 1991),
The Alaskan Gardener's Handbook (Hedla 1987), and
Cold-climate Gardening (Hill 1987).

Tables 7, 8, and 9 list grasses, shrubs, and trees that the *Revegetative Guide* recommends for lands along the Kenai River. They also show the soil drainage/moisture conditions and pH levels ("acid tolerance") for which listed plants are adapted. Figures 10, 11, 12, and 13 illustrate a number of the trees and shrubs. If you'd like to try other species, remember the following guidelines from the *Revegetative Guide*:

* Try to obtain non-native species from areas of similar latitude and climate (e.g., Norway, Sweden, Finland, Siberia, northern Russia and Canada),

* Select species or varieties known to be adapted to climate conditions similar to those in Alaska (e.g., southcentral Canada, northcentral U.S.),

* Obtain as much information as possible on proper handling and storage of selected plant materials; plant materials differ widely in their ability to remain viable during storage and handling.

* Check with local plant specialists before introducing any non-native species to the area. They can tell you if particular non-native species are likely to survive in your area, and whether their introduction might present problems. (Noxious weeds are generally a result of well-intentioned introductions.)

There's an even easier way to select plants suited to your site: use native local plants. **Imitating native plant communities is the surest way to create healthy, well-adapted, low maintenance, resilient, and inexpensive plantings.** Basically, using native plants is a way to take advantage of all the experimenting Mother Nature has already done to find out what grows best on sites like yours.

To find out what native plants are adapted to your site, look at natural plant communities on nearby undisturbed sites similar to yours. Plant maps and soil maps in Chapter VII will help you identify plant communities of interest to you and will help you compare soils in your area with soils used by these communities.

If you want to learn the name of particular plants, collect a few leaves or flowers and take them for identification to local greenhouses (listed in Chapter VI) or the Cooperative Extension Service. As you think about which native plants to use, be creative. Native plants can be combined in many beautiful and beneficial ways.

Table 7. Grasses adapted for the Kenai River corridor (derived from CES 1991)

Common name (cultivar)	acid tolerance	drought tolerance	flood tolerance	seedling vigor	longevity	rooting habit	height	seed production	winter hardiness	fertilizer requirements
Beach wildrye (1)	fair	very good	good	very poor	long	strong sod	tall	very low	high	low
Timothy (Engmo)	good	poor	good	moderate	long	bunch	tall	moderate	high	moderate
Meadow foxtail (Common)	good	fair	very high	good	long	bunch	medium	low	high	moderate
Reed canarygrass (Vantage)	very good	fair	very high	good	intermediate	sod	tall	moderate	moderate	moderate
Red fescue (Boreal or Arctared)	good	good	fair	very good	long	bunch	medium	moderate	high	moderate
Bering hairgrass (Norcoast)	good	poor	good	moderate	long	bunch	medium	moderate	moderate	moderate
Tufted hairgrass (Nortran)	good	good	fair	moderate	long	bunch	medium	moderately high	high	moderate
Bluejoint reedgrass (Sourdough)	very good	good	good	weak	long	bunch (somewhat sod-forming)	tall	low	very high	moderate
Kentucky bluegrass (Nugget, Merion, Park)	fair	good	good	fair	long	sod	short	low	high	high
Alsike clover (Aurora)	good	fair	good	--	short	fibrous	medium	moderate	moderate	low

Table 8. Trees adapted for the Kenai River corridor (derived from CES 1991)

Common name	acid tolerance	adapted to dry soil	adapted to well-drained soil	adapted to wet soil	height2/	growth rate	shade tolerance	rate of coverage
tamarack	high	no	yes	yes	60 ft	slow	low	slow
Norway spruce 4/	high	no	yes	no	100 ft	slow	high	slow
white spruce (and Lutz spruce)	high	no	yes	1/	100 ft	slow	high	slow
black spruce	high	no	yes	yes	60 ft	slow	high	slow
Colorado blue spruce 4/	high	no	yes	no	80 ft	slow	high	slow
lodgepole pine 4/	high	no	yes	no	75 ft	medium	low	slow
Scotch (Scot's) pine 4/	high	no	yes	no	75 ft	slow	low	slow
mountain hemlock	high	no	yes	yes	100 ft	slow	high	slow
thinleaf alder	medium	no	yes	yes	30 ft	rapid	low	rapid
paper birch	medium	no	yes	yes	80 ft	rapid	low	slow
balsam poplar	low	no	yes	1/	100 ft	rapid	low	medium
quaking aspen	low	yes	yes	no	80 ft	rapid	low	slow
black cottonwood	low	no	yes	1/	100 ft	rapid	low	medium
European bird cherry 4/	medium	no	yes	no	45 ft	medium	medium	medium
feltleaf willow	medium	no	yes	1/	30 ft	rapid	low	rapid
Bebb willow	medium	no	yes	yes	25 ft	medium	low	medium
Scouler willow	high	no	yes	1/	20 ft	rapid	low	medium
mountain ash	medium	yes	yes	no	45 ft	rapid	medium	slow

1/ withstands flooding during the growing season 2/ height under optimum conditions; on poore soils, mature height will be reduced
3/ tolerance to growing under low-light conditions (e.g., under a wooded canopy) 4/ non-native

Table 9. Groundcovers and shrubs adapted for the Kenai River corridor (derived from CES 1991)

Common name (Scientific name)	acid tolerance	adapted to dry soil	adapted to well-drained soil	adapted to moist or wet soil	height 1/	rate of coverage	shade tolerance 2/	propagation methods
common juniper* (Juniperus communis nana)	high	yes	yes		2 ft	medium	low	seed
horizontal juniper (Juniperus horizontalis)	high	yes	yes		1 ft	medium	low	seed
Waugekan juniper** (J. horizontalis douglasii)	high	yes	yes		1 ft	medium	low	none
Andora juniper** (J. horizontalis plumosa)	high	yes	yes		1 ft	medium	low	none
flat creeping juniper** (J. horizontalis procumbens)	high	yes	yes		1 ft	medium	low	none
bearberry (Arctostaphylos uva-ursi)	medium	yes	yes		1/2 ft	medium	low	seed, stolon
bog rosemary* (Andromeda polifolia)	high			yes	2 ft	slow	low	seed, stolon
five-leaf bramble (Rubus pedatus)	high		yes	yes	1 ft	rapid	low	seed, stolon, root sprouts,
Alaska bog willow (Salix fuscesens)	high			yes	1 ft	slow	low	seed
netleaf willow (Salix reticulata)	high		yes	yes	1/2 ft	slow	low	seed, stolon
bunchberry (Cornus canadensis)	high	yes	yes		1/2 ft	slow	high	seed, root sprouts
crowberry (Empetrum nigrum)	high		yes	yes	1/3 ft	slow	low	seed, stolon
American red currant* (Ribes triste)	medium		yes		3 ft	medium	medium	seed, root sprouts
Nagoonberry (Rubus arcticus)	high		yes	yes	1/2 ft	slow	low	seed, stolon, root sprouts
cloudberry (Rubus chamaemorus)	high		yes	yes	1/2 ft	slow	low	seed, stolon, root sprouts
bog blueberry* (Vaccinium uliginosum)	high		yes	yes	3 ft	slow	medium	seed

Common name (Scientific name)	acid tolerance	adapted to dry soil	adapted to well-drained soil	adapted to moist or wet soil	height 1/	rate of coverage	shade tolerance 2/	propagation methods
lingonberry (Vaccinium vitis-idaea)	high		yes	yes	1/2 ft	slow	high	seed, root sprouts
dwarf mugo pine** (Pinus mugo mughus pumila)	high	yes	yes		2 1/2 ft	slow	low	none
dwarf arctic birch (Betula nana)	high		yes	yes	3 ft	slow	low	seed
leather leaf (Chamaedaphne calyculata)	high			yes	3 ft	medium	low	seed, stolon
narrow-leaf Labrador tea (Ledum decumbens)	high			yes	2 ft	medium	medium	seed, stolon
Labrador tea (Ledum groenlandicum)	high		yes	yes	3 ft	medium	medium	seed, stolon
sweetgale (Myrica gale)	high			yes	3 ft	rapid	low	seed, root sprouts
Indian snowberry (Symphoricarpos orbiculatus)	medium	yes	yes	yes	3 ft	rapid	medium	seed
mugo pine** (Pinus mugo mugas)	high	yes	yes		8 ft	slow	low	none
Sitka alder (Alnus sinuata)	medium		yes	yes	13 ft	rapid	low	seed
red-osier dogwood (Cornus stolonifera)	medium		yes	yes	12 ft	medium	medium	seed, root sprouts
bush cinquefoil (Potentilla fruticosa)	high		yes	yes	6 ft	medium	medium	seed
prickly rose (Rosa acicularis)	high		yes	yes	4 ft	rapid	medium	seed, root sprouts
Nootka rose (Rosa nutkana)	high		yes	yes	8 ft	rapid	medium	seed, root sprouts
American red raspberry (Rubus idaeus)	medium		yes		4 ft	rapid	low	seed, stolon, root sprouts
littletree willow (Salix arbusculoides)	medium		yes	yes	12 ft	medium	low	seed
grayleaf willow (Salix glauca)	medium		yes	yes	4 ft	medium	low	seed

Common name (Scientific name)	acid tolerance	adapted to dry soil	adapted to well-drained soil	adapted to moist or wet soil	height 1/	rate of coverage	shade tolerance 2/	propagation methods
diamondleaf willow (Salix planifolia pulchra)	high			yes	6 ft	medium	medium	seed
Sitka willow (Salix sitchensis)	high		yes	yes	13 ft	medium	low	seed
Scouler willow (Salix scouleriana)	high		yes	yes	20 ft	medium	low	seed, cuttings
feltleaf willow (Salix alaxensis)	medium		yes	yes	30 ft	rapid	low	seed, cuttings
Bebb willow (Salix bebbiana)	medium		yes	yes	25 ft	medium	low	seed, cuttings
Barclay willow (Salix barclayi)	medium		yes	yes	10 ft	rapid	low	seed
undergreen willow (Salix commutata)	high		yes	yes	6 ft	medium	low	seed
Pacific red elder (Sambucus callicarpa)	medium		yes	yes	12 ft	rapid	medium	seed, root sprouts
Greene mountain ash (Sorbus scopulina)	medium		yes		13 ft	slow	medium	seed
Sitka mountain ash (Sorbus sitchensis)	medium		yes	yes	12 ft	slow	medium	seed
Beauverd spirea (Spirea beauverdiana)	high		yes	yes	4 ft	slow	low	seed
early blueberry (Vaccinium ovalifolium)	high	yes	yes	yes	5 ft	medium	high	seed
highbush cranberry (Vibernum edule)	medium	yes	yes		12	slow	medium	seed
Salmonberry (Rubus spectabilis)	medium		yes	yes	7 ft	rapid	low	seed

* may be either an upright or prostrate shrub   ** non-native
1/ height under optimum conditions; on poorer soils, mature height will be reduced
2/ tolerance to growing under low light, (e.g., under a closed canopy overstory)

COOPERATIVE EXTENSION SERVICE

University of Alaska Fairbanks & USDA Cooperating

SOIL SAMPLING

100G-00044

WHY SOIL TEST?

University of Alaska Fairbanks soil tests help you to maintain a more productive soil, to increase your yield, or to establish plants more quickly - whether for a garden, a greenhouse, a lawn area, or a field. Soil tests provide information on selecting the correct fertilizer, the amount needed and the best time for application. In addition, if liming is needed, recommendations will be made. The **Agriculture Experiment Station** will analyze your soil for available major plant nutrients - nitrogen, phophorus, and potassium - as well as determine the pH of your soil - whether it is acid or alkaline. The **Cooperative Extension Service** will interpret the results and make recommendations for you.

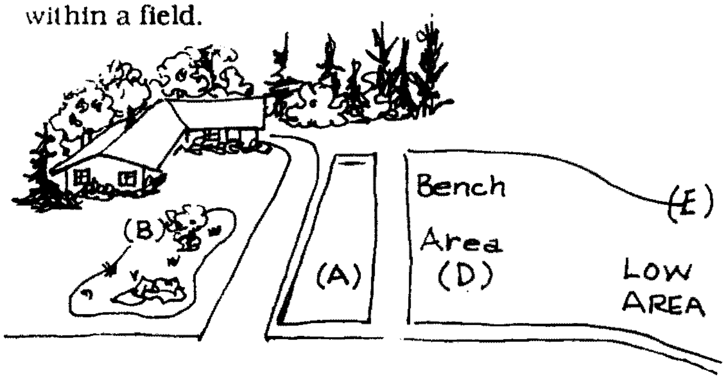
WHY SAMPLE CORRECTLY?

Poor sampling gives misleading test results. Soil testing can be divided into three major steps: (1) taking the sample, (2) making the analysis, and (3) interpreting the results. Taking the sample is probably the most inaccurate of these three steps. Test results to represent an area can be no more accurate than the sample on which the test results lead to inaccurate recommendations. Therefore, you lose yield, appearance and/or money by applying the wrong fertilizer.

Get a representative sample. Remember, just a few grams of soil are actually used in the soil testing procedure, and these several grams must be representative of the total area to be tested. Best decisions can be made only of soil samples are representative of the area sampled and accurately reflect soil conditions.

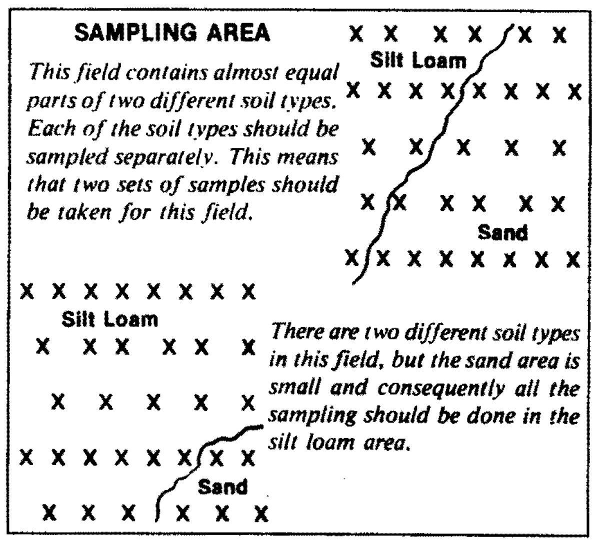
Each soil sample should represent only on soil type,condition or growing situation.

Take a **separate soil sample from each different area:** (a) one for the garden, (b) one for the flower bed, (c) one for the lawn, and (d,e) one for each uniform land area within a field.



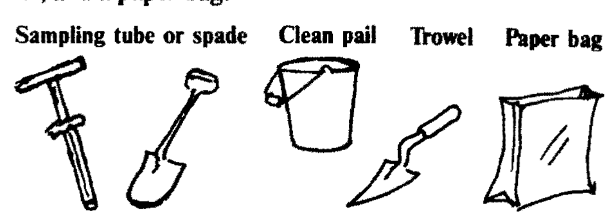
Sample separately the following areas and describe each:

- low spots
- coarse texture soils
- soils of different color
- cropping history
- irrigated vs. non irrigated
- different slopes
- organic soils
- bottom lands
- uplands
- sampling depth
- past fertilizing, liming or manuring histories



HOW DO YOU TAKE A SAMPLE?

Tools needed are simply a spade, a clean plastic pail, a knife or trowel, and a paper bag.

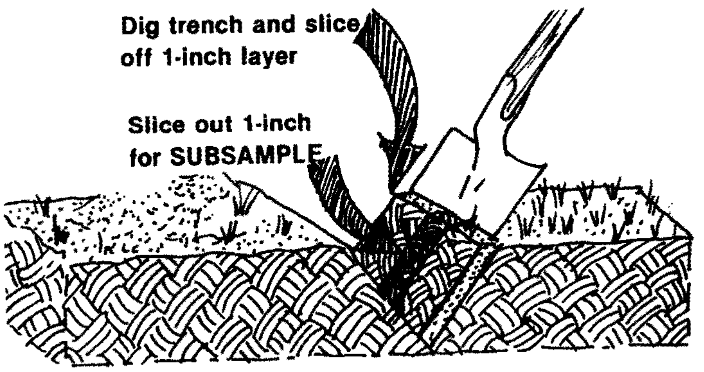


A good soil sample should represent the area. Each sample should consist of subsamples taken from at least five locations within a garden or lawn. Fifteen to twenty subsamples should be taken from a ten acre field. Do not sample shortly after lime, fertilizer, or manure application or when the soil is excessively wet. Don't sample snow-covered or frozen ground because it is difficult to obtain a representative sample. Fall is an excellent time to take your sample. Having the results in the fall can also give you a headstart next spring.

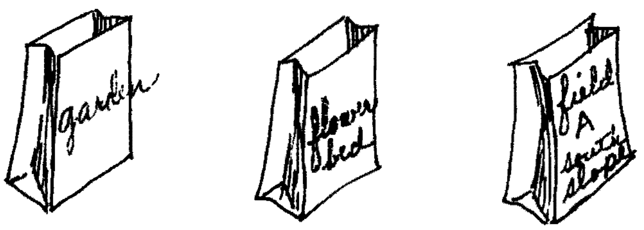
TAKING A SUBSAMPLE

Use a sampling tube, or if using a spade, follow these instructions:

1 Dig a V-shaped hole six inches deep or plow depth.
2. Take a 1-inch slice from one side of the hole.
3. Trim the sides of slice, leaving a 1-inch strip on the spade. Place this strip into the clean plastic pail.



Repeat this procedure until a representative number of subsamples has been taken to make up the sample. Break up clods with your hands and thoroughly mix the soil in the pail by rotating the pail at a 45 degree angle. Remove approximately one pint of soil, place it into a paper bag, and label the bag as to garden, flower bed, south slope field A, etc. Discard the remaining soil.



Repeat the above procedure for the next area to be sampled, placing the samples in a separate paper bag. be sure to label the paper bag promptly before you forget where the samples were obtained. Maintain a record of sampling areas to assist you in correctly applying the recommendations when they are received.

DRYING THE SAMPLES

Air dry all soil samples before mailing. wet or damp samples store for only a few days may yield unreliable results. Remove the soil sample from the paper bag and spread out in a thin layer about 1/4 inch deep. Dry at room temperature. CAUTION: Do not apply artificial drying by oven, stove or furnace as this may alter the sample results.

PROVIDE COMPLETE INFORMATION

After the soils have completely dried, place the samples into the soil test kit bags, fill to the correct mark, and clearly label. Fill out all requested information as completely as possible. This will insure an accurate recommendation.

SUMMARY OF INSTRUCTIONS

1. Take a representative sample.
2. Break up clods or lumps, spread out on a newspaper in a well ventilated location and air dry at room temperature (usually 2 to 3 days). CAUTION: Apply no artificial heating!
3. When dry, mildly crush the coarser granules to about the size of wheat grains and thoroughly mix.
4. Fill bag approximately half full of soil. Roll top of bag several times and bend over tab ends to lock bag closed.
5. Write your name on bag and identify sample with number in lower right hand corner of Soil Sample Information Sheet (100M-0044A).
6. Your district Cooperative Extension Service office may either sell you the Soil Test Kit and have you mail the sample directly to the soil testing lab or request that you bring or mail the sample to the extension office to be bagged and mailed from there. Checks should be made out to the Cooperative Extension Service. Do not send cash through the mail.

SOIL TESTING COSTS

The Cooperative Extension Service and the Agricultural Experiment Station budgets available for this program necessitate a small charge be made to state residents wishing to have soil tested. Be sure to include payment with each sample mailed or left at the district office. Billing and payment procedures necessitate soil samples be processed through a District Cooperative Extension Service office.

157/4/87/WV/3000 Reprinted May 1990

Soil Sampling instructions were developed by Alan C. Epps, Cooperative Extension Service, in 1974. The instructions were refined by T.E. Loynachan, Agricultural Experiment Station, in 1977. For further information contact: Wayne Vandre, Horticulturist, Cooperative Extension Service, University of Alaska Fairbanks, 2221 E. Northern Lights Blvd., Suite118, Anchorage, Alaska 99508-4143.

Figure 10. Willows suitable for use along the Kenai River (from Viereck and Little 1972).

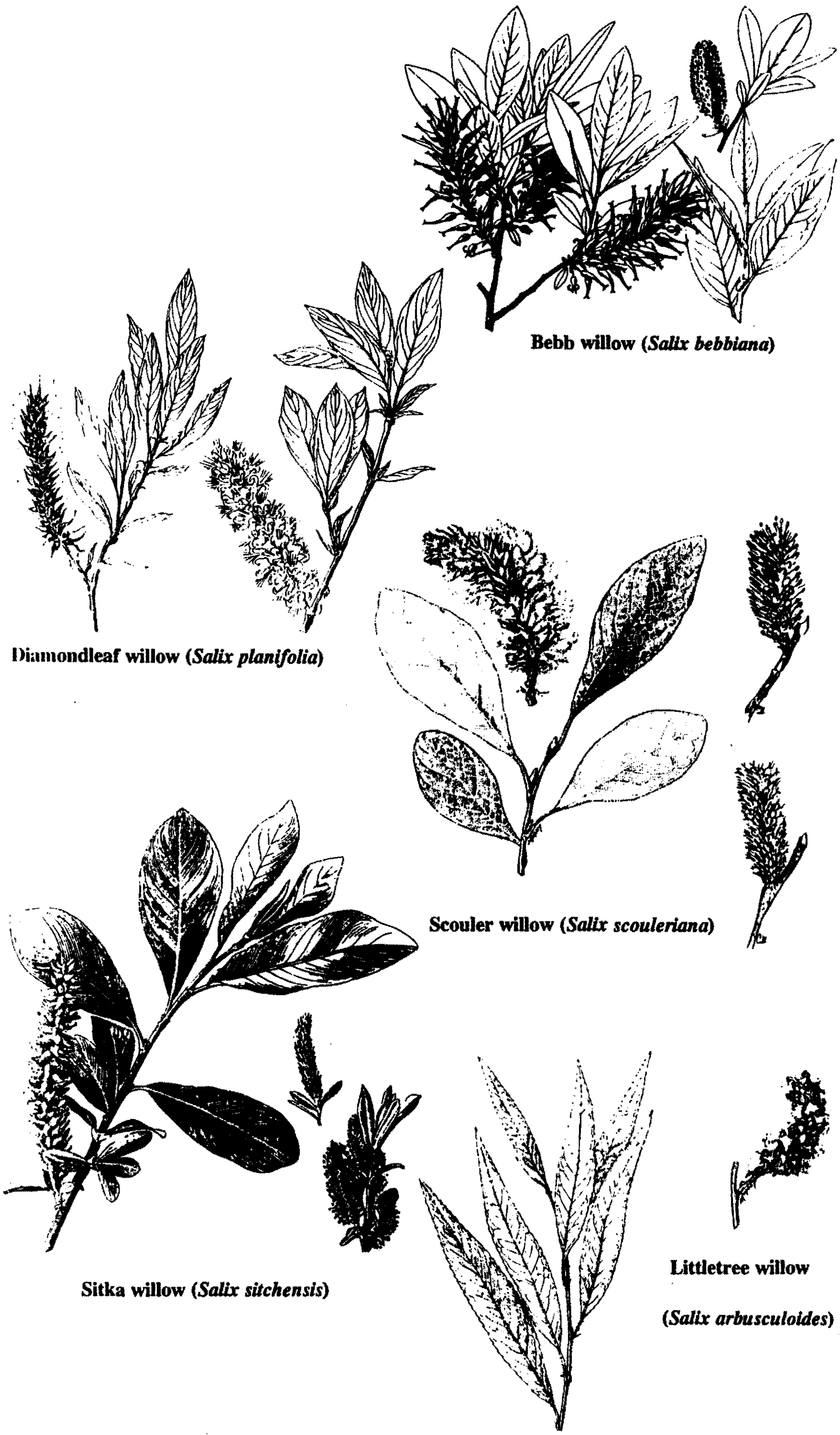


Figure 11. Willows suitable for use along the Kenai River (from Viereck and Little 1972).

Grayleaf willow (*Salix glauca*)

Barclay willow (*Salix barclayi*)

Undergreen willow (*Salix commutata*)

Feltleaf willow (*Salix alaxensis*)

Figure 12. Poplars and mountain ash suitable for use along the Kenai River (from Viereck and Little 1972).

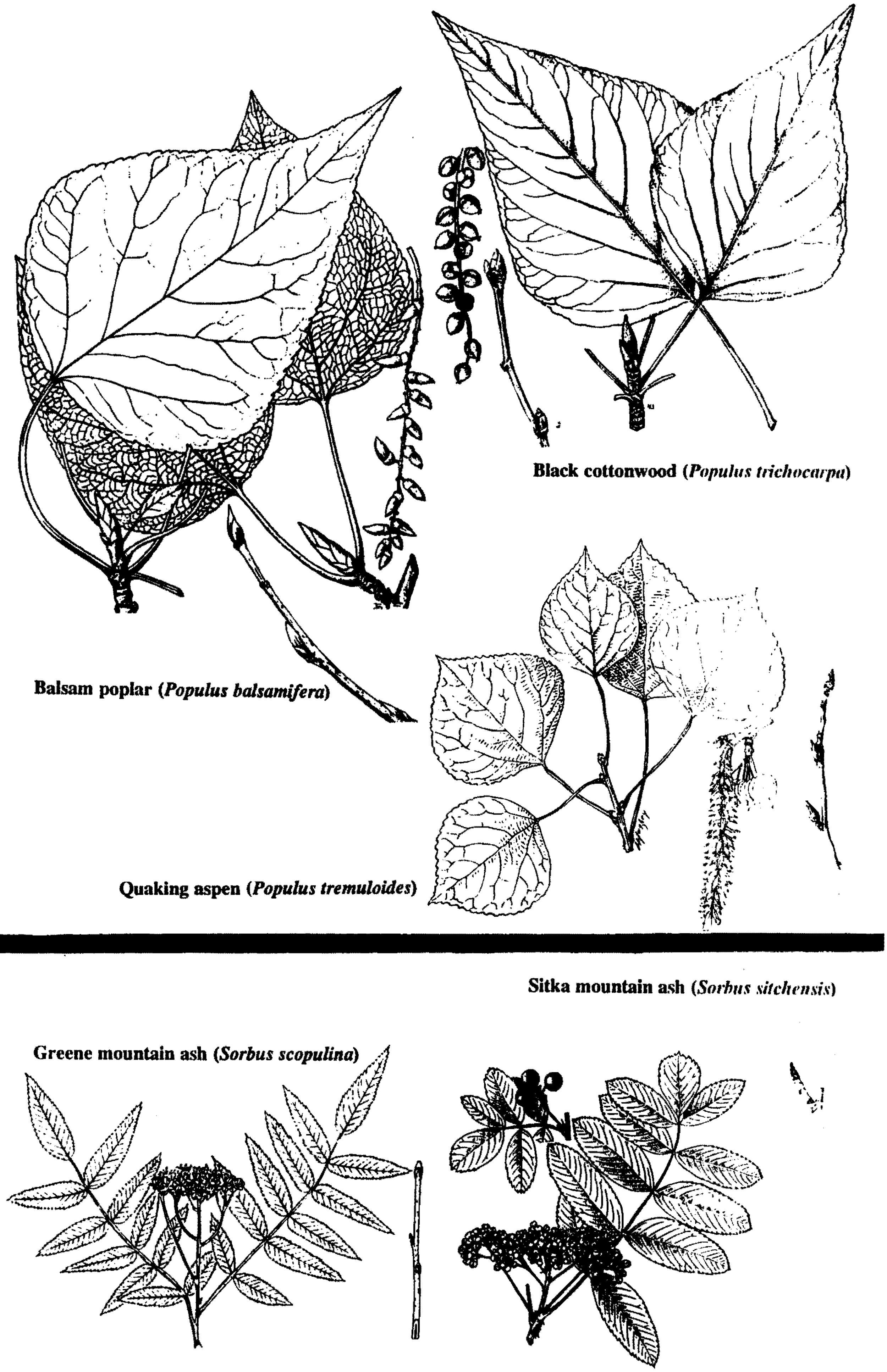
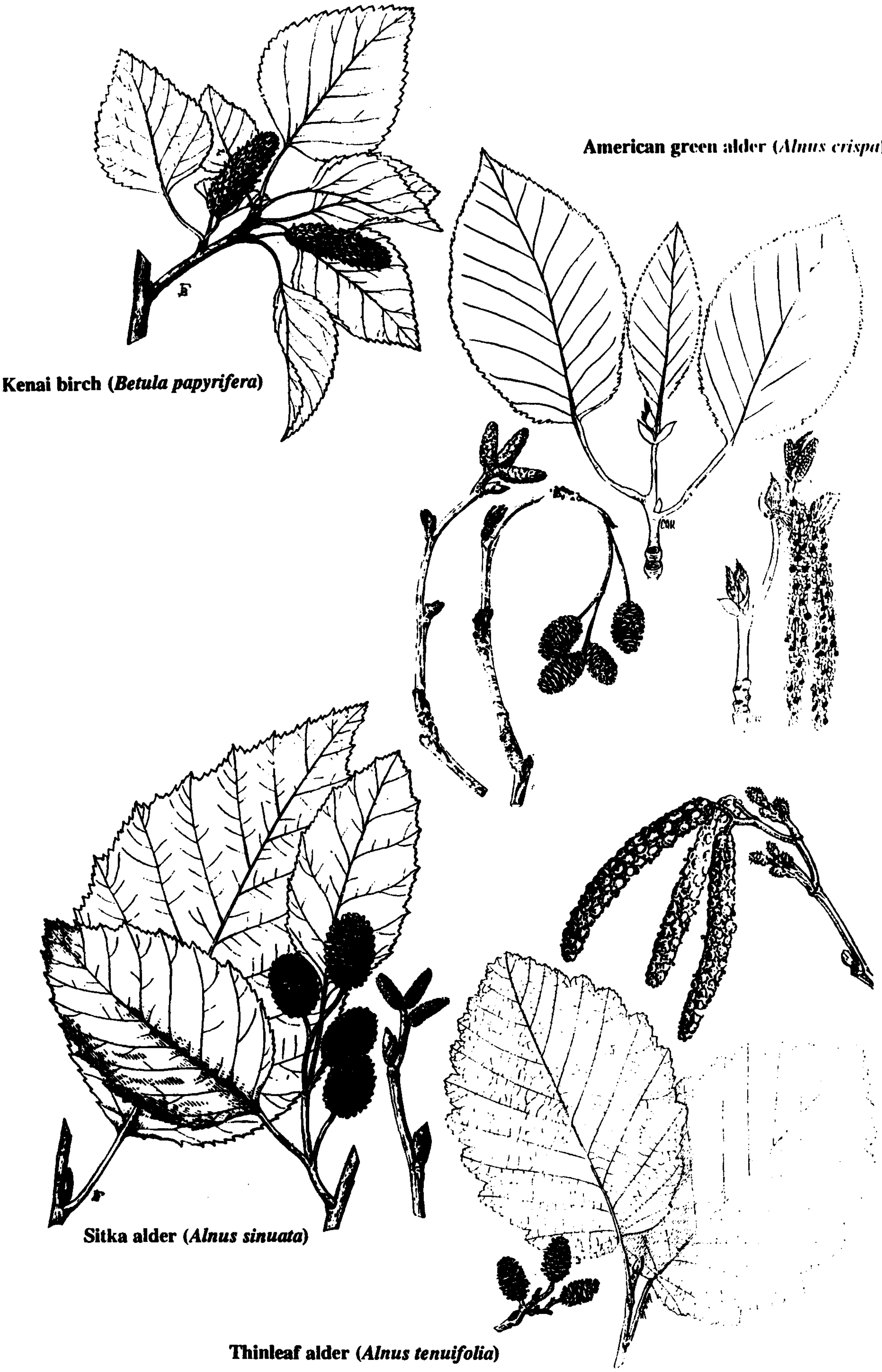


Figure 13. Birches and alders suitable for use along the Kenai River (from Viereck and Little 1972).



(2) Obtaining plants

There are four main sources for the plant materials you need: 1) commercial outlets (greenhouses, home improvement centers, nurseries, mail-order companies, etc.), 2) the Alaska Forest Regeneration Center, 3) transplanted material, and 4) plant material you propagate yourself.

1. Commercial outlets

A number of local nurseries and greenhouses are listed in Chapter VI. When ordering from commercial outlets, there are a number of points to remember.

First, experience shows that seedlings or rooted cuttings at least 18 to 24 inches tall are easier to establish than smaller plants; it makes sense to buy material of at least this size. Bare root seedlings should come with full, healthy root systems and a trunk diameter of at least 1/4 inch just above the root collar (where roots meet stem). As soon as your order arrives, inspect it for dry, moldy, or very small plants, and don't waste time planting damaged material in the ground. (If you want, plant damaged specimens in containers and nurse them along till they regain vigor.)

Secondly, most tree seedlings grown in the Lower 48 states or Canada are shipped frozen. Material that arrives frozen should be kept frozen until shortly before planting and then gradually thawed in a cool, shaded location. Material that has not been frozen should not be allowed to freeze. Instead keep it refrigerated, preferably at 34 to 40 degrees Fahrenheit and 80-100% humidity. Emptying several trays of ice cubes (NOT dry ice) on the root-packing material will keep plants cool and moist. Check plants daily for adequate moisture and keep them in the dark until you're ready to plant. Always protect stored seedlings from warmth and drying.

Thirdly, seedlings come packaged in different ways depending on their size. Container or bare root seedlings usually have their root systems wrapped, bundled, and stored in paper, plastic, or metal containers. Leave roots in their packing and keep them moist as outlined above. Plant tops can be covered with light-colored, untreated canvas, wet burlap, shredded newspaper, or moss until planting. Root systems of larger seedlings and saplings usually come wrapped in wet burlap to prevent drying. Keep this moist until planting.

2. Alaska Forest Regeneration Center

The Forest Regeneration Center operated by the Alaska Division of Forestry provides large numbers of fresh container-grown seedlings for reforestation and conservation use. Prices are very reasonable, but in most cases 100 plants is the minimum order. Orders should be submitted 1 to 1 1/2 years before plants are needed because of the time it takes to custom grow trees and shrubs. Material ordered before December 1 of one year is propagated the following spring and is ready for the customer late in that growing season or early the next. Surplus material is often available on a first-come first-serve basis. (See Chapter VI for the Center's phone number and address.)

The Center routinely grows white spruce, Sitka spruce, paper birch, Siberian larch, lodgepole pine, Scotch pine, and poplars. Other species are grown on request, for example, willows or alders grown for slope stabilization or other conservation uses.

3. Transplanted material

If you can't get what you want from other sources, or you're willing to expend labor to save money, you can transplant material. Transplants can come from friends or neighbors who allow you to dig up material. (Always get the landowner's permission before removing transplants.) Transplants of locally growing native plants may not be as vigorous as nursery grown stock, but on harsh or marginal sites, they tend to have higher survival rates because they are preconditioned to local conditions.

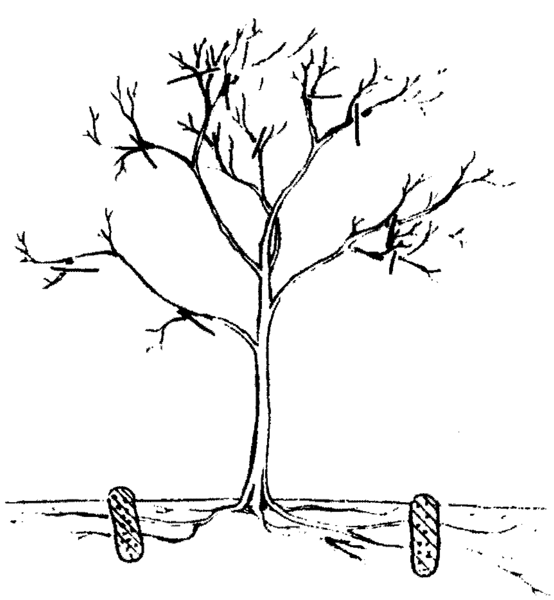
The best time to transplant is in fall after plants are dormant. Insert 2 provides instructions on how to transplant trees (shrubs are handled the same way). Figure 14 shows how to root prune a potential transplant. If you're transplanting a relatively large tree, follow the 3-year root pruning schedule outlined on Figure 14. Root pruning increases transplant survival because it forces plants to grow new feeder roots inside the rootball you cut. A cupful of plant food sprinkled over the cut circle after root pruning encourages more new roots.

If you must move a tree that isn't dormant, soak it well before transplanting and, if possible, transplant in the rain. Dig up as large a rootball as possible and transplant the tree immediately. (You can transplant it into a suitable container instead of into the ground.) Reduce leaf surface to reduce plant stress (up to, but not more than, 1/2 the leaf surface; try to reduce leaf area proportionally to root loss). Wrap the top in a white sheet for a few days to reduce water loss (transpiration) from leaves or needles, and keep the tree heavily watered each day until it shows signs of recovery.

Public road rights of way can be good sources of transplant material. For permission to collect along state-maintained roads, contact the Alaska Department of Transportation, Soldotna/Kenai Highway Maintenance office (they're listed in Chapter VI).

If getting permission to remove transplants isn't feasible, you can propagate some plants yourself from seeds, cuttings, or divisions. Once you know what species you want to propagate, nurseries, greenhouses, the Soil Conservation Service, Plant Materials Center, or Cooperative Extension Service can tell you how to propagate them.

Figure 14. Root pruning a tree before moving it increases its survival. The schedule outlined below is for relatively large trees and can increase transplant survival significantly. For smaller trees, you can root prune one dormant season and transplant the next, but try not to root prune more than 50% of the roots in one year.



First dormant season: Draw a circle on the ground around the tree beneath the drip line (or with a diameter about ten times that of the tree trunk at ground level). Divide the circle into four equal quarters. With a sharp spade, dig a narrow trench into two opposite quarters of the circle. You will hear roots snap as you cut. Backfill your pruning trench with a good soil mixture.

Second dormant season: Root prune a third quarter of your circle as above. (Do not disturb areas cut the previous season.)

Third dormant season: Cut around the entire circle, just outside of your previous cuts. (This cuts the last quarter of roots.) Carefully dig out the tree, wrap up the rootball so it won't dry or break, move it to its new location, and plant immediately. Cut back the twigs with dormant leaf buds (no more than 50% of the buds) to reduce stress in the spring.

ALASKA
GARDENING TIPS

A-00335 July 1985

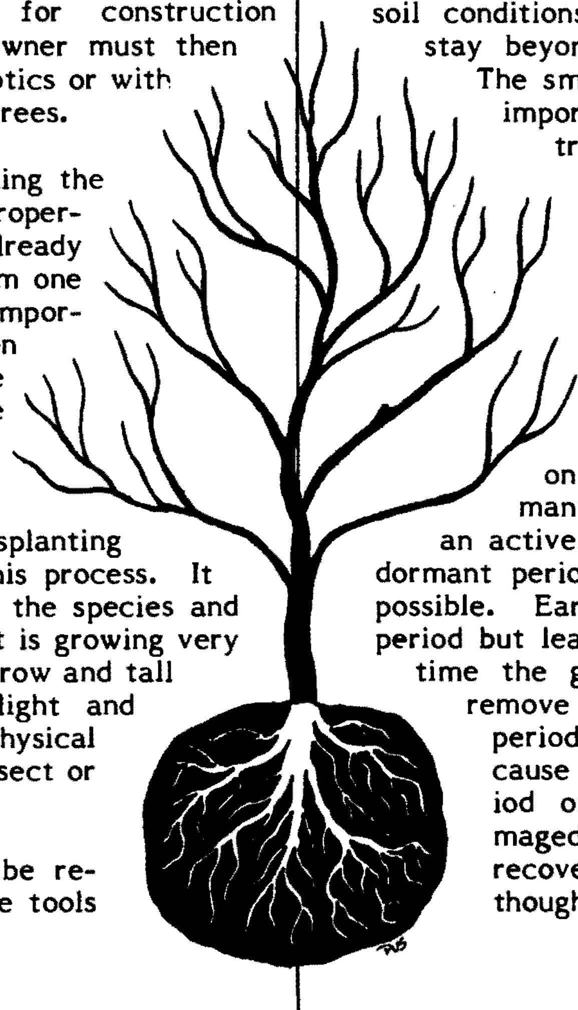
TRANSPLANTING TREES SUCCESSFULLY

A landscaped property is a definite asset to the owner in terms of monetary as well as aesthetic value. In many areas of Alaska the use of native trees is quite common. Some of these may be left during initial construction and landscaping activities but too often they are removed to allow for construction activities. The property owner must then replace them with hardy exotics or with the same species of native trees.

Whether you are undertaking the initial landscaping of your property, adding to the trees already there, or moving a tree from one location to another, it is important to do it correctly. Even the hardiness of a native tree cannot overcome the effects of poor transplanting techniques.

Choosing a tree for transplanting is often the first step in this process. It should be characteristic of the species and in good health. A tree that is growing very close to others is often narrow and tall due to competition for light and space. Look for signs of physical damage and symptoms of insect or disease problems.

Choose a tree that can be removed successfully with the tools you have available. If that is a spade a tree with a trunk diameter of 1-1½ inches is probably the largest you can move without excessive root damage. The root systems of many Alaska trees are relatively shallow rooted and spread out horizontally due to cold underlying soil conditions. When you start digging stay beyond the dripline of the tree. The small roots at the end are the important ones for water and nutrient uptake. Removing or damaging those important feeder roots puts additional stress on the tree during transplanting.



A tree that is in a dormant state is less likely to suffer transplant shock because the demands placed on the root system by a dormant tree are much less than by an actively growing one. Winter is a dormant period but digging is usually not possible. Early spring is also a dormant period but leaf growth often starts by the time the ground thaws sufficiently to remove the tree. The fall dormancy period is usually preferable because it is followed by a long period of time during which a damaged root system can regrow and recover. This will occur even though the tree appears dormant

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COOPERATIVE EXTENSION SERVICE
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and the soil is cold. If you have no choice but to move a tree during the growing season, be very careful not to cause root damage and take precautions to prevent excessive water loss (transpiration) from the leaves during transport and after planting. Selective pruning as well as the use of windbreaks and anti-dessicants are techniques to consider.

Carefully remove the root ball by digging under the roots and toward the center from all sides. It can then be carefully rolled onto a tarp, burlap or heavy plastic and tied securely to hold the root ball in place and prevent root drying.

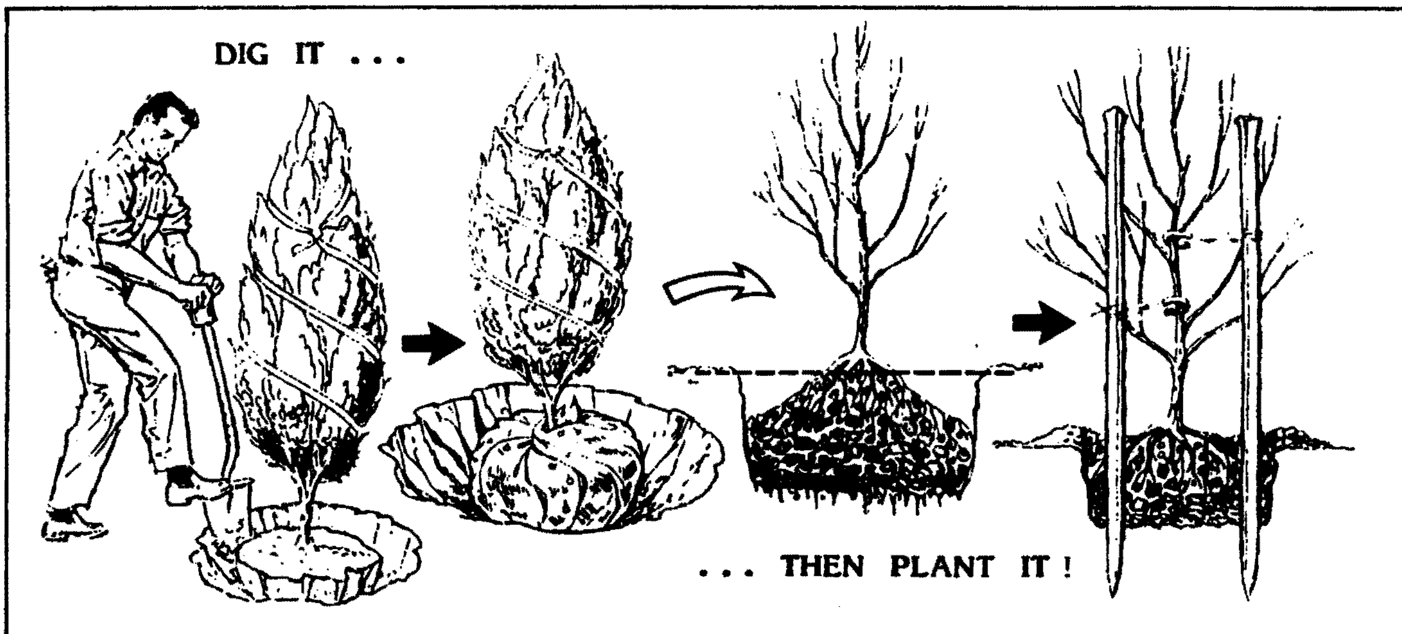
Transporting the tree to the new location should be done in such a way that drying effects are kept to a minimum. Hauling trees in the bed of a pickup for long distances can cause severe water loss from the foliage followed by leaf drop after transplanting.

The new planting site should be chosen and prepared in advance. Consider the tree's requirements for sun, soil, water and air drainage, wind protection and winter protection. Survival of transplanted trees is greatly increased if you can satisfy the environmental needs of each plant.

The hole for replanting should be at least twice the diameter and depth of the root ball. This is especially important if the new site has a tight or poorly drained soil. Backfill with a good porous soil or soil mix until the tree will be positioned at the same depth as it was growing. Place the tree in the hole, remove the wrapping from the root ball and carefully reposition the roots on top of the new soil. Water should be added to the soil several times during the filling procedure to settle the soil and eliminate any air pockets. Continue placing soil in the hole until only a slight depression remains. This will allow for easier watering of the tree.

A complete analysis fertilizer can be mixed with the soil to provide nutrients for continued growth. You should also support the tree using stakes and guy wires. This will help to prevent root tearing if the tree is subjected to strong winds.

Keep the tree well watered during the transplant recovery period. If you were careful in your tree selection and followed correct transplanting procedures, your tree will continue its healthy growth in its new home.



The use of trade names in this publication does not imply endorsement by the Cooperative Extension Service.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, James W. Matthews, Director, Cooperative Extension Service, University of Alaska.

4. Propagating plants yourself

Plants can be propagated from seeds or cuttings. Growing plants from seed can be tricky. *Seeds of Woody Plants in the United States* (USDA Agricultural Handbook 450, USFS 1974) discusses in detail techniques for collecting and handling seeds of different plants. (Reference copies are available at the Cooperative Extension Service, Soil Conservation Service, Forest Service, and Plant Materials Center.) Refer to that publication for specific instructions when you know what seeds you want to collect. The following brief introduction to this topic is from the *Revegetative Guide for Conservation Use in Alaska* (CES 1991).

Timing of seed collection varies among woody species and is extremely important to assure ripe, viable seed. To maximize seed quantity and quality, collect seeds after ripening but before natural dispersal begins. Seeds of some species (e.g., cranberry, birch, alder, mountain ash) remain on the plant for part or all of winter and can be collected then. Most plants only produce good seed crops under certain conditions, so in any given year, you may not be able to collect large amounts of seed from some species.

Once collected, seeds of individual species need to be cleaned and handled in particular ways. For example, dwarf dogwood seeds must be extracted from the pulp immediately after collection or they will be difficult to germinate. In most cases, cleaned seeds should be thoroughly dried at temperatures under 180 degrees Fahrenheit.

The best way to store dried seeds is in airtight containers (plastic or glass) kept at uniform, below freezing temperatures. The next best alternative is storage in a refrigerator at 32 to 40 degrees Fahrenheit.

Seeds of Alaskan woody plants have varying tolerances to handling and storage. Seeds from the majority of trees and shrubs can be stored for at least 3 to 4 years under proper conditions. The most fragile seeds are those of willows, aspen, balsam poplar, and black cottonwood. These seeds are only viable for 10 to 14 days. If you can't plant them immediately, freeze them within 3 to 5 days of collection; these seeds will die within 2 to 4 weeks if stored at room temperature.

For many plants, there's a good alternative to starting them from seed. Instead, **you can grow them from *dormant* or *rooted* cuttings.** "Dormant cuttings" refers to plant material cut from dormant plants and planted while still dormant. Plants become dormant when environmental conditions are too harsh for them to make food for growth and survival. In Alaska, plants go dormant in the winter because freezing temperatures damage actively metabolising plant cells.

Some plant material is remarkably resilient when dormant: you can cut it and store it and stick it in the ground, and when conditions improve, it sends out new roots and shoots and starts to grow. Willows and cottonwoods are particularly well-known for this ability and, therefore, make good dormant cuttings. In addition, they develop aggressive invasive root systems that are excellent at binding soil (but may cause problems to leach fields, underground pipes, and foundations).

Willows have a number of other features that make them exceptionally well suited for revegetating difficult sites, such as steep slopes or eroding riverbanks. In particular, established willows tolerate: drought, excessive moisture, flooding, fluctuating water levels, exposure from erosion, burial by eroding material, rock falls, and regular hedging (for example, by moose). (To top it off, in 1899 a German chemist isolated acetylsalicyclic acid from willow bark, and gave the world its most universal pain reliever: aspirin.) Use of willows and other woody plants for bank stabilization is discussed under Practical ways to promote bank stability.

Once you've chosen what cuttings to use, try to identify individual source plants the growing season before collecting cuttings. That way you can use leaves, flowers, and fruits, for accurate identification. You can also test plants for rooting ability, which is useful because individual plants can differ widely in this. Test a plant's rooting ability by sticking either a growing or dormant cutting in water (with a little Hormex if the plant is known to be hard to root; but Hormex may inhibit rooting in plants that root easily). If you're rooting leafy cuttings, you can reduce the leaf surface area by removing some leaves completely or cutting all leaves in half. Watch how fast roots develop. If roots develop quickly, the source plant is a good candidate for cuttings.

You can flag source plants with surveyors tape so they'll be easy to identify when dormant. If you end up wanting to collect cuttings after leaves fall, but haven't identified source plants in advance, the following twig key and Table 10 can help you identify dormant willows and a number of other woody species.

A key to dormant twigs of selected shrubs (based on *Twig Key to Trees and Shrubs*, Harlow 1941).

Although it's much easier to identify plants using leaves, fruits, and flowers, sometimes you need to identify dormant woody plants. This key will help you determine whether or not you have a twig from one of the following shrubs or trees: alders, willows, poplars (cottonwoods and aspens), spineless currants or gooseberries, birches, mountain ash, ninebark, and *Spirea*. These shrubs all have *alternate leaves* (leaves and buds do NOT grow opposite each other on the stem, they alternate); and none has spines or thorns (although some currants do have thorns). This key will not help you identify dormant shrubs that have opposite leaves and/or spines or thorns. As the numbering system indicates, this represents only a portion of a larger twig key (Harlow 1941). If you reach a point where your sample doesn't match the listed option (or one of the paired options), you know that you DO NOT have a twig from one of the plant groups included. (Many terms are defined at the end of the key.)

74. pith solid (homogeneous), rarely spongy; (sometimes small and not readily distinguishable) --> 81
81. buds (terminals, laterals, or both) present --> 84
84. leaf scars present (use hand lens if necessary) never more than moderately raised, or level with the twig --> 87
87. stipule scars lacking, or if present not continuous --> 89
89. twigs lacking a spicy or wintergreen taste or odor --> 93
93. buds scaly with one or more scales; smooth and hairless or covered with fine hair or down --> 108

108. bud scale single, forming a cap-like covering for the bud; buds commonly flattened; twigs usually slender --> **willow**
108. bud scales 2 or more --> 109

109. buds distinctly stalked; pith triangular in cross-section; usually visible without a hand lens --> **alder**
109. without the above combination of characters --> 110

110. bundle scar single (one); appearing as a dot, straight line, or curve --> 111
110. bundle scars 2 or more --> 119

111. bud scales not possessing a fine, slender tip --> 112
112. stipule or stipule scars lacking --> 115
115. bud scales not hairy on their margins, or if so, also more or less hairy over their entire surface; twigs not purplish --> 116
116. terminal bud present or lacking; bud scales 2 or more, not greatly overlapping; pith never chambered --> 117
117. bundle scar smaller and not protruding; leaf scars usually not triangular but if so, indented --> 118

118. leaf scars uneven or rough; bark tending to peel; stems often wand-like, much branched with slender tips --> **Spirea**

119. bundle scars 3 or more --> 120

120. terminal bud lacking, or if present, not 4 times longer than its diameter at base, usually egg-shaped with the broadest portion near the base or globe-shaped --> 125

125. pith circular or nearly so --> 133

125. pith 4- to 5-angled or star shaped in cross section (several smooth sections should be made across the twig between nodes to see this feature) --> 126

126. first scale of the lateral bud large and directly above the leaf scar --> **Populus** (including cottonwoods and aspen)

133. twigs ridged or lined from the nodes; epidermis soon cracking or shredding; bud scales somewhat loose --> 134

133. twigs usually not ridged; epidermis not shreddy --> 137

134. stipule scars present; bundle scars 5, very unequal in size --> **Physocarpus** (ninebark)

134. stipule scars lacking; bundle scars 3 --> **Ribes** (currant or spineless goosberry)

137. terminal bud present --> 138

137. terminal bud lacking --> 143

138. terminal bud large and conspicuous, scales somewhat hairy or essentially smooth and hairless --> **Sorbus spp.** (Mountain ash)

143. twigs slender or moderately so; leaf scars small; half round, elliptical, or narrow and inconspicuous --> 145

145. stipule scars present --> 148

148. outer bud scales 3 or more --> 150

150. visible bud scales 3 or 4 (except on spur shoots when present); the first pair of scales forming a V-shaped angle above the leaf scar; lenticels on older twigs elongated horizontally; buds more or less resinous when pressed between the fingers; bark on older trees papery or scaly --> **Betula** (birches)

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buds: Embryonic shoots, usually containing rudimentary floral or foliage leaves. The normal position for buds is either in the *axil* or upper angle between leaf and stem, or at the *apex* (tip) of a twig. Those occurring in the leaf axils are called *lateral* or *axillary* buds, while *terminal* buds, which are usually larger, grow at the tip of the twig.

bud scales: Scalelike structures that form a protective covering for winter buds.

bundle scars: On the surface of the leaf scar may be found from one to many small dots or lines, the *bundle scars*, which indicate where the channels of sap conduction entered or passed from the leaf to the stem.

leaf scar: When a leaf falls off, it often leaves a scar where its leaf stem (*petiole*) attached to the twig.

lenticels: Small areas of loose tissue that appear as dots or warts on the surface of the twig; not always conspicuous. (These are actually openings through which air is admitted to underlying tissues.)

node: The more or less swollen portion of the twig that bears the leaf.

pith: The soft spongy tissue that occupies the central portion of a stem. To see whether or not the pith is solid or homogeneous, cut the twig lengthwise through the center with a sharp blade. To see if it's round, star-shaped, etc., look at a cut cross-section of the twig.

stipules: Small leaf-like organs occurring in pairs on the twig, one at each side of the petiole of a leaf; they generally fall during the summer, and usually leave on the twig small narrow **stipule scars**. Not all plant groups have stipule scars.

Table 10. Comparison of dormant willows, poplars, alders, birch, and mountain ash.

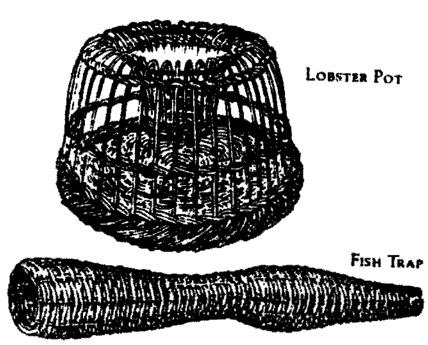
	TWIGS/BARK	GROWTH FORM/ OTHER FEATURES	BUD SIZE	TERMINAL BUD/ BUD SHAPE	BUD RESIN	BUD SCALES	BUD POSITION	PITH X-SECTION
WILLOWS	twigs slender, wiry, tough; may separate easily from branch; young stems ("osiers" or "whips") pliable & strong; bark w/bitter quinine taste	shrub w/many trunks; sprouts vigorously from stumps & cuttings; invasive roots	<1/2"	no terminal buds, no bud scars like aspen, cottonwood, or balsam poplar	no	single caplike scale	hugging twig	round
QUAKING ASPEN	twigs slender, first reddish (sometimes hairy), turning gray with age; bark mostly smooth & whitish- or greenish-gray w/dark warty patches	tree w/small, high, round-topped crown; produces root suckers	1/4"	terminal buds, produce ring-like scars at intervals on twigs; buds conical, pointed, & red-brown	sometimes slightly resinous	several shiny reddish overlapping scales	extending at angle from twig	angled or star-shaped
BLACK COTTON-WOOD/ BALSAM POPLAR	twigs moderately slender-to-stout, w/raised leaf scars & orange lenticels, red-brown & hairy turning gray w/age; bark smooth, greenish-gray, becoming thick & furrowed	tree; stumps & roots sprout vigorously; wide spreading root system	to 3/4" to 1"	terminal buds, produce ring-like scars at intervals on twigs; buds long, egg-shaped, pointed, & red-brown	amber or brown resin fragrant & sticky in in spring	several shiny brown overlapping scales	extending at angle from twig	angled or star-shaped
ALDERS	twigs slender, reddish or orange-brown w/dots, turning gray, sometimes hairy when young; bark thin and gray w/"warty" lenticels	usually thicket-forming shrub; clusters of small "cones" remain on twigs in winter; moisture loving	1/4-1/2"	no terminal bud; buds reddish or purple & w/fine hairs, buds often stalked	no	2-3 valvate (edges meet) red scales	extending at angle from twig	triangle shaped
PAPER BIRCH	twigs slender, reddish-brown w/small white dots, (sometimes hairy); mature bark thin & papery, white-to coppery, inner bark fragrant	tree; often stump sprouts; dark horizontal lenticels on trunk	1/4"	no terminal bud; buds conical, long-pointed, & chestnut brown	slightly	3 (rarely 4) overlapping scales	extending at angle from twig	small and round
MTN. ASH	twigs stout, w/large leaf scars, rusty w/white hairs when young, bark thin & reddish, inner bark fragrant	shrub or small tree; oblong lenticels, red berries persistent	1/4-3/4"	terminal buds; buds reddish brown, oblong, pointed, w/white or rusty hairs	gummy exudate in <u>Sorbus scopulina</u>	overlapping scales	extending at angle from twig	large and round

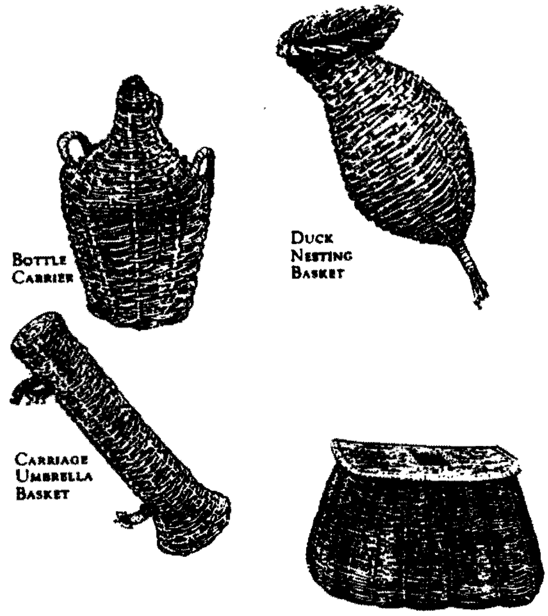
"Bud scale," "pith," "lenticel," and other terms defined at end of preceding twig key.

Cuttings from actively growing, juvenile wood often root more easily than those from older wood on mature plants. Plants can be encouraged to produce juvenile wood by severe pruning. Figure 15 shows how willows can be "pollarded" or "coppiced" to provide cuttings for years. (Moose regularly "pollard" willows, but the new wands rarely have much chance to grow.) Traditionally, the wands used in "wickerwork" were grown in stooling beds (see sidebar). Stooling beds are useful if you want to grow a large amount of material, and are discussed further under Soil Bioengineering.

Dormant cuttings should be relatively long and thick. For "live stakes," at least 18 inches long; for "bundles," 3 ft long or longer. (How to use stakes and bundles is described in Practical ways to promote bank stability.) Cuttings should be at least 1/4 inch in diameter (or about as big around as a pencil). Cuttings up to 2 inches or more in diameter may still root, depending on the species. Drying out is a cutting's worst enemy, and the larger and longer the cutting, the lower its chance of dessication. Cut the stems you've chosen with a sharp knife or shears, making sure each cutting has at least two or three healthy buds and its ends are cleanly cut and unsplit.

Keep dormant cuttings frozen or refrigerated until you're ready to plant, and don't let them dry out or become too moist in storage. (You can wrap them in damp newspapers, peat moss, or similar material.) Dormant cuttings can be planted from early spring, after the ground has thawed, to July 1. They can be taken straight from storage to the planting site.





A forgotten craft: wickerwork
(from Seymour 1984)

When I lived in Wales I had a very good friend named John Jones, who was a Gypsy man and proud of it. He used to sit at my fireside many a night and, among other things he taught me, was basket making. . . He always insisted on the supremacy of the thin pliable wands of various kinds of willow tree as basket-making material.

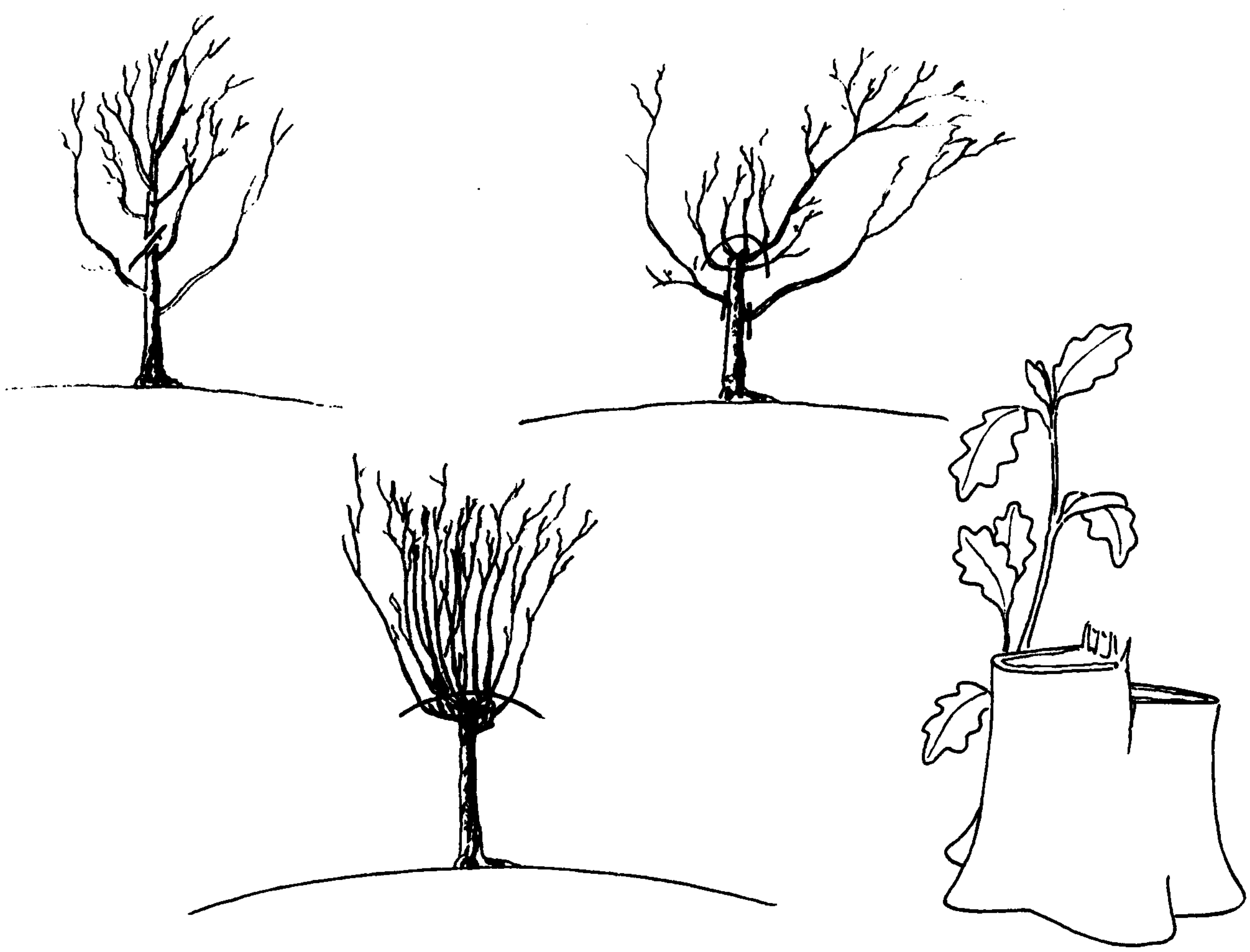
Willow basket making is what we refer to when speaking of *wickerwork*. It is the flexibility of willow that allows the most ingenious work and it is the ease with which willow can be grown and harvested that allows basket making on a large scale. What you call the young willow fronds used for basket making depends on where you come from. *Withy* is the term I use although it has West Country origins, whereas *osier*, or simply *rod*, are more widespread.

Withy beds are established by pushing willow branches into damp ground -- they grow with no trouble at all. They are left to grow for the first three years and then cut down to the *stools* (cut down to ground level) every year thereafter. The cutting itself is back-breaking work and is a wintertime activity. . . The withy cutters that used to work near my home in Ireland were salmon fishermen making the most of the winter when they could not fish.

Plants can also be propagated from rooted cuttings. Material to be rooted can be collected during either the dormant or growing seasons. Cuttings root most readily in a container filled with rooting medium of sand or half-and-half mixtures of sand and peat moss, vermiculite and peat moss, or vermiculite alone. The container and rooting medium should drain rapidly. Fill the container with rooting medium and insert the cutting to about half its length. (Rooting hormone promotes root growth in some plants, but may inhibit root growth in others.) Keep cuttings out of direct sunlight and water them frequently as they root. If possible, keep the soil warm (around 70 degrees F.) and the air cool. If you're rooting leafy cuttings, you can reduce water loss from leaves by reducing leaf area and by inverting a plastic bag or clear glass over the plant. Ventilate these "mini-greenhouses" for a few minutes every day or two.

Dormant cuttings can also be rooted outside (as live stakes and bundles, see the discussion on Soil Bioengineering). Doing this allows you to root cuttings in a convenient spot where you can monitor their growth and water them as needed; but you also have to transplant them to their final location. Rooted cuttings have higher survival rates than unrooted dormant cuttings. When cuttings have rooted, you can transplant them into containers or plant them outside. Rooted cuttings grown inside should be hardened off before they are planted outside (see Planting shrubs and trees). Once rooted, cuttings are treated like other seedlings.

Figure 15. Willows pollarded to produce new wands; a coppiced oak.



(3) Planting

Many readily available gardening books give excellent guidance on how to plant and care for grasses, shrubs, and trees. We refer you to such publications for more detail. Space here allows us to provide only the most basic guidelines. Planting of seeds and growing stock is discussed below; transplanting was discussed earlier.

The following basic guidelines for establishing herbaceous and woody plantings are from *A Revegetative Guide for Conservation Use in Alaska* (CES 1991). For more details, including recommendations on which species to plant and how much seed and fertilizer to use, contact the Soil Conservation Service or the Cooperative Extension Service. In addition, the CES has handouts describing methods for planting lawns.

1. Planting grasses and other herbaceous plants

Any seedbed must provide moisture for germination and nutrients for plant growth. This is best provided by mineral soil or mixed mineral soil-organic matter. When establishing grasses or other herbaceous plantings, the upper 4 to 6 inches of soil should consist of loamy material able to hold at least 1 inch of water. The soil must be porous enough to allow root penetration and friable enough to be tillable for good seedbed preparation.

Proper seedbed preparation is important in establishing plants. If possible, incorporate some dead vegetation or other organic matter into your seedbed before planting. After tilling and packing, the seedbed should be firm and moist. (Your foot shouldn't sink into the soil more than an inch if your seedbed is firm enough.) A well-prepared seedbed requires less seed for a successful planting, so energy put into seedbed preparation can save you time and money in the long run. Seed with either a drill or broadcast seeder. If you broadcast seed, rake it into the soil lightly after seeding.

On steep sloping land, prepare the seedbed as well as possible, but leave the surface roughened. Surface irregularities will help hold seeds and water. Mulching can be very beneficial on sloping sites (see below).

For best results, seed after May 15 and before June 15. The *Revegetative Guide* recommends that you avoid seeding grass in the Kenai River area after August 1. After that date, too few growing-degree days are left to allow grasses to develop adequate reserves before winter dormancy begins. Without adequate reserves, seedings are likely to suffer winterkill. You can seed before May 15 if temperatures have warmed up enough and the ground is not too wet.

Once you've finished seeding, you may want to mulch seeded areas. Mulches such as hay, straw, wood fibers, peat moss, and various kinds of woven netting and erosion control blankets provide immediate erosion control. They also aid germination by holding seeds in place, retaining soil moisture, reducing temperature fluctuations in the soil, and absorbing the impact of falling raindrops. Mulch covers are particularly beneficial on steep or droughty sites.

Mulch can be applied by hand or mechanical means. If woven mulch mattings are used on steep slopes, their uphill edges should be buried in a trench dug several feet back from the slope edge, as per manufacturers' instructions. Chapter VI lists several commercial sources for woven mulch mattings and erosion control blankets (see "Erosion control matting and geotextiles — vendors").

If you don't want to seed your grass cover yourself, you can have it hydroseeded. Several local landscape services listed in Chapter VI can hydroseed for you.

2. Planting shrubs and trees

Before deciding where to plant trees or shrubs, check what their mature sizes will be so you can place them in appropriate locations. Many shrubs and small round-crowned trees will grow about as wide as they grow tall; most native Alaskan trees will grow 3 to 5 or more times taller than wide. Space trees and shrubs no closer than half their mature width apart. (For example, shrubs that grow 15 ft wide should be placed 7 or 8 ft apart.) Shrubs used to create hedges can be placed closer together to form a dense screen. Don't plant species with aggressive, invasive roots (e.g., some cottonwoods) too near foundations, pavement, leach fields, etc.

Planting sites in low-lying areas or on north-facing slopes may have shorter growing seasons and be more susceptible to frost damage than other sites, both early and late in the growing season. Undisturbed soils in these areas may still be frozen near the surface until mid-summer. Disturbing the surface moss and organic mat will speed soil warming, but can cause surface runoff and erosion if done carelessly. Select hardier species for harsher sites (see p. 28 for ways to learn about your own "micro-site" conditions).

IT'S BETTER TO PUT A $50 TREE IN A $100 HOLE THAN A $100 TREE IN A $50 HOLE.
— Int'l Society of Arboriculture

The best time to plant trees and shrubs is when they are dormant, that is, in the fall after leaves drop or in the spring before buds swell and break open. However, as long as you care for woody plants properly after planting, you can plant them any time the soil isn't frozen. You'll have to decide which planting time makes most sense to you given your local climate and site conditions. Avoid fall planting where snow cover is unreliable or in areas subject to frequent freeze-thaw cycles, especially areas with heavy, dense soils and high moisture contents. Spring planting isn't possible until the ground thaws. Sometimes the combination of very cold soils, relatively high temperatures, and drying winds causes severe moisture stress to plants planted in the spring. Take extra care to keep plantings cool and moist if you plant during the relatively warm, dry conditions that may occur during spring and early summer.

Soil in the planting hole should be sufficiently porous to allow root penetration. Ideally, the upper 8 inches of soil should consist of loamy material. Soil pH is critical for many woody plants. If you can, have the soil pH tested and choose species adapted to grow at that pH (see insert 1, after p. 29).

The planting hole should generally be a little larger in diameter than the diameter of the top of the plant or about twice as wide as the root ball. The depth will vary according to the size of the root system. To prevent root binding, roughen the inside surfaces of the planting hole.

Plant at the same depth as the original root system (see Figure 16). The proper height is often shown by a dark stain on the trunk marking the difference between root and trunk bark. (On balled and burlapped trees, the burlap may be tied much higher than the appropriate soil line.) Roots of plants set too deep in the ground can suffocate; roots not set deep enough can dry out.

If possible, plant into a hole that has been thoroughly wetted by filling it with water. When you're ready to plant, remove all root wrapping or take the plant from its container, place the plant at the correct depth in the hole on a pile of loosened or backfilled soil, (spread the roots of bare root stock over this mound of loosened soil), backfill soil into the hole, and gently firm the soil around roots or root ball. Water thoroughly to settle the soil and remove air pockets. Gently firm soil around roots again; you want to create a good root-soil contact, but you don't want to compact the soil too much. (Very hard tamping with your foot is too much.) Create a small ridge around the hole to hold water.

There are a few additional points to remember when handling and planting trees and shrubs:

1) Harden off (acclimitize) indoor-grown seedlings and rooted cuttings before you plant them outside. A week or 10 days before planting, begin leaving plants outside for short periods of time in protected locations (an hour or so to start with). Double the time each day until the plant can remain outside for over 24 hours.

2) Always handle plants by their containers or root balls, not by their trunks. Be careful not to drop wrapped root balls or they will break apart and damage fragile roots.

3) Keep bare or wrapped roots moist at all times (but don't drown them). Leave plants in their containers, or roots packed or wrapped, until plants are at the planting site ready to be planted. Just before planting, remove packing or wrapping from bare roots or root balls. You can loosen root balls to encourage roots to branch out.

4) Protect shrubs and trees from competition until they grow taller than surrounding grasses and weeds. To do so, keep an area about 3 ft in diameter free of competing growth around each woody plant.

(4) Caring for plants

It's critical to take care of plants once they're in the ground. Plantings probably fail from "post-planting neglect" more than from any other cause. Greenhouses, nurseries, the Plant Materials Center, and the Cooperative Extension Service can all advise you on proper care of planted material.

Figure 16. Drawings 1 through 11 illustrate various ways that trees should NOT be planted. The ideal planting is shown in drawing 12 (from Boehner and Brandle, no date).

The two most important things you can do to promote planting success are: water and fertilize properly. This is particularly true for the first two growing seasons, but is also important in following years until plants are well-established. On harsh sites, adequate fertilizing and watering can be critical to plant survival. (And these are usually the sites you most want covered with vigorously growing plants.) The harshest sites along the lower Kenai River are those with droughty soils on south-facing slopes. (Droughty soils have high percentages of sand or gravel, low fertility, and low moisture-holding ability.)

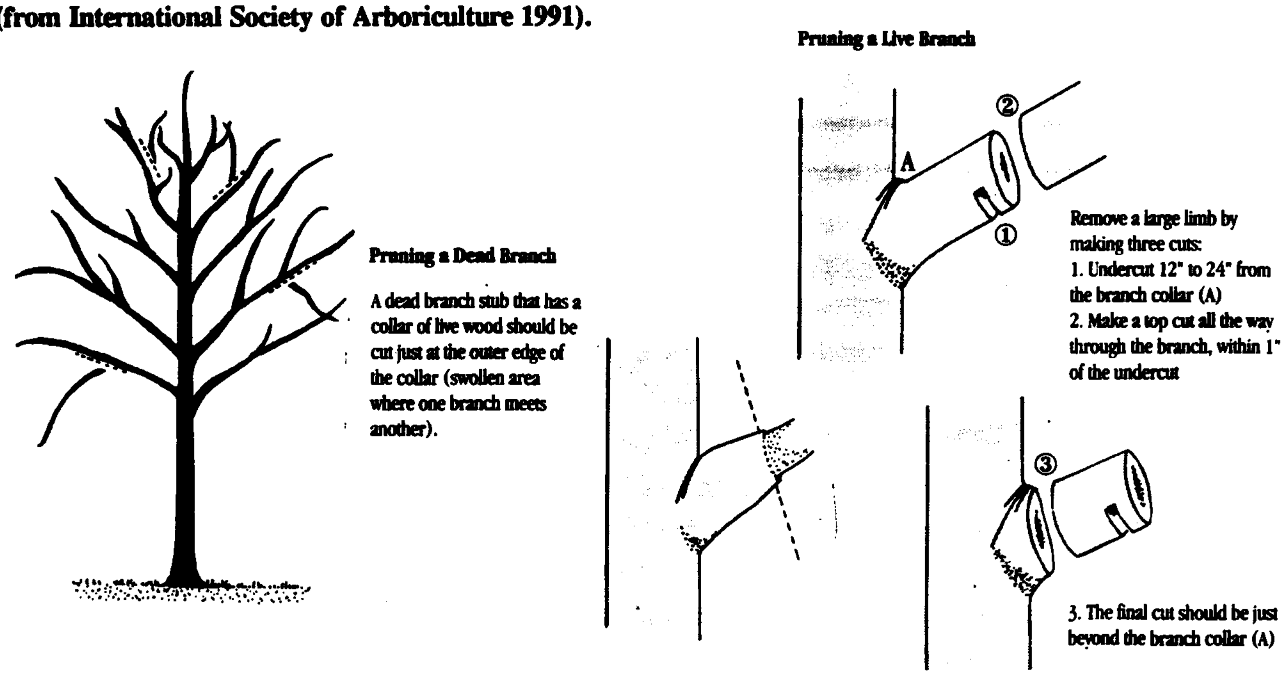
Water newly planted trees and shrubs regularly, once a week if there's no rain. When the soil is dry 4 inches below the surface, it's time to water. Discontinue watering in the fall so growth will stop and plants will harden off for winter.

Fertilization rates should be determined through soil testing (see insert 1, after p. 29). Many woody plants, particularly native species, can be damaged by indiscriminate fertilization. If possible, thoroughly mix fertilizer into the soil. Containerized seedlings from commercial outlets usually have a 2-year supply of fertilizer incorporated into the container medium, enough for initial establishment and early growth. Be sure not to broadcast granular fertilizer on streambank plantings where it could be washed into streams.

Another important aspect of plant care is pruning correctly when pruning is needed. Figure 17 illustrates correct pruning techniques.

Finally, because of the rapid spread of spruce bark beetle on the Peninsula (ADNR 1992), we suggest you follow instructions contained in insert 3 when handling spruce logs. In addition, Forest Insect and Disease Leaflet 127, *The Spruce Beetle*, from the U.S. Forest Service provides useful information about spruce bark beetles.

Figure 17. How to prune. Pruning is best done winter to early spring. Prune sparingly; pruning reduces leaf surface needed for photosynthesis. Prune when damaged limbs threaten the tree or surrounding structures. Cut so the outermost bud remaining on the branch is pointing in the direction you want the branch to grow. Preserve the branch collar (don't cut flush with the trunk). Commercial wound dressings may interfere with healing; the best post-pruning care is to fertilize and water according to the plant's needs (from International Society of Arboriculture 1991).



SPRUCE BARK BEETLES

CONTROL OPTIONS FOR THE HOME OR LOT OWNER

100G-0-067

Spruce beetles are always present in spruce forests, and it is only when an abundance of breeding material is available to them, along with favorable weather conditions, that they can increase to epidemic numbers. Spruce beetles prefer to attack, and can kill, large diameter spruce.These trees are often valued ornamentals. Other trees such as aspen, birch and hemlock are not attacked by spruce beetles.

This short guide presents suggestions for reducing the possibility of spruce beetle caused tree mortality, and control options which may be useful in the home or small lot setting.

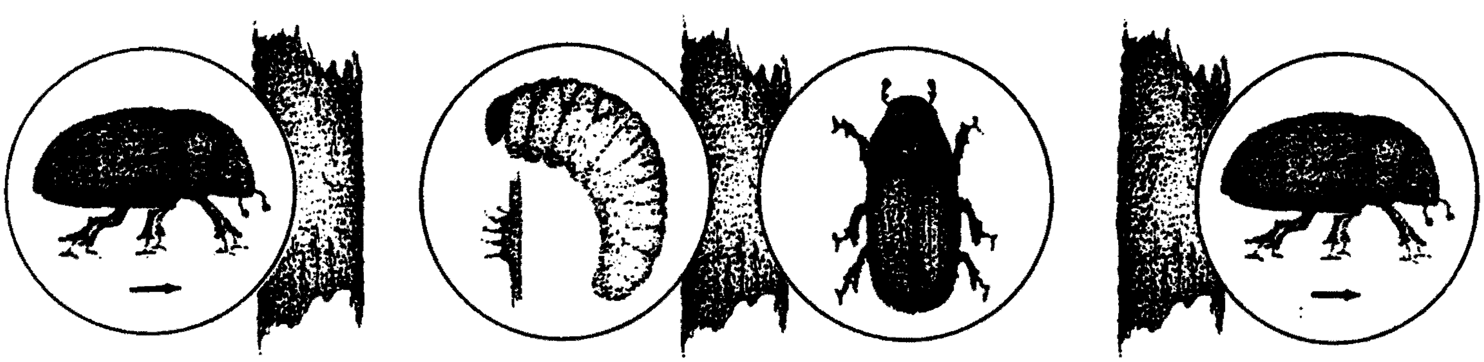
I. Suggestions for reducing the possibility of spruce beetle infestation

1. **Maintain the health of the trees** on the lot; spruce beetles prefer to breed in weakened standing or windthrown trees. Fertilizing and watering each tree early in the growing season helps to promote tree vigor. **Removing windthrown trees helps eliminate potential sources of infestation.** These trees should be split or debarked immediately to help dry out the material.

2. **Avoid importing infested material,** such as firewood containing live spruce beetles, to the home-site or the lot.

3. During home construction, **avoid damaging** trees with mechanical equipment, placing excess soil over tree roots, or altering drainage.

4. **Consider the health** of the tree and all options before making a decision on control measures. Fast growing, healthy trees are more resistant to spruce beetle attacks than are slower growing or unhealthy trees. These may need more attention and protection.



spring *summer* *fall* *winter* *spring*

COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF ALASKA FAIRBANKS & USDA Cooperating

II. Spruce Beetle Damage

First, using this flow chart, determine whether your tree is attacked or unattacked. Control and management options are then listed on the following pages.

KEY TO SPRUCE BEETLE DAMAGE

SPRUCE

if unattacked

GREEN NEEDLES

NO visible rust-colored boring dust on bark, in bark crevices, especially at eye-level and below, or on the ground

NO rust-colored, opaque globules of pitch mixed with boring dust on bark especially at eye-level and below

= Unattacked tree (See A)

if attacked

GREEN NEEDLES

Reddish-brown boring dust **PRESENT** on bark, in bark crevices, especially at eye-level and below, or on the ground

Reddish-brown, opaque globules of pitch and boring dust **PRESENT** on bark, especially at eye-level and below.

Woodpecker activity may be present.

= Tree attacked this season (See B)

OR

FADED YELLOW OR BRIGHT RED NEEDLES

Evidence of previous beetle attacks as described above

Beetle larvae, pupae, and/or adults present under bark

Woodpecker activity may be present

= Tree attacked last season (See C)

OR

NO NEEDLES REMAINING ON TWIGS

Tree appears reddish-brown in overall color

Evidence of previous beetle attacks and emergence holes

No beetle larvae present, though some adult beetles may be present under bark

Woodpecker activity may be present

= Tree attacked last season or before (See D)

OR

NO NEEDLES AND NO TWIGS REMAINING-- TREE SILVER-GRAY

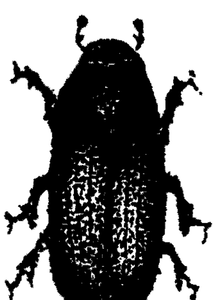
Loose bark with evidence of previous beetle activity on the underside

No live beetles present

= Tree attacked 3 or more seasons ago (See E)

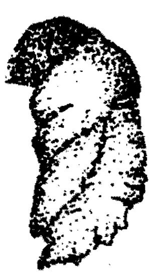
ASPEN, BIRCH, HEMLOCK AND OTHER TREES

Are NOT attacked by spruce beetles

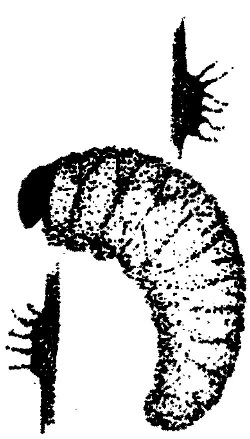


adult

egg



pupa



larva

III. Control Options

A. Unattacked Tree

Fertilize and water each individual tree early in the season to encourage vigor. A fertilizer high in phosphorous such as 8-32-16 may help in root production which in turn helps the tree in water and nutrient uptake. An application of one pound of fertilizer per inch of tree diameter is suggested. Incorporate fertilizer into root zone area and water well.

Prune the lower branches on full-crowned trees; no more than one-third of the total tree height should be removed. Based on Forest Service research findings, removing these lower branches may be an effective step in reducing the possibility of spruce beetle attack. Pruning should be done in the fall, and the branches should be removed from the area and disposed of.

Spray the tree with an insecticide registered for use on spruce trees to prevent spruce beetle attacks. **This should be done in spring before the end of May in order to protect the tree prior to the beetle's emergence and dispersal flight. Currently three chemicals are registered for preventative use against spruce beetles:**

carbaryl
or
chlorpyrifos
or
lindane

Follow all label directions when using any pesticide
(Note: "Sevimol"® *and* "Sevin SL"® *are registered formulations of carbaryl available in large containers, and both are costly and/or hard to find. Because of this, as well as the cost of spraying equipment and protective wear, homeowners may wish to consider the services of a qualified pest control operator. Please see Cooperative Extension Service fact sheet: Choosing a Pest Control Operator. The use of trade names does not imply endorsement by CES.)*

All recent windthrown trees should be removed from the area prior to mid-May. They should be debarked or split **immediately** for firewood to encourage drying of the phloem tissue beneath the bark, therefore discouraging the beetles from attacking the material. Seriously damaged trees should be either removed or sprayed as previously described. Stumps should not be left aboveground, or if so, should be debarked down to 2 inches below the soil surface.

For home or lot owners with many trees:

- Thinning trees reduces competition and increases vigor.
- Select valued trees for individual protection, using one or more of the options presented in this outline.
- Contact State of Alaska Service Forester for more information.

B. Tree Attacked This Season

Recently attacked trees can become next spring's infestation source, so it is important to determine the degree of initial attack. One or two beetle attacks don't necessarily mean the tree will die; however, it is important to realize: 1) you may not notice all the attacks; and 2) there is a good chance that the tree will be attacked again, successfully, next season. It helps to be observant, but when in doubt, it also helps to ask a qualified person such as your area Extension Pest Scout.

A heavily attacked tree should be removed during the coming fall, or before May of the following spring to avoid infestation of surrounding trees. The tree should be **debarked** or **fire-scorched immediately** upon felling to destroy the beetles and larvae within. Scorched wood may then be used as firewood since it is not fully burned. **Stumps should not extend above ground, and if so, should be debarked down to 2 inches below the soil surface.** (Note: heavily attacked trees which are removed in the fall following new attacks may also be split for firewood and allowed to dry over the winter. This may prevent the young, newly hatched larvae from developing into adult beetles).

C. Tree Attacked Last Season

Trees that were attacked last season are the sources for attacking beetles this season and the next. Because of the beetle's 1- or 2-year life cycle, these infested trees are important to identify as they contain the new generation of beetles which are ready to emerge and attack new trees.

Determine if beetles are present by removing a section of bark near the lower portion of the trunk.

Remove the infested tree prior to the coming May and debark or fire-scorch the material immediately upon felling. This will prevent the beetles from emerging and attacking surrounding trees by killing any adults and larvae within the material. The wood may then be split and used for firewood.

D. Tree Attacked Last Season or Before

Usually only adult beetles remain under the loose bark, and these will be ready to emerge and find new host trees as early as mid-May or early June.

Determine if beetles are still present by removing a section of bark from the lower portion of the trunk and examining the underside. If no beetles are under the bark - see section E.

Remove the infested tree prior to the upcoming spring and debark or fire-scorch the material immediately upon felling. This will prevent the remaining adult beetles from emerging and attacking surrounding trees. The wood may then be split and used for firewood.

E. Tree Attacked 3 or More Seasons Ago

This **dead tree** will have **no spruce beetles remaining** under the bark. Other beetles and larvae may be observed, but they are of little concern as they are beneficial wood decomposers, and not "tree killers."

Cut the tree down to use as firewood.

Leave the tree standing to serve as wildlife habitat. (The tree should be removed however, if it is unstable or endangering persons or property.)

The use of trade names does not constitute endorsement by the Cooperative Extension Service nor by the USDA Forest Service

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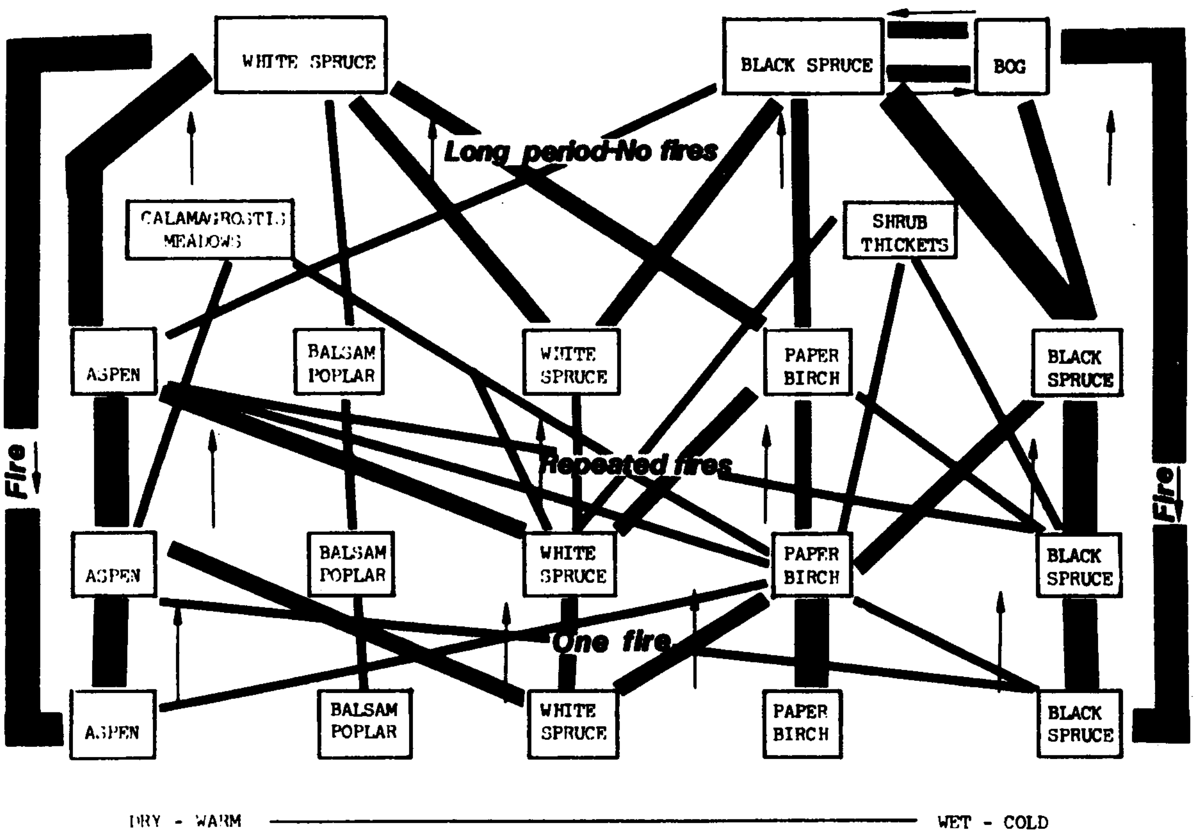
Introduction to plant communities

Plant communities are recognizable groupings of plant species that are often found growing together because they are adapted to similar environmental conditions. Environmental features that most influence where a particular plant will grow include: soils, moisture, light (both intensity and daylength), temperature, and disturbances (from natural events, such as floods and fires, and from animals and human beings). Some plants are adapted to a wide range of conditions and are found in many different sites and plant communites; others have very narrow habitat tolerances and occur in few sites and communities.

Plants themselves change the conditions where they grow. For example, leaves and decomposing plant parts add organic matter to soils; stems and roots increase a soil's ability to absorb rainfall; leaf litter insulates soils and thereby changes soil temperatures; leaves create shade, lowering air temperatures on sunny days, but leaves also reduce loss of heat from the ground to the atmosphere on cold and cloudless nights.

As conditions at a site change over time, plant species better adapted to the new conditions may outcompete the plants that originally "pioneered" the site. This process, whereby one plant community is succeeded by another as conditions change, is called *plant succession.* Plant succession can take many paths and can be retarded or redirected by disturbances such as fire, flooding, or human activities. (You, after all, can control plant succession on your own property.) Figure 18 outlines some of the paths plant succession can take after a site is cleared by fire. Figure 19 illustrates a common successional pattern in northern forests.

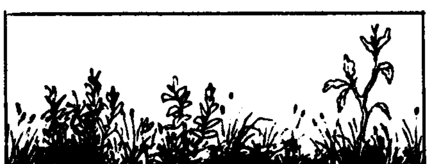
Figure 18. Paths plant succession may take after fire. (Based on interior Alaskan forests, but illustrates post-fire succession on the Kenai Peninsula; from Viereck and Schandelmeier 1980:48).



Plant communities can be named after the dominant *overstory* species (the tallest plants in the community, usually trees and tall shrubs) or after the dominant *understory* species (plants growing beneath the canopy formed by the overstory species). Both overstory and understory communities were distinguished, mapped, and "sampled" during the Kenai River study[1]. The name assigned to each plant community lists all the species that make up 20% or more of total plant cover in that community. (Scientific names are often used to name plant communities; Table 2 in Chapter VII lists the common and scientific names of plants mapped along the Kenai River.) A number of other terms are also used to describe communities. These are defined in Table 11.

Within the Kenai River study corridor, 80 overstory and 40 understory plant communities were distinguished and mapped on aerial photographs. On the photos, and on plant community maps in Chapter VII, codes identify what communities occur where: the overstory code is listed first, followed by the understory code. **Plant communities and their codes are listed in Tables 3 and 4 in Chapter VII.** Common communities are briefly described in the following section.

Figure 19. Typical succession in a northern forest (from Richberger and Howard, no date).



***Stage 1.** Pioneer grasses, forbs, and shrubs.*

***Stage 2.** Shrub stage with invasion of intolerant seedlings.*

***Stage 3.** Mixed species stand of young intolerant trees.*

***Stage 4.** Mature stand of intolerant trees with understory of tolerant seedlings.*

***Stage 5.** Mature stand of tolerant species with understory of their own seedlings.*

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1 During this process, plant communities were outlined on aerial photographs and then examples of each were visited on the ground to collect data on species composition, plant cover, plant height, etc. This process will be described in detail in the "Technical Report" for the Kenai River Study.

Knowing what plant communities occur in an area, and something about each community (species present, plant cover, etc.) is useful for a number of reasons. For example, plant community information can indicate:

- what soil conditions occur where (especially, soil productivity/fertility and soil water regime or wetness/dryness),

- what kinds of wildlife may use a particular area (plants are a critical habitat component, see Chapter II, Section B),

- where to look for particular kinds of plants,

- what kinds of plants should be used to revegetate disturbed areas (this can be determined by referring to similar undisturbed areas),

- history of past disturbances such as floods and fires.

In addition, plant community maps can tell us how common and widespread different plant communities are in the mapped area. Communities that are relatively rare may deserve special consideration. If a rare community is destroyed, there may be no other suitable sites for those plants, and the animals that use them, to survive. Disturbing a site that supports a community common in surrounding areas does not have the same significance. Data on acreages and relative occurrence of plant communities could not be compiled in time for this *Landowner's Guide*, but will be presented in the "Technical Report" for the SCS Kenai River Study (due in early 1993).

Seven "interpretations" of plant community data were made by Tom Ward, SCS State Forester, as part of the Kenai River study. (Tom also oversaw plant community mapping and inventorying.) Making plant community "interpretations" involves using collected plant data to estimate how well (or poorly) different plant communities are suited for particular purposes. Although seven purposes have been considered so far, SCS data can theoretically be used to develop any number of additional interpretations needed by landowners. The seven interpretations developed to date are:

1. moose habitat suitability
2. spruce bark beetle hazard
3. wild berry abundance
4. willow abundance (potential sources of "soil bioengineering" material)
5. cottonwood abundance (potential sources of "soil bioengineering" material)
6. goshawk habitat suitability
7. wood volume

Tables 5 and 6 in Chapter VII show these "interpretation ratings." To save space in this *Guide*, the basis for making each interpretation (e.g., data used, how these data were evaluated, etc.) is not outlined here. That information will be contained in the "Technical Report" for the Kenai River Study.

Table 11. Definitions of common terms used in the Kenai River study to describe plant communities.

aspect: The predominant direction (north, south, etc.) that a sloping area of land faces.
canopy: The vertical projection downward of the aerial portion of shrubs and trees, usually expressed as percent of ground covered.
closed stand: A group of plants, usually trees, that has 60% or more canopy closure.
closure: Looking up through the canopy, that portion of the sky that is covered by plant parts.
conifer: Cone-bearing, needle-leaf, evergreen trees (white spruce and black spruce in the study area).
cover: Aerial plant parts that extend horizontally and "cover" the ground; usually expressed in percent of the total area.
dbh: Diameter at breast height (4.5 ft above the ground) of a tree stem.
deciduous: Broadleaf trees that drop their leaves in fall (aspen, birch, cottonwood, willow, alders, etc.).
diverse: A plant community with a comparatively large variety of different species.
forbs: A non-woody plant that is not a grass.
forest: A distinct group of trees, distinguishable from other surrounding groups of trees.
herbaceous: General term for all non-woody plants, including grasses and forbs.
open stand: A group of plants, usually trees, that has between 25% and 60% canopy closure.
overstory: The tallest layer of plant cover, usually composed of trees, but in the context of this study, any kind of vegetation that overtops another layer of plants.
plant community: A distinct combination of plant species that occur together in a repeated pattern over the landscape.
pole: A coniferous tree with a dbh of 5 to 9 inches; a deciduous tree with a dbh of 5 to 11 inches.
productive: A comparatively fast-growing, well-stocked, vigorous plant community or forest stand.
regeneration: The process of establishing a new stand of trees on a site where trees have been removed by harvest, fire, insects, floods, etc.
reproduction: Trees less than 4.5 ft tall.
sapling: Trees taller than "breast height" (4.5 ft) but with a dbh less than 5 inches.
sawtimber: Trees meeting minimum size criteria for milling into lumber (9 inches dbh for conifers; 11 inches dbh for deciduous trees).
type: A mapped plant community, assigned a code in this study.
understory: Plants (usually shrubs, grasses, and forbs) growing underneath a canopy of taller plants (usually trees).
upland: Plant communities that do not meet the definition of a wetland.
vigor: A general term for good health, imlplying fast growth.
well-stocked: A stand of trees with very few openings or gaps, the ground is fully occupied with trees.
wetland: Plant communities composed of species known to be typically adapted for life in saturated soil conditions. Marshes, muskegs, and bogs are examples of wetlands.
woodland: A stand of trees with 10% to 25% canopy closure.

Plant communities along the lower Kenai River

Tom Ward
SCS State Forester

Plant communities along the lower Kenai River were mapped at two levels: *overstory* (overtopping trees, shrubs, etc.) and *understory* (low growing or ground vegetation). The overstory classification is based on *A Preliminary Classification for Vegetation of Alaska* (Viereck et al. 1982). Species, height, and closure of the overstory were recorded (Level IV of the Viereck classification). **Tables 3 and 4 in Chapter VII provide keys to overstory and understory plant community codes.**

(1) Overstory plant communities

Typically only tree cover is referred to as *overstory*, but the two-tiered classification used in this study began with plant cover that could be seen on aerial photographs: where no tree cover occurs, the dominant vegetation was mapped as overstory, regardless of its height.

Overstory plant communities of the lower Kenai River are divided into six groups: (1) coniferous forest, (2) deciduous forest, (3) mixed coniferous-deciduous forest, (4) tall shrubs, (5) low shrubs, and (6) herbaceous. Within each group, stands were distinguished according to crown closure (e.g., "closed" or "open") and for forested types, tree size ("sawtimber," "pole," "reproduction," etc.). (See Table 11 for useful definitions.)

Although the study area begins at Cook Inlet and extends only 50 river miles inland from the coast, the forest found can be generally described as "interior spruce-hardwood." It is very similar to the boreal forest found in the Matanuska-Susitna Valley and river valleys north of the Alaska Range. Common tree species are white spruce, black spruce, paper birch, quaking aspen, and black cottonwood.

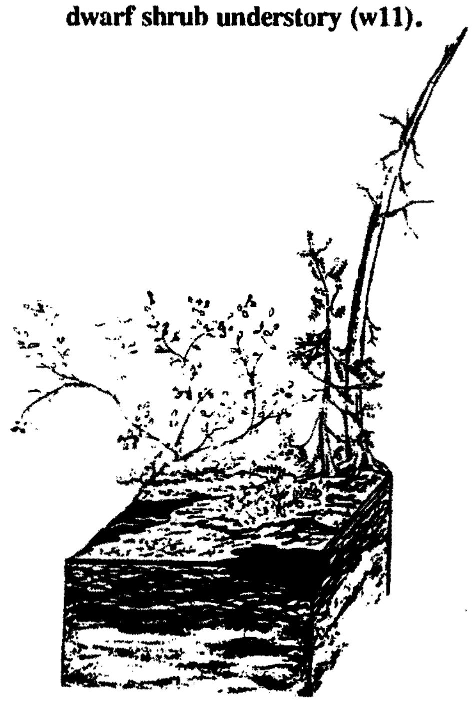
1. Coniferous forests

Coniferous forests consist of black spruce, white spruce, and combinations of these two species. Lutz spruce (a cross between white and Sitka spruce) were not found in the area.

Typically **black spruce forests** occur in pure stands on poorly drained, cooler sites, such as north slopes and peat moss bogs. Most black spruce stands are associated with wetland understory communities. Stands are most often "open" (25-60% canopy closure) or "woodland" (10-25% closure), but some "closed" stands (60-100% closure) were mapped. Mature black spruce are typically less than 6 inches in *diameter at breast height* (dbh) and less than 30 feet tall. The largest of the 150 black spruce measured was 10.9 inches dbh, and the tallest of 10 trees measured for height was 59 feet.

Understory communities associated with upland black spruce include feathermoss-dwarf shrub communities (d1-d3, d5, and d11). Wetland black spruce stands occur with feathermoss-peat moss-dwarf shrub communities (w7, w11, w27) (Figure 20).

Figure 20. Black spruce woodland (11Rw) with feathermoss-peat moss-dwarf shrub understory (w11).



White spruce forests occur on better drained sites and a variety of aspects, mostly with upland understory communities, although some wetland white spruce communities were mapped. Pure stands and closed stands are uncommon; open, woodland, and mixed stands are the rule. The largest white spruce measured was 20.8 inches dbh (out of 574 trees measured), and mature trees greater than 10 inches dbh were not uncommon. The tallest tree was 100 feet in height (out of 263 trees measured); four additional trees were over 90 feet tall. Very few young stands of white spruce occur along the lower river. Trees over 100 years old are common, and several were over 200 years, the oldest being 280 years. White spruce vigor declines after about 150 years of age.

Upland white spruce stands occur with a variety of understory plant communities, most often one of the feathermoss-dwarf shrub communities (d3 or d11), bluejoint-fireweed (d21 or d47), or riparian alder (d30) communities. Wetland white spruce often occurs with alder (w3 or w4), bluejoint (w1 or w9), or horsetail (w23) communities.

Mixed black and white spruce stands are not uncommon, particularly in areas subject to frequent fires. These stands occur on a variety of sites, which may reflect the abundant availability of seeds of both species after fire. The canopy closure in these stands is often open or woodland.

Both wetland and upland understories are associated with this forest type. On poorly drained wetland sites, grass-willow (w29) or peat moss-dwarf shrub (w7) communities are common. Feathermoss-dwarf shrub communities (d1-d3, d11) are common on upland sites.

2. Deciduous forests

Paper birch is the most common deciduous species along the lower Kenai River, occurring in pure stands and occasionally in combination with quaking aspen and black cottonwood. Paper birch stands occur on a variety of sites and aspects, and on both uplands and wetlands. Often birch will form dense young stands after disturbances such as fire.

In dense, young stands, understory plant communities are simple, with few species (d1, d2) (Figure 21a). Gradually competition for light reduces the number of trees, and the understory may become lush and complex (d26, d42) (Figure 21b). Finally near the end of its normal life span (about 150 years), the birch stand consists of large, widely spaced trees, and the understory may be dominated by bluejoint (d21, d45). Where birch occurs in wetland communities, it is usually associated with bluejoint (w1, w29). The largest diameter found in the 224 birch trees measured was 19.5 inches dbh; the tallest height in 17 measured trees was 62 feet.

Figure 21(a) - Dense young birch forest (d1, d2); (b) - older birch forest (d26, d42).

Quaking aspen stands are relatively uncommon in the study area, occurring on well-drained soils, particularly on south-facing aspects. Aspen occurs only in upland situations. Common understory plant communities include feathermoss-dwarf shrub (d3, d11) and grass-dwarf shrub (d26). Like paper birch, aspen will colonize disturbed areas in dense, closed stands and then gradually form open stands of large trees at maturity (about 80-100 years). The largest aspen of the 69 measured was 18.5 inches dbh. Aspen heights were not measured.

Cottonwood is the least common of the deciduous trees along the lower Kenai River. Both black cottonwood and balsam poplar may occur in this areas, as well as hybrids of these two very similar species. Range maps indicate that black cottonwood is much more likely than balsam poplar to occur in the study area.

Cottonwood occurs in small stands or long narrow bands immediately adjacent to the Kenai River. Sometimes cottonwood forms pure stands, but often it is mixed with white spruce and occasionally with birch or aspen. Often gravel bars and islands are colonized by cottonwood, together with willow and alder.

Understory communities associated with cottonwood stands include very simple early-successional upland (d1, d2, d47) and wetland (w9, w3, w23) communities.

Cottonwood is the largest tree species found on the lower Kenai River. The largest of 45 cottonwoods measured was 27.3 inches dbh. Trees over 15 inches dbh were common. Although no cottonwood heights were measured, it is likely that some exceeded 100 feet.

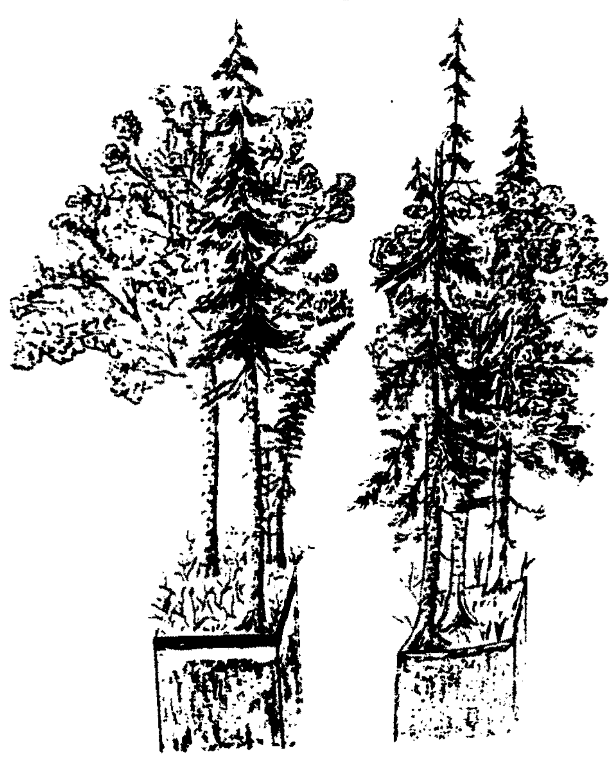
3. Mixed coniferous-deciduous forests

Black spruce occurs most often in pure stands, but will occassionally form mixtures with birch, aspen, white spruce-birch, and white spruce-aspen. These mixed stands are similar to mixed black spruce-white spruce stands and tend to form on upland benches subject to frequent fire. Understories of feathermoss-dwarf shrub (d1, d2, d5) are common.

White spruce occurs in combination with deciduous species more often than in pure stands. These appear to be the most productive stands in the study area, both in terms of tree and understory growth.

Mixed white spruce-birch is the most common forest combination in the study area, occurring over large areas immediately adjacent to the river and on slopes of almost any aspect (Figure 22). Not many young stands occur; most are over 100 years old. Closed, open, and woodland stands can be found, but closed stands are most common. A wide variety of understory plant communities occur with these stands, mostly upland communities but also some wetland. Under upland closed and open stands, two kinds of understories are common: feathermoss-dwarf shrub (d3, d11) or alder-bluejoint-horsetail (d30). Woodland understories include communities with a high grass component (d21, d45). Wetland understories include horsetail (w23) and alder-bluejoint (w3, w4) communities.

Figure 22. Mixed white spruce-birch communities.



Aspen occurs in combination with white spruce-birch, forming stands very similar to those described above, but occurring only on uplands and mostly on south-facing slopes.

White spruce-aspen also occurs only on uplands and mostly on south slopes. Understory communities tend to be feathermoss-dwarf shrub (d3, d11), but often with a higher grass and forb component (d26, d42) than is typical of white spruce-birch understories. This is probably due to increased light, which reaches the forest floor because of the more open aspen canopy and south-facing aspect.

White spruce-cottonwood and white spruce-cottonwood-birch stands occur on floodplain sites next to the river. These are probably the most productive forests in the study area. Understory plant communities associated with these forest types on drier soils include oak fern-bluejoint-forb (d42), fireweed-horsetail-bluejoint (d47), and alder-bluejoint-horsetail (d30). Wetland understory communities include horsetail (w23) and alder-bluejoint (w3).

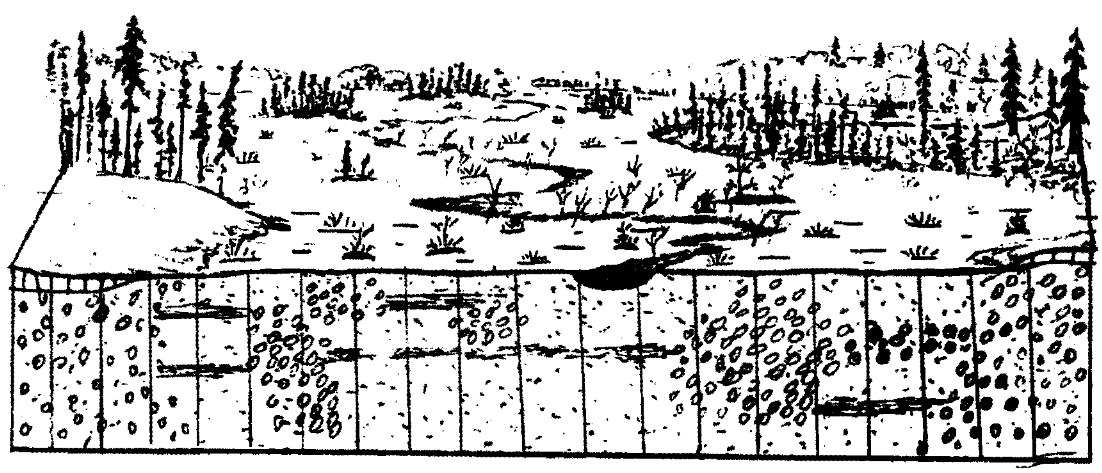
4. Tall shrub communities

Willow, alder, and combinations of willow and alder occur immediately adjacent to the river, in bog areas, and in wetland sites at the toe of north slopes. These shrubs range from about 3 feet in height to occasionally over 20 feet. Associated with these types are understories characterized by horsetail and bluejoint (w3, w9, d30).

5. Low shrub communities

Willow, dwarf birch, and several species of ericaceous shrubs (Labrador tea, blueberry, etc.) cover large boggy wetland areas (Figure 23). Associated with these cover types are cottongrass-peat moss (w35), crowberry-sedge (w38), and marsh five finger-sedge (w31) understory plant communities.

Figure 23. Low shrub wetland community.



5. Herbaceous communities

Meadows of grasses, sedges, and forbs range from dry, upland sites to moist, seasonally flooded areas and wetlands characterized by standing water during the growing season. The grass species in nearly all of these communities is bluejoint (*Calamagrostis canadensis*).

Upland meadows of grass-willow-fireweed (d21) occur on elevated levees and benches adjacent to the river. These meadows often have a component of scattered shrubs, including willow, currant, or raspberry.

Moist, seasonally flooded meadows occur in bowl-shaped depressions or around the margins of more permanently flooded areas described below. Mixtures of grasses and sedges, with some willows, make up these communities (w1, w9, w29).

Wet meadows are either sedge-dominated (w10, w35, w45) or *Sphagnum* (peat) moss dominated (w33, w40, w11). Sedge wet meadows tend to be shallow ponds or marshes with cottongrass and one or more species of sedges. *Sphagnum*-dominated wet meadows have standing water, cottongrass, and sedges, but also hummocks of moss and dwarf shrubs such as cloudberry, bog cranberry, and crowberry.

(2) Understory plant communities

The understory classification corresponds to the most detailed level of the Viereck classification (Level V). Plant communities are described in terms of the species that usually occupy the greatest area (percent cover) of the community. Understory plants are divided into *upland* communities and two kinds of *wetland* communities: *tidal* and *freshwater*. (See Table 4, Chapter VII, for key to codes).

1. Upland plant communties

Thirteen upland plant communities were mapped and sampled. Probably the youngest community in terms of plant succession is **fireweed-horsetail-highbush cranberry-bluejoint reedgrass** (d47, see Table 4 in Chapter VII for a key to understory map codes). This community is found under young, productive stands of hardwoods and white spruce.

Five feathermoss-dominated communities appear to form a successional sequence from youngest to oldest. **Feathermoss** (d1) is the simplest, having little diversity and sometimes less than 30% plant cover. This community was found under sapling- or pole-stands of black or white spruce or mixed coniferous-deciduous forest. **Feathermoss-lowbush cranberry** (d2) has greater species diversity and higher cover values. It is found mostly under sapling mixed coniferous-deciduous stands. **Feathermoss-dwarf dogwood-lowbush cranberry** (d3) is even more diverse and found mostly under closed sapling and pole stands of mixed coniferous-deciduous forest. **Feathermoss-lowbush cranberry-dwarf dogwood-low shrub** (d11) is one of the most diverse and commonly occurring upland communities in the study area. It occurs under a decidedly older and more open forest of mixed coniferous-deciduous species. A thicker organic mat in this community may result in cooler, damper forest floor conditions. A more open forest canopy, supplying more light, probably contributes to the lush growth of this community.

Two additional communities are closely related to those described above. **Feathermoss-lichen-lowbush cranberry-crowberry** (d5) occurs on drier, less productive forest sites. It is found under slow growing sapling and pole stands of black spruce and mixed black spruce-deciduous forest. Lichens and altai fescue are common in this community. **Oak fern-rose-bluejoint-feathermoss** (d42) is a lush, diverse community that occurs on some of the most productive forest sites. It is found under closed mature stands of mixed white spruce and either birch or cottonwood.

A pure **horsetail** community (mostly *Equisetum arvense*, d48) is found under productive stands similar to d42 above. This rather simple community is transitional between upland and wetland areas and is found on moist sites near the river. Another moist, productive riparian zone community is **alder-horsetail-bluejoint** (d30). This rather common community is often found under open, mature white spruce or mixed spruce-birch forest.

Three bluejoint reedgrass-dominated communities were mapped. The simplest is pure **bluejoint** (d45), found under open or woodland stands of mature white spruce or birch. **bluejoint-feathermoss-dwarf shrub** (d26) is somewhat like the feathermoss-dominated stands above (d2 to d5 and d11), but occurs mostly under older, closed deciduous and mixed white spruce-deciduous forest. **bluejoint-willow** (d21) is a grass-tall shrub community with a frequent alder component. It is found under open mature stands of deciduous and mixed white-spruce deciduous forest and sometimes in open meadows near the river.

An uncommon community is **willow** (d16). It occurs under young, open black spruce-birch stands and is usually composed of Bebb and/or Scouler willows.

2. Wetland plant communities

Wetland plant communities are those composed of species known to be "...typically adapted for life in saturated soil conditions" (SCS 1988). Marshes and bogs are examples of such communities, which are "...transitional areas between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" (Cowardin et al. 1979).

Wetland plant communities are considered particularly important, and merit special attention, because of the many benefits they offer. For example, wetlands provide:

- wildlife habitat for mammals, such as beaver and river otter, and waterfowl, such as ducks and geese;
- habitat for fish spawning and rearing;
- recreational and educational sites;
- flood control (wetlands store flood waters and release them slowly, thus reducing flood peaks);
- groundwater recharge areas;
- groundwater discharge areas (springs);
- nutrient areas (enriched detritus from wetlands provides the basis for many wetland and aquatic food chains);
- sediment trapping areas (wetland plants act as natural filters, removing sediments and other pollutants from flowing water);
- shoreline anchoring and dissipation of erosive forces along shorelines;
- ecological diversity.

Among birds, migratory waterfowl are particularly dependent on wetlands. They and other birds make the greatest use of wetlands during breeding season, from mid-April to the end of July. Wetlands used most heavily for breeding have about equal areas of open water and vegetation, and include shrubs for hiding cover. Examples of wetland plant communities likely to fit this description include w10, w33, w39, w40, w44, and w45.

Tidal wetland communities

Thirteen tidal wetland plant communities are found in areas periodically flooded by brackish water during high tides. Tidal influence extends from the mouth of the Kenai River upstream to about river mile 12. Near the river's mouth, tidally inundated areas sometimes extend beyound the boundaries of the study corridor. Tidal communities become progressively narrower upstream.

Plant communities in tidally influenced areas differ markedly from those in the rest of the study corridor. Some of these plant communities are heavily used by waterfowl, as described by Rosenberg in *Wetland Types and Bird Use of the Kenai Lowlands* (1986). Tidal marshlands are particularly important to migrating snow geese in spring and fall. These marshlands include the following plant communities: **creeping alkali grass** (T2), ***Ramenski* sedge-Pacific silverweed-seaside arrowgrass** (T3), **large alkali grass-seaside arrowgrass** (T8), and **many-flowered sedge** (T12). Migrating geese and ducks prefer areas with a variety of plant communities interspersed with shallow open water. These conditions and communities are found mostly downstream from the Warren Ames Bridge near Kenai.

The Kenai lowlands caribou herd also uses plant communities in the tidal area. Wetland shrub communities upstream from the bridge are used most often, including **feathermoss-bluejoint-horsetail-low shrub** (w27), **peat moss-feathermoss-low shrub** (w11), **sedge-marsh five finger-low shrub** (w31), **cottongrass-willow-peat moss-bluejoint** (w35), and **crowberry-sedge-peat moss-willow** (w38). Scattered black spruce can be found in these communities, perhaps providing a certain amount of cover and arboreal (tree-growing) lichens, a preferred winter food for caribou. Sedges in tidal marsh communities (see T3 and T12 above, for example) are also sometimes used for food. Grazing occurs mostly upstream from the bridge, but also sometimes downstream (Andy Loranger pers. comm.).

Freshwater wetland communities

Twenty-two freshwater wetland plant communities were mapped. These occur in a variety of habitat types, from open marshlands with standing water to shrub and forest communities, usually dominated by black spruce.

The plant community with the greatest amount of open water is **buckbean-cottongrass** (emergent vegetation, w39). This community occurs most often in the lowlands near the river's mouth, just upstream from the Warren Ames Bridge. Four plant communities dominated by sedges (*Carex* species) also include considerable open water. These are **sedge, 1 to 3 species** (w45), **sedge-willow** (w30), **sedge-marsh five finger-horsetail** (w10), and **sedge-marsh five finger-low shrub** (w31). These four communities are also common in the marshland areas just upstream from the Warren Ames Bridge.

Two unusual communities found in the same area appear to have been affected by subsidence (sinking of land) and inundation after the 1964 earthquake: **Cottongrass-willow-peat moss-bluejoint** (w35) and **crowberry-sedge-peat moss-willow** (w38). Both occur among stands of scattered black spruce apparently killed by drowning or exposure to saltwater after the earthquake.

The wettest forested plant community is **feathermoss-bluejoint-horsetail** (w27) found under black spruce, both open and closed canopies. Two alder-grass communities (w3 and w4) also contain considerable standing water. These communities occur in a variety of situations, with and without tree cover, in open or closed stands under black spruce, white spruce, and/or birch.

Peat moss (*Sphagnum* moss) dominates five wetland communities. The two wettest are ***Sphagnum*-cottongrass** (w40) and ***Sphagnum*-bog rosemary-sedge** (w33). Both tend to occur along the lower river in treeless areas. These two communities form floating mats — crossing them on foot is like walking on a waterbed. ***Sphagnum*-marsh five finger** (w46) often occurs under open black spruce stands in the lower and middle areas of the study corridor. Two ***Sphagnum*-feathermoss-low shrub** communities were mapped (w7 and w11), almost always in association with black spruce stands. Both contain a diversity of heath (ericaceous) shrubs and other plants, although w11 is somewhat more diverse and perhaps reflects a later successional stage than w7. Both could be considered classic black spruce bogs.

Two dissimilar horsetail communities were mapped. **Horsetail-peat moss-feathermoss** (w41) is a simpler, perhaps younger variation of the bog communities described above. It occurs under open and woodland black spruce forests. **horsetail, 1 to 3 species** (w23) is probably the "driest," most productive wetland community in terms of tree growth. It occurs in old, filled-in sloughs near the river under closed stands of mixed white spruce and/or cottonwood.

Four bluejoint-dominated communities were mapped. The simplest, a nearly pure **bluejoint** grass community (w1), occurs under open or woodland spruce stands or in open meadows. **Bluejoint-horsetail** (w9) is slightly more diverse and is more often associated with riparian shrubland or productive riparian forest. **Bluejoint-willow** (w29) is a grass-low shrub community occurring in woodland forest or meadow situations. It is noteworthy that, in addition to dominating these four wetland communities, bluejoint reedgrass dominates three upland communities as well, including a nearly pure grass community and a grass-willow community somewhat similar to those described above. This demonstrates the wide range of sites to which this native grass is adapted. (This is the grass species found most commonly along Kenai River banks.)

D. USING RIVERBANK INFORMATION

Introduction to riverbank management

Many users of this *Guide* don't own parcels directly on the Kenai River. Instead, their lots may be one or more parcels back from the river's edge, and they don't need to deal with riverbank management. But as of Fall 1992, over 4,000 parcels are platted adjacent to the Kenai River. If you own one of them, you face a significant challenge and bear a serious responsibility. For reasons explained in Chapter III, riverbanks are among the most constantly changing environments on earth, and learning to live with the constant possibility of change is always a challenge. In addition, you and the other thousands of **riverfront landowners together can do more to protect or harm Kenai River fisheries than almost anyone else concerned with the river**, including regulatory and management agencies, and that's a serious responsibility. You and your riverfront neighbors own almost 70% of Kenai River banks from Skilak Lake to the river's outlet in Cook Inlet. As you'll see in the next section, what you do on your riverbanks has tremendous consequences for salmon, particularly for young salmon who must have appropriate bank-edge habitats to survive and grow. With that said, you can see why we want to provide information that can help you meet both the challenge of living with the river and the responsibility of caring for its fish.

As we explained at the start of this chapter, before you can effectively manage any natural resource, including riverbanks, you need to know: what **goals** you want to achieve through your management actions, what **conditions and processes** characterize your environment, and what **personal resources** (time, money, equipment, etc.) you can reasonably commit to management activities. You also need to know what management actions require permits. On riverbanks, any action that could damage the habitats of anadromous fish or could interfere with fish migration, spawning, passage, rearing, etc. must first be permitted by the Alaska Department of Fish and Game, Habitat Division. In addition, many actions on the river require a permit from the U.S. Army Corps of Engineers; and development of lots within the City of Soldotna's "Kenai River Overlay District" requires a permit from the city's planning and zoning commission. (Permitting on the Kenai River is discussed in Chapter II, Section D.) Unless otherwise indicated, permits are <u>not</u> needed to pursue management actions described in the following sections unless, for some reason, you plan to operate equipment or deposit material below "ordinary high water."

Goals: Different landowners want different things from their riverbanks. Some want easy access to the river and a place to launch their boat: the river, not the banks, is their focus. Some want a sheltered spot to sit, soak up sun, and listen to the birds and the swishing of the water: the banks themselves have intrinsic value. Goals are personal; your choices will reflect your values, experiences, and circumstances. But whatever goals you choose, we assume you and other Kenai River landowners have at least two riverbank-related goals in common, namely, a desire to:

* protect the river's capacity to produce fish (which involves protecting fish habitats and not interfering with fish life history stages of spawning, incubation, rearing, and passage), and

* maximize the stability of your riverbanks.

The first section below, <u>The relationship between riverbanks and fish</u>, focuses on the first goal. **If you follow guidelines on maintaining healthy bank-edge and instream habitats (and protect the river's water quality), you'll be meeting your responsibility to protect the Kenai River's capacity to produce fish.**

After focusing on how to manage riverbanks to benefit fish, we discuss ways to maximize bank stability[1], but the first goal isn't dismissed. Instead, we focus on bank-stabilizing approaches that protect riverbanks while also creating high quality fish habitats. Fortunately, many things you can do to stabilize riverbanks also benefit fish, such as planting willows, alders, and other deep-rooted plants; using spruce tree revetments and submerged root wads to protect eroding banks; building boardwalks to minimize trampling of plants that hold banks together. These approaches are discussed below. In addition, because so many landowners want to access the river to fish from its banks or launch a boat, we also discuss ways to do this; again focusing on methods that protect both bank stability and fish habitats.

Most other riverbank goals can, with a little common sense and information from this *Guide*, be pursued in a number of ways compatible with maintaining bank stability and fish productivity. If you'd like help pursuing riverbank goals not addressed here or elsewhere in this *Guide*, refer to Chapter VI for sources of additional help and information.

Environmental conditions and processes:
Chapter III discusses "parts" and "processes" that characterize rivers and riverbanks, emphasizing those that characterize the Kenai River. Understanding your riverbank conditions and processes is fundamental to figuring out how best to protect your banks; it's hard to stabilize a bank unless you know what's making it unstable.

If your property is in the City of Soldotna, the SCS inventoried your riverbank conditions in 1990. Refer to the section called <u>Riverbank data</u>, later in this chapter, for information about the relative stability of different kinds of riverbanks.

1 "Stability" is a relative term when applied to riverbanks. Chapter III describes the many processes that keep banks in a more or less constant state of flux. The question landowners must address is how to live successfully with the kind of flux that *naturally* characterizes riverbanks.

The relationship between riverbanks and fish

Terry Bendock
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Alaska Department of Fish and Game, Sport Fish Division

On the Kenai River, there's a heap of concern over returning adult salmon every summer. What is really hard to do, is focus attention on these same fish during an earlier but just as crucial part of their lifecycle, namely "rearing." Rearing covers the period between a salmon's emergence as a fry from the gravel beds in which it was spawned, incubated, and hatched to its migration to sea as a smolt. Salmon have a hard time surviving and returning as adults unless they outmigrate as large and healthy smolts, which depends on the quality of rearing habitats.

Different salmon species require different rearing habitats. Some species smolt soon after emerging from the gravel. Others remain in fresh water for 1, 2, or 3 years. In the Kenai River, chinook (king) salmon rear in the drainage for 1 year. Most coho (silver) salmon rear for 2 years, but some may stay for 3.

Despite their different life histories, all salmon share some habitat requirements. For example, a narrow strip of water along the banks is a critical rearing area for all juvenile salmon. This phenomenon can best be explained by the presence of *cover* and its effect on the water column. The term *cover* is used by biologists to describe any number of habitat features that are important to juvenile fish. In the Kenai River, cover includes woody vegetation along shorelines, irregular and undercut banks, overhanging and aquatic vegetation, woody debris like logs and root wads, large rocks or boulders, and the turbidity of the glacial green water. Stream-side vegetation is the most important type of cover. When vegetation is removed, other cover types such as depth, turbidity, and rock size become important factors in habitat suitability, but they cannot substitute for a well-vegetated bank.

The biggest effect that cover has on the water column is to slow flow velocity along stream banks. When salmon first emerge from the gravel, they are very poor swimmers and immediately seek out areas of slow moving water, usually found near the shoreline. Zones of optimum velocity for young salmon are found in pools and eddies that are created by irregularities, vegetation, and debris along the bank. Stream banks that provide cover, particularly if they are vegetated, also provide the best feeding areas for young fish. Overhanging and submerged vegetation provide: (1) substrates for aquatic organisms that juvenile fish feed on and (2) organic material furnishing additional nutrients for young salmon. Recesses along banks, debris, and areas shaded by vegetation also provide comfort zones where juvenile fish can rest and hide from predators.

OVER 80% OF THE YOUNG SALMON IN THE KENAI RIVER CAN BE FOUND WITHIN 6 FT OF THE BANK.

By the middle of their first summer, salmon are proficient enough swimmers to travel throughout most of the river drainage if they swim close to the shoreline or bottom where velocities are lowest. Since areas where fish are born may not be the best areas to feed and grow, juvenile salmon use their new swimming abilities to disperse throughout the drainage in search of the best rearing areas. At the same time, the amount of available bank habitat along the Kenai River is increasing due to high mid-summer flows, which creates additional space and food for fish when they need it most. [As water levels drop in the fall, available bank-edge habitat decreases.] As the season progresses, young salmon that will overwinter in fresh water start moving to safe overwintering areas such as Skilak Lake. This migration begins in late August and is over by early October.

Studies conducted in the 1980's demonstrate just how important velocity and cover are to juvenile salmon in the Kenai River [Burger et al. 1985]. Research has shown that over 80% of the young salmon in the Kenai River can be found within 6 ft of the bank. Most juvenile chinook salmon were found in velocities less than 1 ft/second, but few were found in still water. Juvenile coho salmon, on the other hand, preferred still water, and few were found in velocities exceeding 0.25 ft/second. Obviously, water velocities this slow can only be found near the banks and bottom of the river. Understanding these habitat preferences helps explain why almost 95% of the juvenile salmon seen along mainstem banks are chinook, while coho salmon are found in backwater pools, man-made canals, sloughs, and other areas where there is little current.

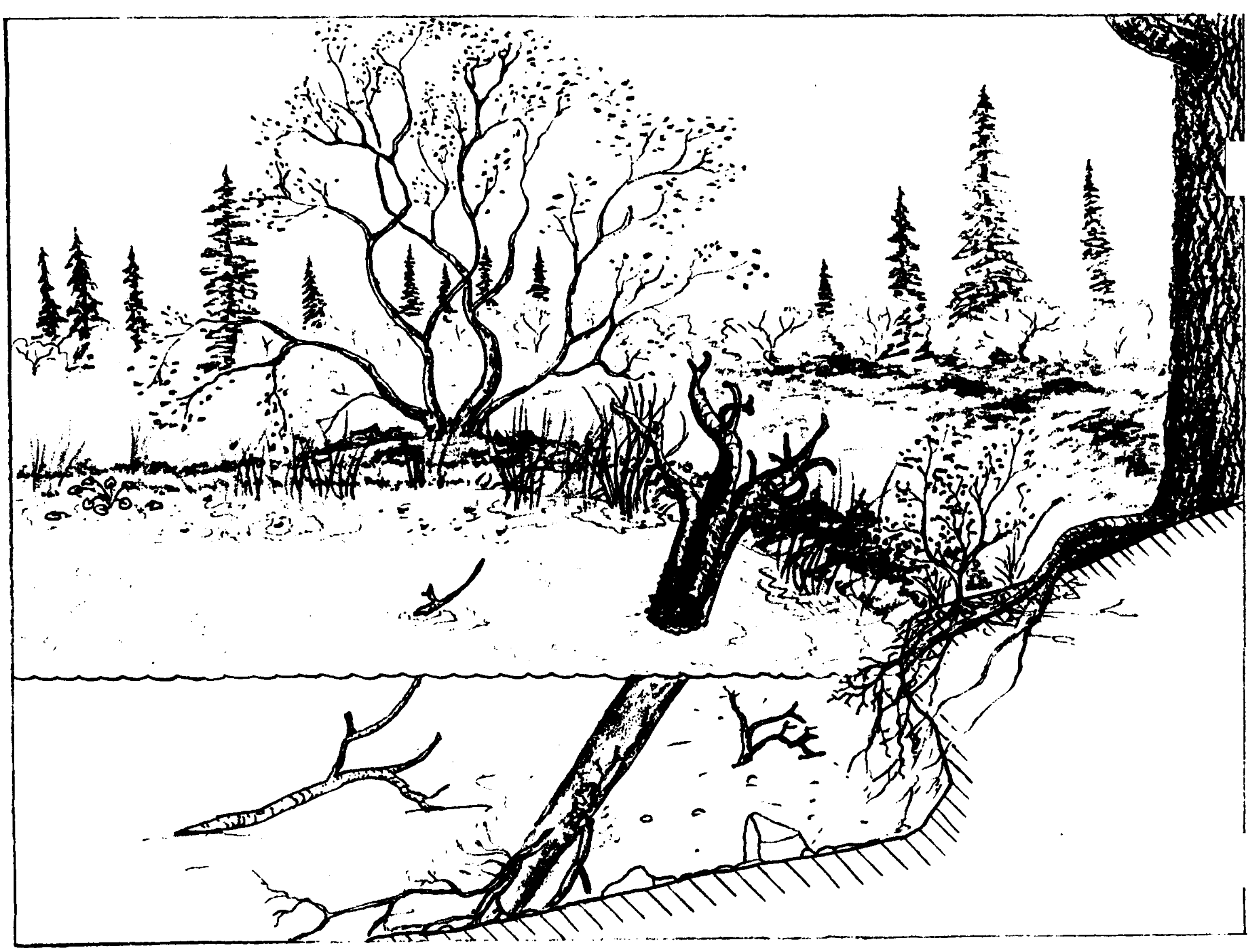
Since the survival of juvenile salmon in the Kenai River is linked to their freedom of movement within the drainage and the habitat conditions they find as they move, biologists are concerned about the proliferation of structures and other changes along river banks that affect migrations and habitat conditions. Most juvenile salmon cannot maintain themselves in velocities over 2 ft/second, yet biologists have measured velocities across the tips of groins in the Kenai River that exceed 8 ft/second. Cutting back bankside vegetation, cleaning up debris, and smoothing banks with improper revetments can all reduce cover and increase flow velocity.

Effects of instream structures and other bank alterations often go unnoticed because we seldom see dead juvenile fish. [Neither can we easily see that spawning areas have become unsuitable or unavailable.] However, many studies throughout the Northwest have shown that disrupting important life history functions reduces fish survival. Many structures and other bank changes displace fish from former rearing areas [and spawning habitats]. They also impede the upstream migrations of fish, increasing their stress and vulnerability to predation. Studies have demonstrated that adverse effects from structures and habitat loss are cumulative, suggesting that we have already sustained significant impacts on the Kenai River, where by 1984, there were 68 groins, 52 boat ramps, and 37 boat harbors or slips along the mainstem. [The ADF&G is currently inventorying bank developments along the Kenai River (ADF&G 1992). Chapter III, Section B summarizes human impacts on rivers.]

If we continue to modify riverbanks in ways that make less rearing habitat available to juvenile salmon, the overall productivity of the Kenai River will go down. That will mean fewer and fewer adult salmon may return each summer, no matter how much concern we heap on them [or how we change regulations governing sport, subsistence, or commercial fishing].

Figure 24 illustrates a riverbank that provides good rearing habitat for young salmon.

Figure 24. Example of a riverbank that provides good rearing habitat for salmon.



The Alaska Department of Fish and Game, Habitat Division, suggests the following guidelines for managing riverbanks to protect fish habitats. **In the following sections, these guidelines are supplemented with additional ways to stabilize riverbanks *and* improve bank-edge habitat.**

1. site buildings, facilities, and parking areas well away from riverbanks;

2. consolidate use of boat docks, ramps, and river access points;

3. where stream bank access is necessary, utilize elevated boardwalks, access stairways, and floating docks [see <u>Structures</u> later in this chapter];

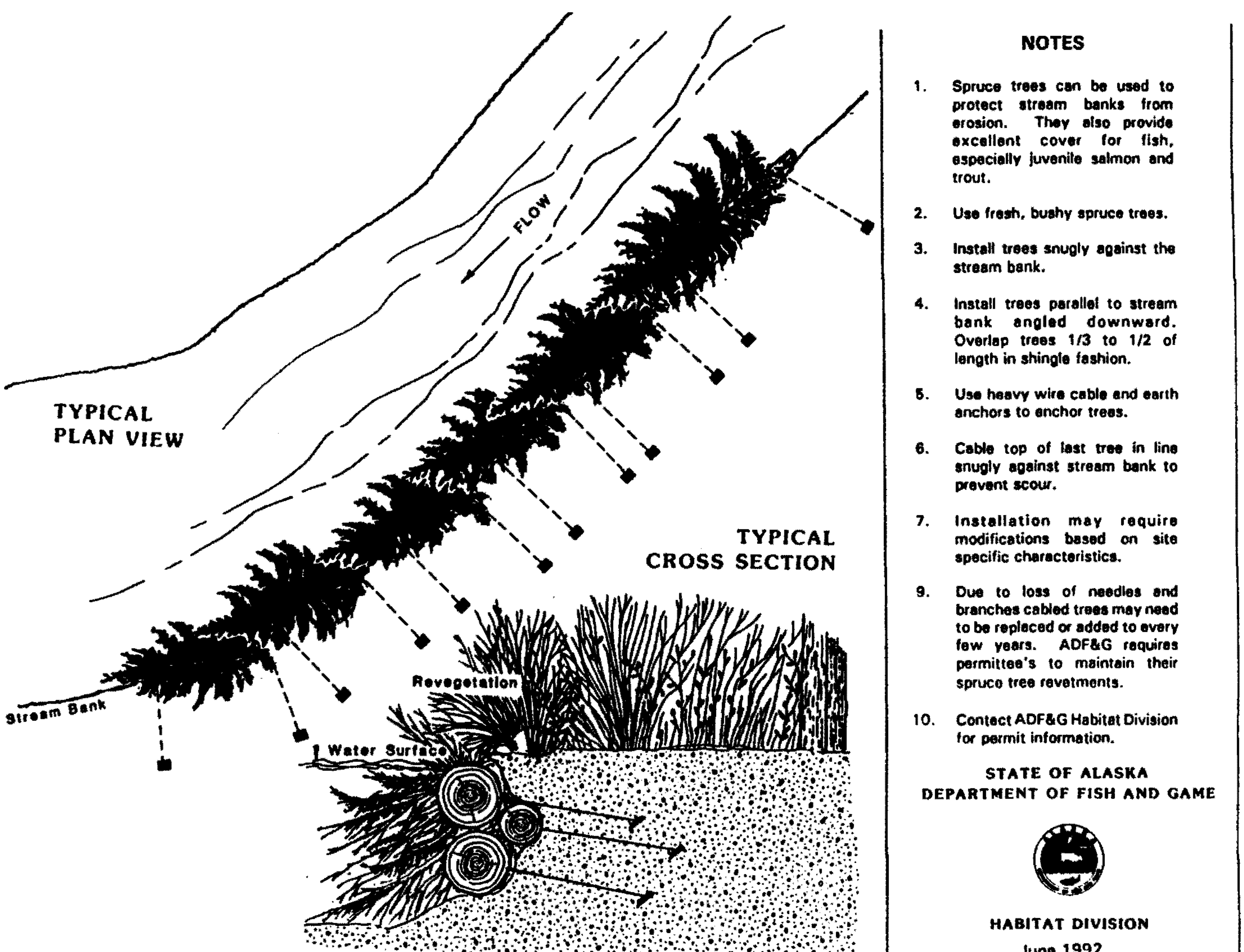
4. prevent or minimize trampling and destruction of existing vegetation;

5. encourage growth of stream bank vegetation in disturbed areas by revegetating cleared areas and limiting access;

6. spruce trees can be used to protect stream banks from erosion (Figure 25); they provide excellent cover for fish, especially juvenile salmon and trout. (Revetments require ADF&G permits.) [It may also be possible to use *live fascines* or *bundles*, illustrated in Figure 30, as live "floating revetments" and breakwaters, but this idea has not been tried.]

7. contact the Alaska Department of Fish and Game, Habitat Division, for permit information.

Figure 25. Spruce tree revetments for bank protection and fish habitat improvement.



Maximizing riverbank stability

When it comes to riverbanks, two expressions are worth remembering: "An ounce of prevention is worth a pound of cure," and "If it ain't broke, don't fix it." (But don't break it, either.) In other words, if your riverbanks are currently "stable"[1], you can avoid a lot of frustration, expense, and possible property loss by keeping them stable. In the simplest terms, that means: **don't disturb stable banks**. Sound as that advice may be, however, it isn't always practical. And for some landowners, it comes too late. In somewhat less simple terms, then, the best way to maximize bank stability is to: **protect and promote features that keep banks stable, while avoiding actions that make them unstable**. (See Chapter III for information on what makes riverbanks unstable.)

On riverbanks, prevention is nearly always much cheaper and easier than cure. On some riverbanks, cure is essentially impossible once prevention fails. "Conditionally stable" sites fall into this category. On conditionally stable banks, "...stability is maintained by an extremely delicate balance which is conditional on a special ingredient in the environment. That ingredient, such as a mat of soil-binding roots on an oversteepened slope, functions as the stabilizing kingpin in the landscape. If the kingpin is weakened or released, the landscape can literally fall apart under the stress of even modest events" (Marsh 1991:44). On the Kenai River, steep, well-vegetated, high terrace slopes, particularly those on outside riverbend curves and lacking a floodplain "buffer," are usually "conditionally stable" at best. The stability of such slopes is maintained by a well-developed mat of vegetation that ties together the slope face in a unified mass and protects the toe of the slope. If the vegetated mat is disturbed, it's likely to begin unraveling, eventually exposing the toe of the slope. Once the river starts cutting away the toe, it may be almost impossible to stop the process by any practical means. As the toe keeps eroding, the bank keeps failing, and no natural mechanism for healing can take hold. (Refer to Chapter III for background on high terrace riverbanks.)

Another riverbank-related adage, this one coined by the Army Corps of Engineers, is: "Vegetation is nature's way of protecting a streambank" (Keown 1983:1). In fact, plants are your single best ally in protecting banks from both erosion and failure. The ways in which plants stabilize banks are outlined below. Understanding these can help you maximize the bank-protecting functions of your own plantings.

(1) The relationship between plants and riverbanks

VEGETATION IS NATURE'S WAY OF PROTECTING A STREAMBANK.

How plants reduce bank erosion

In Chapter III, we looked at the causes of riverbank erosion and failure. If your banks are eroding or failing, we suggest you review that material and try to determine what processes are weakening your banks. Once you know *why* your banks are unstable, the following information can help you identify treatments most appropriate for your situation.

Plants reduce bank erosion by helping bank materials resist the pulling ("tractive") forces of gravity, wind, and water. They do this in six main ways (illustrated in Figure 26).

1. Highly branched networks of plant roots bind soils together and hold them in place. Depending on plant species, roots can grow above and/or below the waterline.

1 "Stability" is a relative term when applied to riverbanks. Chapter III describes the many processes that keep banks in a more or less constant state of flux. The question landowners must address is how to live successfully with the kind of flux that *naturally* characterizes riverbanks.

2. Plant parts growing close to the ground, and plant parts and litter covering the ground's surface, protect soil particles from the forces of flowing water and blowing wind, both by sheltering the soil and by reducing wind and water velocities so they don't have as much erosive energy.

3. Leaves, stems, and branches intercept raindrops so that soils are protected from rain's erosive splash.

4. Plant stems, foliage, and litter filter out soil particles carried by surface flows so that sediments are redeposited, not washed away.

5. Plant stems and roots increase soil pore spaces and channels into the soil (increase infiltration) so more rainfall can be absorbed into the soil before erosive runoff begins.

NATURE HAS BEEN REINFORCING SOIL FOR AGES WITH LIVE ROOTS OF PLANTS.

6. Stems, branches, foliage, and other plant parts growing or hanging below the water's surface physically resist stream flows, thus reducing flow velocities adjacent to banks. Stream flows that lose energy by deforming plants have less energy for eroding soil or rock particles from the bank.

How plants reduce bank failure

Although plants are most effective at protecting banks from surface erosion, they also help prevent bank failure, particularly the shallow sliding of slopes. Gray and Leiser (1982) outline four ways in which woody vegetation decreases slope failure.

1. **root reinforcement** Roots mechanically reinforce soils by transferring shear stresses in the soil to tensile resistance in the roots. In somewhat technical terms:

> A root-reinforced soil behaves as a composite material in which elastic fibers of relatively high tensile strength are embedded in a matrix of relatively plastic soil. Additional strength is mobilized within the composite material by the development of tractive forces between the fibers and surrounding matrix... The net effect of fiber reinforcement... is to increase the shear strength of the soil... Another important effect is to make some soils tougher, that is, able to resist continued deformation without loss of residual strength... In addition, plant roots do not corrode; instead they tend to be self-repairing and regenerating. Roots also tend to respond to unfavorable stress conditions at a site... in a self-corrective manner through a remarkable bio-adaptive process termed *edaphoecotropism*. This process allows roots to escape unfavorable site conditions by a shaping or reorientation of the root system. Edaphoecotropic orientation of main root branches in trees and shrubs is important both in the safe anchoring of plants in the soil and conversely in increasing the stability of the soil or slope anchorage itself... Nature of course has been reinforcing soil for ages with live roots of plants." (Gray and Leiser 1982:38, 39)

2. **soil moisture modification** Plant *transpiration*[2] dewaters the ground, thus reducing water's weight and lubricating wetness, both of which contribute to bank failure. Vegetation also affects the rate of snowmelt, which in turn affects soil moisture.

3. Tree trunks and large woody stems can act like firmly anchored "pilings" to **buttress** soils (see Figure 26). They also cause **"soil arching."** "Arching in slopes occurs when soil attempts to move through and around a row of piles (or trees) firmly embedded or anchored in an unyielding layer. ...The trees in effect behave as both cantilever piles and as the abutments of 'soil arches' that form in the ground upslope of the trees" Gray and Leiser 1982:55ff.

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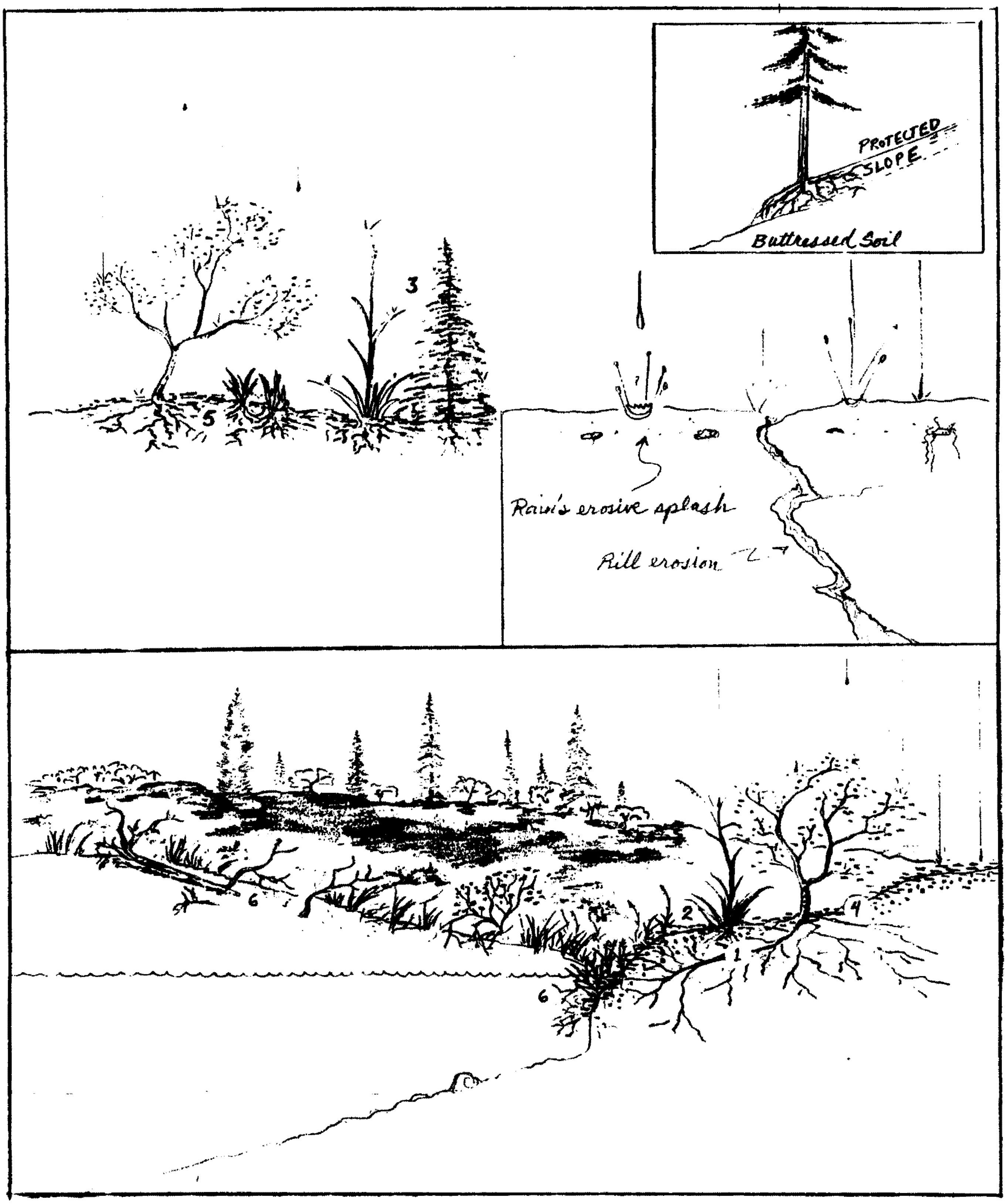
2 transpiration: The photosynthetic and physiological process by which plants release water into the air in the form of water vapor. Water lost from leaves is replaced by water absorbed by roots from the soil; the higher the rate of transpiration, the more water the roots remove from the soil.

Figure 26. How plants protect riverbanks (numbers correspond to text under "How plants reduce bank erosion").



4. **surcharge** Weight of vegetation on a slope exerts stress perpendicular to the slope. The perpendicular force exerted by rooted trees tends to increase the slopes's resistance to sliding (but *weight* on a slope may have a destabilizing effect, see below).

Gray and Leiser (1982) also point out that plants may theoretically destabilize slopes by the three mechanisms listed below. None of these, however, is believed to add significantly to slope instability.

1. **surchage** Weight of vegetation on a slope may exert downslope stress to some degree. After analyzing the effects of the weight of trees on slopes, Gray and Leiser concluded that "...the influence of surcharge from the weight of trees on either creep rates or safety factors in long slopes is not likely to be very significant one way or another" (1982:61).

2. **root wedging** Roots penetrating cracks, fissures, and channels in a soil or rock mass may theoretically cause local instability by a wedging or prying action. Gray and Leiser note that neither the importance nor significance of root wedging is known. They note: "In any event, judging by the preponderance of evidence from published field and laboratory studies, the beneficial effects of root systems far outweigh any possible adverse effects" (1982:38).

3. **windthrowing** Pressures exerted against sloping ground if strong winds blow downslope through trees may theoretically exert a destabilizing influence. "Strong winds blowing parallel to the ground surface will exert an overturning moment on trees. This can lead to so called wind throwing or blowdowns which create localized disturbances in the soil mantle... The total downslope force created by a wind blowing through a stand of trees, and hence its overall effect on slope stability, has never been evaluated" (Gray and Leiser 1982:38).

(2) Practical ways to promote bank stability

Approaches for stabilizing riverbanks fall into five general categories:

1. **conventional plantings**: establishing and maintaining woody and herbaceous plants on riverbanks by planting, transplanting, and other techniques discussed earlier;

2. **soil bioengineering practices**: using live woody plants as structural reinforcements and barriers to soil and slope movement, as well as growing woody plants in the spaces of inert constructions such as crib walls;

3. **inert construction**: using structures built of timber, rock, concrete, reinforced earth, and other non-living materials;

4. **slope reshaping**: changing slope steepness or shape; often used with erosion control blankets, mattresses, nettings, geotextiles, geogrids, etc.; and

5. **mixed approaches**: combining any of the above; for example, reshaping a slope to divert surface flows away from a bank face combined with grass plantings in the diversion channel ("grassed waterway") to slow and filter flows;

In addition, soil stabilizing chemicals sold under a variety of product names ("soil seal," for example) are sometimes used to reduce surface erosion from slopes.

The approaches most likely to be within the capabilities of landowners trying to "do-it-themselves" are: conventional plantings, some soil bioengineering practices, and a few simple structures that help protect banks from overuse, namely access stairs, boardwalks, and floating docks. On banks that aren't too high, reshaping to decrease slope angle may also be an option. If you reshape your banks, cut slopes back so that they have at least 2 ft of horizontal distance for every 1 ft of vertical drop, which creates a 2:1 slope (see Figure 10 in Chapter III). A 3:1 slope is even more stable. (Reshaped slopes are highly erodible until new plantings are established. Cover bare slopes with mulch.)

Before you begin evaluating your site and looking for solutions, you might want to review the seven steps of "do-it-yourself planning" outlined at the beginning of this chapter. Also, consider the following:

1. Remember that **"...any attempt to control streambank erosion should be recognized as a continuous, rather than a one-time effort"** (Iowa DWAWM 1984). Whatever you do to protect your banks, inspect your work regularly, particularly after high waters go down, and make necessary repairs during low flows.

2. **Try to learn the history of your bank**; this can help you understand what processes are occurring at your site. If possible, compare photographs of your site taken at several different periods to see incremental changes in your bank conditions. (Sources of aerial photography are listed in Chapter VI.)

3. **It's useful to know how high seasonal river levels reach on your property**. (That way you'll know what parts of your banks are inundated when and for how long.) To get a feel for this, choose a few easy-to-see landmarks on your bank that you can use as long-term reference points (large trees, boulders, structures, etc.). On a regular basis, jot down in a notebook: (1) the date, (2) where the river reached relative to your landmarks, and (3) the river *stage* (water height) and *discharge* (volume of flow per unit time) on that day (call the U.S. Geological Survey Water Resources Division for this information, they're listed in Chapter VI. The Kenai Soil and Water Conservation District hopes to coordinate the painting of a river gauge on the footings of the Soldotna Bridge — that would provide a river-height reference everyone could use.) In your notes, also jot down any other information relevant to you. After you have streamflow and river level data related to your property, you can refer to tables and hydrographs in Chapter III for data on average monthly Kenai River flows and compare this to your notes of the same month. This information should give you some idea of river stages at different times of year, and what various stage heights mean in terms of your banks.

4. **Review soil information for your site.** Soil information helps you assess what conditions you'll be dealing with during your project. The SCS can help you interpret what your soils mean in terms of what you want to accomplish.

5. **Try to begin and end streambank protection projects at relatively stable points along the bank.** (You don't want your project to increase erosion at its ends.) Banks on inside curves and straight reaches are usually relatively stable. Whatever stabilization approach you use, begin projects at the upstream end of your site and work downstream. Take advantage of any feature that offers a stable upstream starting point by "tying" your project to it or by using it to protect your project.

6. **The bank surface you create with your project should be at least as "rough" as the bank surface you start with.**

7. **Keep excessive weight off riverbank slopes**, including buildings, heavy equipment, debris piles, etc. Increasing the load on a slope can decrease its resistance to failure. Also, try not to operate heavy equipment on bank slopes. Doing so can weaken the ground and cause a chunk to break away and slip into the channel.

8. **Don't let livestock overgraze riverbanks**. Loss of vegetation and trampling contribute to erosion.

9. Subsoil moisture or groundwater seeping out of banks may destabilize the slope. If this situation exists on your bank, it may be

helpful (but also expensive) to install subsurface drains along the bank to **divert bank seepage through a non-erosive outlet** into the river. Alternatively, you could try to **dewater the slope by dense plantings of moisture-loving shrubs** such as willow.

10. **Divert surface runoff and drainage away from areas susceptible to erosion.** Grassed waterways, diversion dikes, or other conservation practices can be used to intercept and reroute overbank flows away from the tops of banks. Diversions should carry flows to a location where water can be discharged into the river without causing erosion. Runoff should not be allowed to pond on the tops of banks. Ponded water can seep into bank slopes; the increase in saturation and water weight can cause bank failure. The Soil Conservation Service can help you design non-erosive diversion practices.

11. Finally, you may want to **review Alaska Department of Fish and Game recommendations** listed earlier as you plan how to protect your banks.

THE BEST THING YOU CAN DO TO PROMOTE BANK STABILITY IS TO PROTECT EXISTING PLANTS FROM DISTURBANCE.

The rest of this section focuses on conventional plantings, soil bioengineering practices, and structural approaches that most Kenai River landowners can undertake themselves. All approaches discussed below do not harm, and usually improve, fish habitats while helping stabilize banks.

(1) Conventional Plantings

Because plants are so effective in stabilizing banks, and because plantings: (1) are often easier and less expensive to establish and maintain than other bank stabilizing systems, (2) often "self-repair" if damaged, (3) are unlikely to cause any serious damage to adjacent areas (instream or riparian) even if installed by nonprofessionals, and (4) provide many benefits to landowners and fish (discussed earlier in this chapter), conventional plantings are the recommended first approach for a landowner interested in "do-it-yourself" bank stabilization.

Selection, acquisition, planting, and care of plants were discussed earlier in this chapter. Refer to earlier discussions for basic information. The following recommendations, when combined with earlier guidance, can help you maximize the slope-stabilizing effects of conventional plantings.

1. If your riverbanks are currently well vegetated and stable, count your blessings. The best thing you can do to promote bank stability is **protect existing plants from disturbance.** Existing plantings are particularly effective if they include a mixture of both woody and herbaceous species. If trees or shrubs block your view, prune or top them rather than cutting them down (see Figure 8 earlier in this chapter). If your bank is densely forested, careful pruning and/or thinning can allow more sunlight to reach groundcover plants, improving their vigor and ability to help stabilize banks. The SCS and the Alaska Division of Forestry can advise you on proper tree thinning methods.

2. **Include woody species**, particularly shrubs, in your bank plantings. (Tables 8 and 9 earlier in this chapter list trees and shrubs recommended for conservation use by the *Revegetative Guide for Conservation Use in Alaska.*) In general, herbaceous plants such as grasses and forbs will not reinforce soils and stabilize slopes as effectively as woody species (although they are effective in reducing surface erosion). "The root system of woody plants, trees, and shrubs usually consists of both a lateral root system and a central, vertical root system. Secondary vertical or near-vertical roots called sinkers may also grow down from the laterals. Although the lateral roots play a role in binding the soil on a slope together in a unitary mass, the main resistance to sliding on hillslopes is provided by vertical roots" (Gray and Leiser

1982:43). Roots of herbaceaous plants tend to be weaker and penetrate less deeply than those of woody plants. (In Alaska, however, few roots grow below the top 20 or so inches of soil because soil temperatures at greater depths are too cold.) Woody plants are particularly important on the toe of your bank. The soil-binding action of roots and the flow-retarding "roughness" of woody stems are needed there most.

Many willows (*Salix* spp.) are particularly good for slope stabilization because they have vigorous, invasive roots and tolerate drought, excessive moisture, flooding, fluctuating water levels, exposure from erosion, partial burial, rock falls, and regular hedging. Identification, propagation, conventional planting, and transplanting of willows were discussed earlier in this chapter. In addition, willows and other readily rooting trees and shrubs can be planted as "live stakes," as described below. Collected and planted correctly, live stakes can be a quick and cost-effective way to get dense, stabilizing shrub cover on a riverbank.

Live stakes are made from dormant cuttings (described earlier under Propagating plants yourself). They can be planted from early spring, after the ground thaws, until July 1. To plant live stakes, cut dormant cuttings into pieces at least 18 to 24 inches long, with at least 2 buds on each stake. (Cut ends should be at least an inch or so from the nearest bud.) Stick a shovel into the ground as vertically as possible, push it forward, and place the cutting so it stands upright (buds pointing up) in the hole behind the shovel. The hole should be deep enough for at least 3/4 of the cutting to be buried, but at least one bud should remain an inch or two above the ground. (As long as a bud shows aboveground, bury as much of the stake as possible.) Remove the shovel, fill in the hole, and step around the cutting to firm the soil around it. Live stakes should be planted firmly enough that they cannot readily be moved or pulled out. Spacing between stakes varies according to site conditions, but good coverage should be achieved by placing plants 2 to 3 ft apart in staggered rows. Planting sites should be kept moist, particularly during early stages of establishment. (For more information, refer to *A Field Guide for Streambank Revegetation* available from the Alaska Division of Parks.)

If you want to grow your own live stake material (or material for bundles, wattles, or other bioengineering practices discussed below), you can establish "stooling" or "withy" beds. Many deciduous trees, once well-established, can be cut just above ground level, and the cut-over stump, or "stool," will send out numerous shoots. In stooling beds, willows are cultivated so that they can be pruned this way every year or two. The pruned stumps send out large quantities of long, straight, unbranched whips (also called "wands," "withes," or "osiers") that make excellent dormant cuttings for live stakes and bundles.

Stooling beds are generally established in damp or marshy sites because willows grow rapidly with adequate moisture. Well-managed stooling beds can produce abundant supplies of uniform, young, straight, unbranched whips, many feet in length, per year; and the stools will continue producing for a hundred years or more. Whips can be cut when dormant with shears, a chain saw, a mower- or tractor-mounted cutter bar, or by any other method that will shear them off just above ground level. If you develop stooling beds, be sure to start with planting stock that you know roots readily so you can be sure your cuttings will root readily too. At the end of the section on soil bioengineering practices, you'll find instructions on establishing stooling beds (see Vegetative propagation of poplar and willow).

3. **Include sod-forming (creeping) grasses and forbs in your groundcover plantings.** Sod-forming plants tie soils and slopes together with an ever-expanding network of rhizomes (underground lateral stems that send out roots and shoots) or stolons (aboveground lateral stems that send out roots and shoots).

Sod-forming grasses adapted to the Kenai River corridor include: red fescue, beach wildrye, and Kentucky bluegrass. In addition, bluejoint (*Calamagrostis canadensis*), the common native grass found along the river, is mildly rhizome-producing under some conditions. Because it's the indigenous grass on Kenai River soils, you may want to include bluejoint in any grass mix you use on your banks. Creeping forbs such as Nagoonberry and others listed in Table 9 are also beneficial in holding soils together. (The Plant Materials Center has released an aggressively spreading variety of Nagoonberry, call them for more information.) One landowner appears to be having success protecting his banks with commercially sold sod strips. The 18-inch wide, 4 1/2 inch-thick strips were laid down his bank like strips of carpet and extended below ordinary high water. Because the strips consist of Kentucky bluegrass, long-term survival of the sections inundated by ordinary high water is unknown. Whatever groundcover you use, be sure it doesn't outcompete young trees and shrubs.

4. **Imitate natural plant communities as much as possible.** Imitating natural plant communities is the surest way to create healthy, stable, and resilient plantings. Banks are subject to wide fluctuations in environmental conditions (discussed in Chapter III); a natural mix of plant species is most likely to include plants adapted to whatever conditions develop.

5. **Allow plant litter and woody debris to accumulate naturally, both on banks and in the water.** Vegetative litter protects banks from surface erosion. Woody debris and plant litter in the water along banks create "roughness" that slows flow velocities, thus reducing bank erosion. Woody debris, especially root wads and large logs, also provides cover and food sources very important for juvenile salmon and other aquatic organisms.

Although allowing natural debris to accumulate has many benefits, you should remove large woody debris from the river channel if it appears to be increasing local bank erosion (for example, by deflecting flows towards a weak spot in the bank). Also, to avoid attracting spruce bark beetles, handle downed spruce according to recommendations in insert 3, after p. 48.

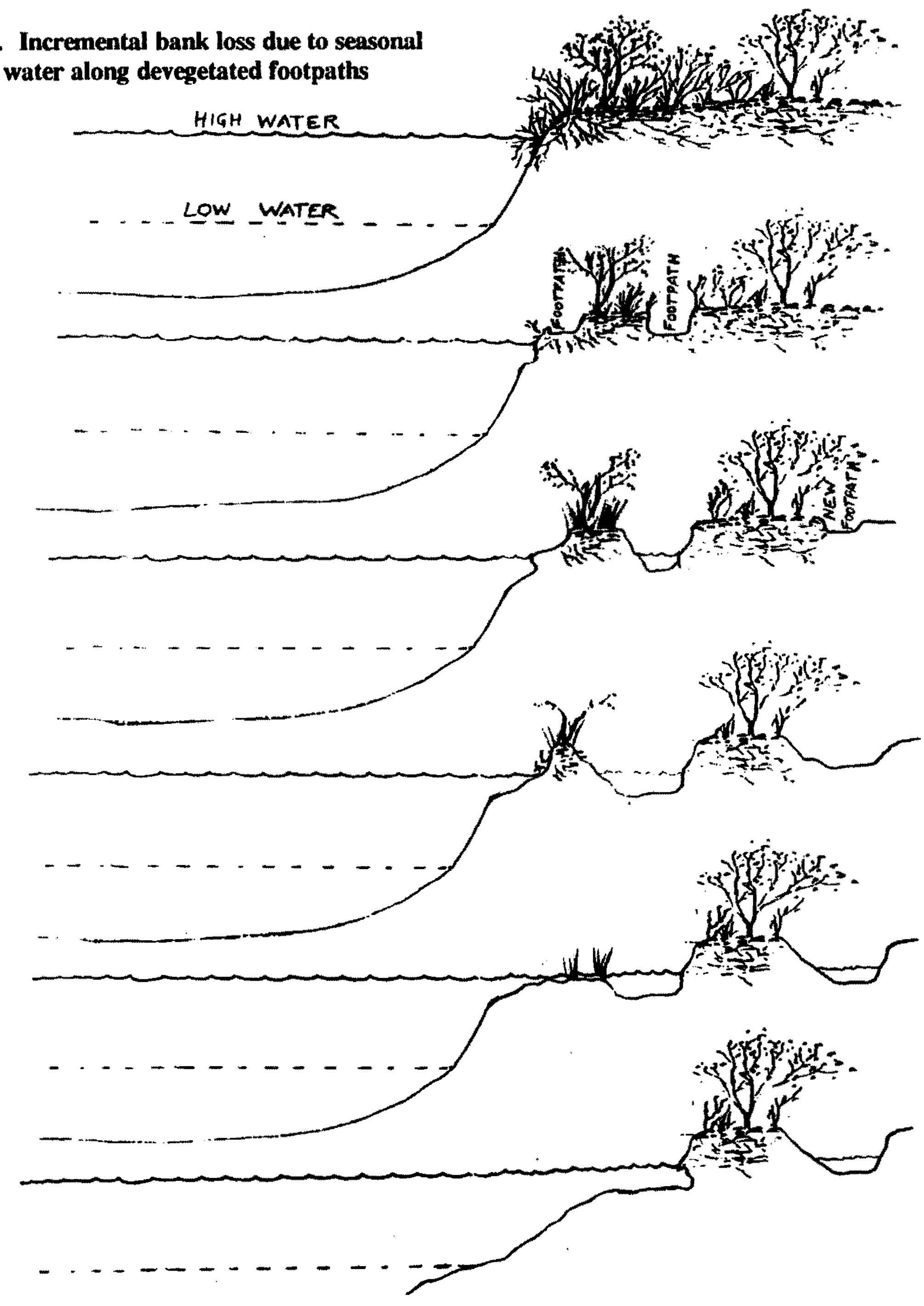
6. **Protect and encourage vigorous woody and herbaceous growth along the riverbank edge and in any areas likely to be wetted during seasonal high flows.** For maximum bank stability, encourage an interwoven curtain of foliage, stems, branches, and debris to blanket the wetted face and horizontal surfaces of your banks. In particular, avoid letting bared footpaths develop along the tops of banks subject to saturation from rising river levels. Once footpaths are worn bare, bank areas riverward of these paths are no longer tied to the rest of the bank. Instead, as water levels rise and banks become wet and heavy, bared footpaths provide a weak cleavage zone along which the river can carve off chunks of bank, which then collapse outward into the water. Repeated year after year, this incremental process leads to significant bank loss and destruction of bank-edge fish habitats (see Figure 27). Unfortunately, bank fishing is usually heaviest midsummer, during sockeye runs. This is just when streamflows are highest and banks are most saturated and vulnerable to trampling.

7. If you plan to treat a large area with woody plants, **consider "pretesting" to confirm that you've selected appropriate species and that you're handling and planting them correctly**. The season before planting a large area, select candidate species to test in small subareas of your site. Collect, store, and plant this "test" material the same way you plan to handle the rest of your plants. This way you can see if you're handling material properly and getting the success rate you need before treating a larger area. To prevent erosion in the meantime, plant fast-growing annual or perennial grasses on exposed, potentially erodible slopes (or on any cleared areas). Covering new grass seedings with mulch retains soil moisture and provides immediate erosion control; dead grasses

can later serve as mulch. But keep perennial grasses from outcompeting woody plantings.

8. **Cut down trees that are leaning over on your bank slopes.** (If they're not leaning too much, prop them up instead.) When "leaners" and "sweepers" fall into the river, their root wads tear out of the bank, leaving a large, exposed, erodible hole. If before they fall, you cut leaners at or just above the ground, their roots continue binding the bank for several years, giving you time to plant woody species around the stump. Birch and other deciduous trees usually stump sprout, so their root systems survive and continue to bind soils even after the main trunk is cut. (Cut trees can be used as "tree revetments," shown earlier, but get a permit first from the Alaska Department of Fish and Game. Tree revetments act as breakwaters, reducing the erosive action of boat wakes.)

Figure 27. Incremental bank loss due to seasonal high water along devegetated footpaths



(2) Soil Bioengineering

Soil bioengineering (also called "biotechnical slope protection and erosion control") involves using an integrated combination of structures and live plants to control bank erosion or failure. In many cases, live woody material serves both mechanical and biological functions, providing structural reinforcements or barriers immediately after installation, then providing other stabilizing benefits as plants take root and grow. In other cases, non-living mechanical structures, such as stone toe walls or log cribs, are used with living plants. Because bioengineering mixes vegetative and structural approaches, it requires some understanding and consideration of both; it is, therefore, more challenging than conventional planting in terms of "doing-it-yourself."

In costs, soil bioengineering treatments often fall somewhere between conventional plantings and purely mechanical approaches. Conventional plantings are generally the least costly to design, install, and maintain; purely structural treatments often cost the most. However, although bioengineered treatments may cost more than conventional plantings, they can often control banks that are too unstable for plantings alone.

IN BIOENGINEERING, LIVE PLANTS AND PLANT PARTS ARE USED AS BUILDING MATERIAL FOR EROSION CONTROL AND LANDSCAPE RESTORATION... — SCHIECHTL (1980)

Besides lower costs, bioengineering treatments can have other **advantages** over non-living structures. These may include:

1. **longer effective lifespan and lower maintenance requirements** (plants can tolerate flooding and minor slippage of surrounding soils, and they are often "self-repairing" after minor disturbances, structures aren't);

2. **more natural appearance** (plant growth quickly hides biotechnical structures, which are themselves usually made of natural materials);

3. **use of readily available materials** (bioengineering emphasizes use of local plants and materials);

4. **"labor-skill-intensive" rather than "energy-capital-intensive"** ("The nature of biotechnical slope protection systems is such that well-supervised, skilled labor can often be substituted for high-cost, energy-intensive materials" (Gray and Leiser 1982:1).);

5. **higher habitat values** (plants with high habitat values for fish or wildlife can be incorporated in bioengineering practices so long as they are adapted to local conditions).

Bioengineering can also present a number of **challenges**. To begin with, **many bioengineering techniques require large amounts of plant material.** Obtaining enough material of correct species, diameter, age, etc. may be difficult. Plant sources along the Kenai River may be relatively scarce, and the plants used for bioengineering are often the same species moose need most for winter forage. Given adequate lead time, however, appropriate plant sources can usually be found. In the worst case scenario, you can grow your own material within 3 or 4 years. (See the discussion Growing your own plants for bioengineering at the end of this section.)

Another difficulty is that, because bioengineering success depends on the vigor of installed live material, **plants must be handled, installed, and maintained correctly**. If you're unsure of your techniques, you might want to "practice" the bioengineering method you plan to use. Ideally, your practice site should be a small section of your main project area. The survival and growth rates of your plantings will indicate what you can expect from your larger project given your techniques. If your trial isn't as successful as you'd hoped, you'll be able to improve your techniques based on real experience .

A third difficulty relates to the gravelly soils found on many Kenai River banks. These often have few "fines" (particles less than 2 mm in diameter). As a result, they have low moisture- and nutrient-holding capacity, and low inherent fertility. **You may need to mix topsoil in with gravelly soils to improve their ability to support plant growth.**

Finally, although bioengineering has been used in Europe and other parts of the world for centuries, it's only now being rediscovered in the United States as financial and environmental costs of structural approaches receive new scrutiny. In Alaska, a few small-scale bionengineering projects have been installed (mostly with the guidance of the Plant Materials Center and the SCS), but no significant bioengineering projects have so far been tried along the Kenai River. As a result, **these approaches should still be considered somewhat "experimental."** This should soon change. The City of Soldotna has received funding to install bioengineering practices at two city-owned sites: Centennial Campground and Soldotna Creek Park. Engineering work is scheduled for the spring of 1993, installation for the spring of 1994. The SCS plans to assist in monitoring and evaluating these projects, and will help develop educational materials based on what's learned. If you're interested in following these projects, contact the Soldotna City Manager or the SCS.

As mentioned earlier, soil bioengineering projects are generally more challenging for the do-it-yourself'er than conventional plantings. On some riverbanks, especially those that are steep, high, and/or subject to active undercutting, bionegineering requires professional guidance. Nonetheless, on less challenging sites — for example, banks less than 4 or 5 ft high and not too steep or unstable, some bioengineering practices are within the capabilities of most landowners. Table 12 indicates where conventional plantings are appropriate and where bioengineering techniques might be more effective.

Table 12. Comparisons between vegetative plantings and soil bioengineering (from SCS 1992).

	Category	Examples	Appropriate uses	Role of vegetation
LIVING	**Vegetative plantings**			
	Conventional plantings	Grass seedlings Transplants Forbs	Control water and wind erosion. Minimize frost effects.	Control weeds. Bind & restrain soil. Filter soil from runoff. Intercept raindrops. Maintain infiltration. Moderate ground temperature.
	Soil bioengineering			
	Woody plants used as reinforcement, as barriers to soil movements, & in the frontal openings or interstices of retaining structures.	Live staking Live fascine Brushlayer Branchpacking Live cribwall Live gully repair Vegetated rock gabion Vegetated rock wall Joint planting	Control of rills & gullies. Control of shallow (translational) mass movement. Filter sediment. Improved resistance to low to moderate earth forces.	Same as above, but also reinforce soil, transpire excess water, & minimize downslope movement of earth masses. Reinforce fill into monolithic mass. Improve appearance and performance of structure.

The following section describes soil bioengineering treatments within the capabilities of many Kenai River landowners. These instructions have been excerpted from the Soil Conservation Service's *Engineering Field Manual*, Chapter 18: "Soil Bioengineering for Upland Protection and Erosion Control." Because these approaches are basically untried on the Kenai River, any documentation you keep about what you try, how you install it, and how it performs would be valuable. (Contact the Soil Conservation Service for help in documenting, monitoring, and evaluating your projects.)

General guidelines for bioengineering practices

The following general guidelines and considerations from the SCS *Engineering Field Manual* apply to all bioengineering practices outlined below:

a. Soil bioengineering systems are **most effective when they are installed during the dormant season**, usually the late fall, winter, and early spring. Summer installation is not recommended. Rooted plants can be used, but they are sometimes less effective and more expensive.

b. Soil bioengineering is **often a useful alternative for small, highly sensitive, or steep sites where the use of machinery is not feasible** and hand labor is a necessity. However, rapid vegetative establishment may be difficult on extremely steep slopes.

c. The **usefulness of soil bioengineering methods may be limited by the available medium for plant growth**, such as rocky or gravelly slopes that lack sufficient fines or moisture to support the required plant growth. In addition, soil restrictive layers, such as hardpans, may prevent required root growth.

d. **The biotechnical usefulness of vegetation would be limited on slopes that are exposed to high velocity water flow or constant inundation.**

e. **Newly installed soil bioengineering projects require careful periodic inspections until plants are established.** Newly planted vegetation is vulnerable to trampling, drought, grazing, nutrient deficiencies, toxins, and pests, and may require special management measures at times. Initial failure of a small portion of a system normally can be repaired easily and inexpensively. Neglect of small failures, however, can often result in the failure of large portions of a system. Periodic pruning and replanting may be required to maintain healthy and vigorous vegetation.

f. **Retain existing vegetation whenever possible and limit removal of vegetation.** (Limit cleared area to the smallest practical size; limit duration of disturbance to the shortest practical time; remove and store existing woody vegetation that may be used later in the project; schedule land clearing during periods of low precipitation whenever possible.)

g. **Stockpile and protect topsoil.** (Topsoil removed during clearing and grading operations can be reused during planting operations.)

h. **Protect areas exposed during construction.** Temporary erosion and sediment control measures can be used (see, for example, "Best Management Practices" used by the Alaska Department of Transportation and Public Facilites, included in Chapter III, Section B.).

i. **Divert, drain, or store excess water.** Install a suitable system to handle increased and/or concentrated runoff caused by changed soil and surface conditions during and after construction. If needed and possible, install permanent erosion and sediment control measures in the project before construction is started.

j. **Fit the soil bioengineering system to the site.** This means considering site topography, exposure, geology, soils, vegetation, and hydrology. For example, bioengineering designs should address topics like:

- What earthwork will be needed? (A steep undercut or slumping bank, for example, requires grading to flatten the slope for stability. The degree of flattening depends on the soil type, hydrologic conditions, geology, and other site factors.)

- When will plant collection, site preparation, project installation, and other steps be scheduled and how will they be timed and coordinated? Planning and coordination are needed to achieve optimal timing and scheduling.

- How much moisture do the plants being used require and how will meeting their moisture needs affect other aspects of the project? The same question pertains to particle size of fill being used. Free drainage is essential to the mechanical integrity of earth-retaining structures and is also important to vegetation, which generally cannot tolerate soils that stay waterlogged for long periods. The establishment and maintenance of vegetation, however, usually requires the presence of some fines and organic matter in the soil to provide adequate moisture and nutrient retention. In many cases biological requirements can be satisfied without compromising engineering performance of the structure. With cribwalls, for example, adequate amounts of fines or other amendments can be incorporated into the backfill.

Specific bioengineering practices

(1) Live stake (Figure 29)
(i) Description: Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground. If correctly prepared and placed, live stakes root and grow.

A system of stakes creates a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. This is an appropriate technique for repair of small earth slips and slumps that are frequently wet.

(ii) Applications and effectiveness:
- A technique for relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.
- May be used for pegging down surface erosion control materials.
- Enhances conditions for natural invasion and establishment of other plants from surrounding plant communities.
- Can be used to stabilize areas between other soil bioengineering techniques, such as live fascines.

(iii) Construction guidelines:
[Live staking was discussed on p. 72 as a "conventional planting" technique.]

(2) Live fascines (also called "wattles" or "bundles") (Figures 30 and 31)
(i) Description: Live fascines are long bundles of branch cuttings bound together into sausage-like structures.

When cut from appropriate species and properly installed with live and dead stout stakes, they will root and immediately begin to stabilize stopes. They should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This system, installed by a trained crew, does not cause much site disturbance.

(ii) Applications and effectiveness:
- An effective stabilization technique for slopes.
- Protects slopes from shallow slides (1 to 2 ft depth).
- Immediately reduces surface erosion or rilling.
- Suited to steep, rocky slopes, where digging is difficult.
- Capable of trapping and holding soil on the face of the slope, thus reducing a long slope into a seris of shorter slopes.

- Enhances vegetative establishment by creating a microclimate conducive to plant growth.

(iii) Construction guidelines:

Live materials—Cuttings must be from species, such as young willows or cottonwoods, that root easily and have long, straight branches.

Live material sizes and preparation:

- Cuttings tied together to form live fascine bundles vary in length from 5 to 30 ft or longer, depending on site conditions and limitations in handling.
- The complete bundles should be 6 to 8 inches in diameter, with all of the growing tips oriented in the same direction. Stagger the cuttings in the bundles so that tops are evenly distributed throughout the length of the uniformly sized fascine.
- Live stakes should be 2 1/2 ft long in cut slopes and 3 ft long in fill slopes.

Inert materials—String used for bundling should be untreated twine.

Dead stout stakes used to secure the live fascines should be 2 1/2 ft-long, untreated, 2 by 4 lumber. Each length should be cut again diagonally across the 4-inch face to make two stakes from each length (Figure 28). Only new, sound, unused lumber should be used, and any stakes that shatter upon installation should be discarded.

Installation:

- Prepare the live fascine bundles and live stakes immediately before installation.
- Beginning at the base of the slope, dig a trench on the contour just large enough to contain the live fascine. The trench will vary in width from 12 to 18 inches, depending on the angle of the slope to be treated. The depth will be 6 to 8 inches, depending on the individual bundle's final size.
- Place the live fascine into the trench.
- Drive the dead stout stakes directly through the live fascine every 2 to 3 ft along its length. Extra stakes should be used at connections or bundle overlaps. Leave the top of the stakes flush with the installed bundle.
- Live stakes are generally installed on the downslope side of the bundle. Drive the live stakes below and against the bundle between the previously installed dead stout stakes. The live stakes should protrude 2 to 3 inches above the top of the live fascine. Place moist soil along the sides of the live fascine. The top of the fascine should be slightly visible when installation is completed.

Next, at intervals on contour or at an angle up the face of the bank, repeat the preceding steps to the top of the slope (Table 13). When possible, place one or two rows over the top of the slope.

Long straw or similar mulching material should be placed between rows on 2.5:1 or flatter slopes, while slopes steeper than 2.5:1 should have jute mesh or similar material placed in addition to the mulch (see Chapter VI for sources of erosion control matting).

Figure 28. A dead stout stake.

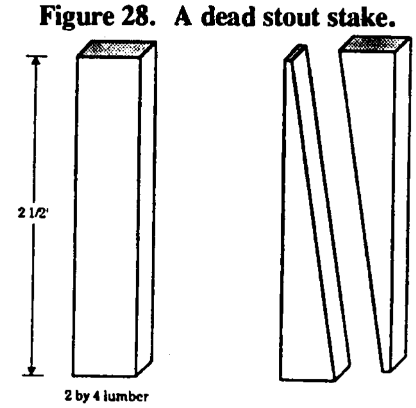


Table 13. Live fascine installation guidelines.

Slope	Slope distance between trenches (ft)	Maximum slope length (ft)
1:1 to 1.5:1	3 – 4	15
1.5:1 to 2:1	4 – 5	20
2:1 to 2.5:1	5 – 6	30
2.5:1 to 3:1	6 – 8	40
3.5:1 to 4:1	8 – 9	50
4.5:1 to 5:1	9 – 10	60

Figure 29. Live stakes.

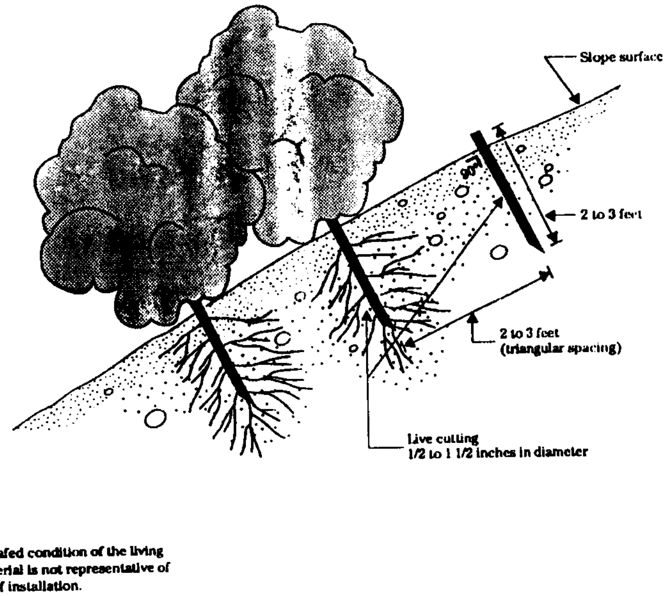
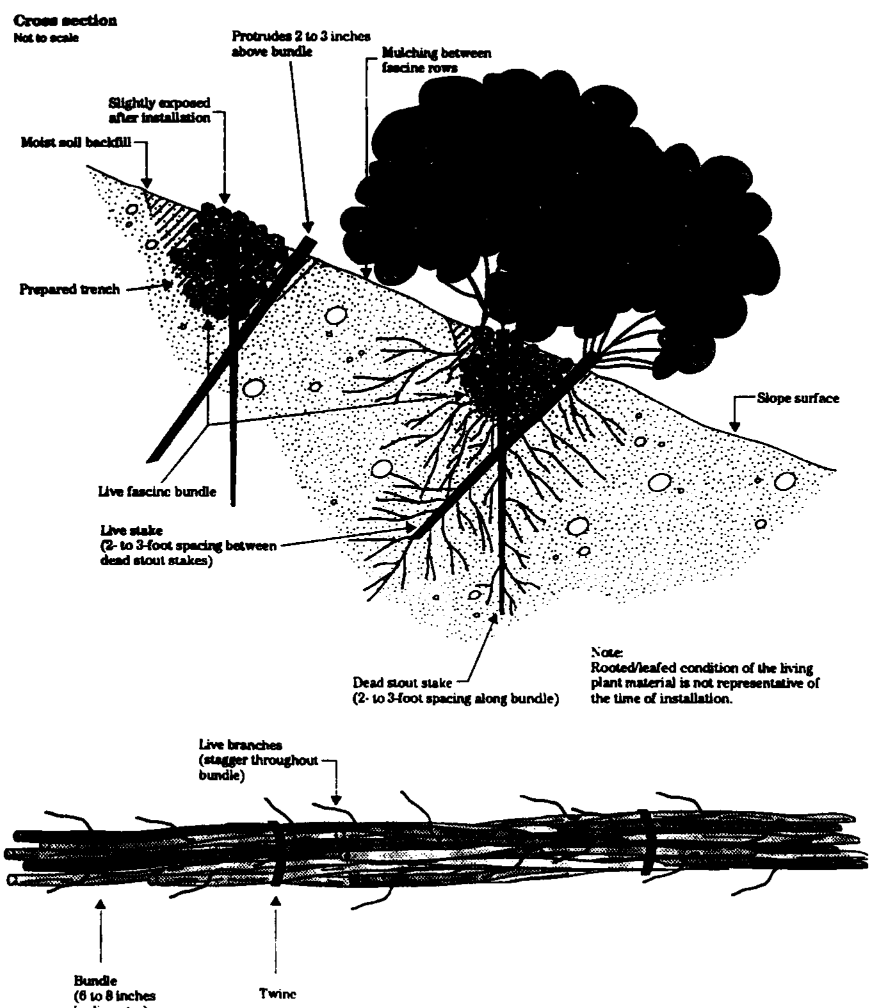


Figure 30. Live fascines. (The idea of using live fascines as live, floating breakwaters or revetments has not been tried. Theoretically, however, long bundles could be anchored to riverbanks like spruce tree revetments. The woody bundles could be expected to trap sediments, and could conceivably root during low water and grow. An ADF&G permit is required for all revetments.)



(3) Brushlayer (Figure 31)

(i) Description: Brushlayering is somewhat similar to live fascine systems because both involve the cutting and placement of live branch cuttings on slopes. The two techniques differ principally in the orientation of the branches and the depth at which they are placed in the slope. In brushlayering, the cuttings are oriented more or less perpendicular to the slope contour. The perpendicular orientation is more effective from the point of view of earth reinforcement and mass stability of the slope.

Brushlayering consists of placing live branch cuttings in small benches excavated into the slope. The benches can range from 2 to 3 ft wide (deep). The systems are recommended on slopes up to 2:1 in steepness and not to exceed 15 ft in vertical height. Brushlayer branches serve as tensile inclusions or reinforcing units. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion.

(ii) Application and effectiveness:
Brushlayers perform several immediate functions in erosion control, earth reinforcement, and mass stability of slopes:

- Breaking up the slope length into a series of shorter slopes separated by rows of brushlayer.
- Reinforcing soils with unrooted branch stems.
- Reinforcing soils as roots develop, adding significant resistance to sliding or shear displacement.
- Providing slope stability and allowing vegetative cover to become established.
- Trapping debris on the slope.
- Aiding water infiltration on dry sites.
- Drying excessively wet sites.
- Adjusting the site's microclimate, thus aiding seed germination and natural regeneration.
- Redirecting and mitigating adverse slope seepage by acting as horizontal drains.

(iii) Construction guidelines:
Live material sizes—Branch cuttings should be 1/2 to 2 inches in diameter and long enough to reach the back of the bench. Side branches should remain intact for installation.

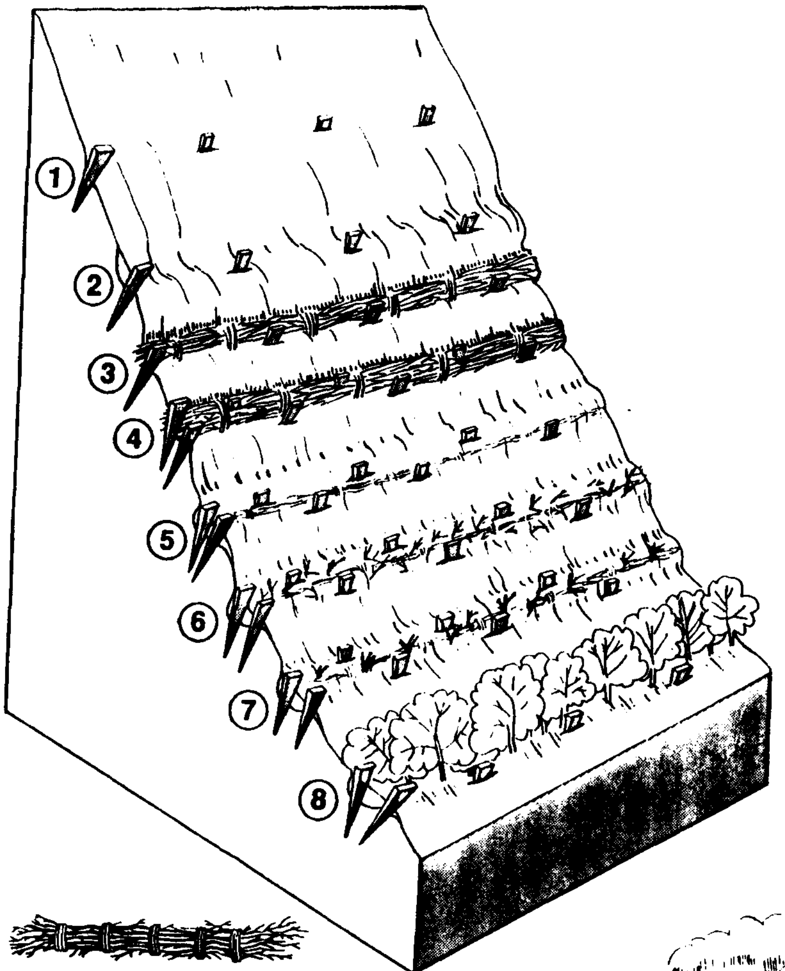
Installation:

- Starting at the toe of the slope, benches should be excavated horizontally, on the contour, or angled slightly down the slope, if needed to aid drainage. The bench should be constructed 2 to 3 ft wide (deep).
- The surface of the bench should be sloped so that the outside edge is higher than the inside edge.
- Live branch cuttings should be placed on the bench in a crisscross or overlapping configuration.
- Branch growing tips should be aligned toward the outside of the bench.
- Backfill is placed on top of the branches and compacted to eliminate air spaces. The brush tips should extend slightly beyond the fill to filter sediment.
- Each lower bench is backfilled with the soil obtained from excavating the bench above.
- Long straw or similar mulching material with seeding should be placed between rows on 3:1 or flatter slopes, while slopes steeper than 3:1 should have jute mesh or similar material placed in addition to the mulch (see Chapter VI for sources of erosion control matting).
- The brushlayer rows should vary from 3 to 5 ft apart, depending upon slope angle and stability (Table 14).

Table 14. Brushlayer installation guidelines

Slope	Slope distance between benches Wet slopes (ft)	Dry slopes (ft)	Maximum slope length (ft)
2:1 to 2.5:1	3	3	15
2.5:1 to 3:1	3	4	15
3.5:1 to 4:1	4	5	20

Figure 31. Top: wattling installation; Bottom: contour brush layer installation (from Chatwin et al. 1991).

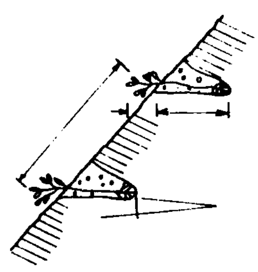


Wattle

1. **STAKE ON CONTOUR**, using an Abney or Sunto type level. Contour staking is of particular importance on wide slopes with erodible soils. Stakes should be about 40-60 cm long, and driven to a firm hold.
2. **TRENCH ABOVE** the stakes to one-half the diameter of bundles. Material dug from the trench should be wasted downslope to cover lower wattles.
3. **PLACE BUNDLES** in the trench.
4. **STAKE THROUGH THE BUNDLES** close to bundle ties.
5. **COVER THE BUNDLE** with soil and tamp the soil firmly into place. Walk along bundles to add additional tamping.
6. **COMPLETED** wattling resembles a slight terrace with twigs (7-10 cm) protruding along the downslope side.
7. **PARTIALLY BURIED AND STAKED BUNDLES** protect against erosion.
8. **WATTLES ROOT AND SPROUT**, further protecting and stabilizing the slope.

CONTOUR BRUSH LAYER CONSTRUCTION

- **UNDERTAKE SLOPE PREPARATION**, drainage control and toe wall construction where required.
- **BEGIN WORK** at the bottom of the slope.
- **DIG TERRACES** 50-100 cm wide, manually or with machinery.
- **SPACE TERRACES** about 1 m on steep slopes.
- **ENSURE TERRACES** slope up at least 10°.
- **ENSURE BRANCHES** are at least 1 m long with a mixture of different ages, species thicknesses and length. Branches 2-5 m in length are more effectively used in constructed fills or embankments.
- **PLACE BRANCHES** along the terrace in a crosswise fashion, with only one-quarter to one fifth of their length protruding.
- **PLACE ROOTED PLANTS** 0.5-1.0 m apart among the layer of branches.
- **IN NON-COHESIVE SOILS**, prepare short terrace segments. This helps prevent ditch collapse and soil drying.
- **BACKFILL THE TERRACE DITCH** with material dug for the terrace above.
- **INTERPLANT WITH** shrubs and grass-legume seed.



[(4) Branchpacking and (5) Live gully repair are omitted here because they appear to have limited applicability along the Kenai River. The two techniques are similar: branchpacking is designed to repair small localized slumps and holes in slopes; live gully repair is designed to repair small rills and gullies. If you are interested in instructions for either of these techniques, contact the Soil Conservation Service.]

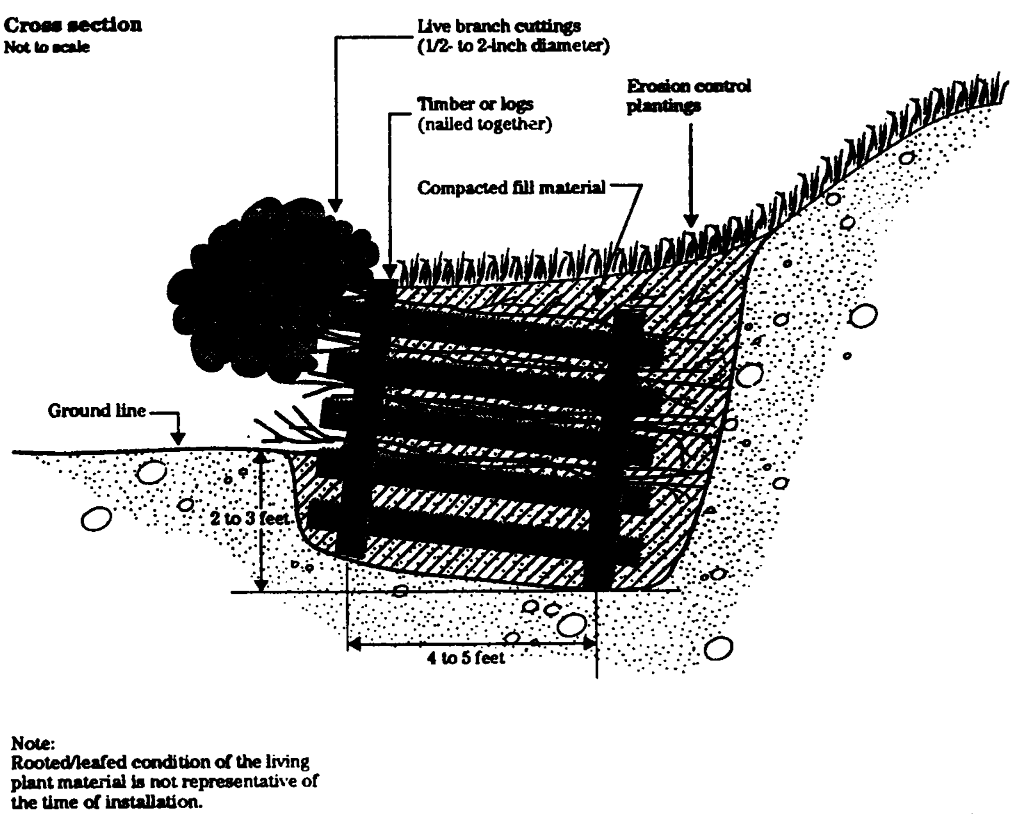
(6) Live cribwall (Figure 32)

(i) Description: A live cribwall consists of a hollow, box-like interlocking arrangement of untreated log or timber members. The structure is filled with suitable backfill material and layers of live branch cuttings, which root inside the crib structure and extend into the slope. Once the live cuttings root and become established, vegetation gradually takes over the structural functions of the wood members. [You might think of live cribwalls as "a bank in a biodegradable box." By the time the box decomposes, the bank is held together by plant roots and stems.]

(ii) Applications and effectiveness:

- This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.
- This technique is not designed for or intended to resist large, lateral earth stresses. It should be constructed to a maximum of 6 ft in overall height, including the excavation required for a stable foundation.
- Useful where space is limited and a more vertical structure is required.
- Provides immediate protection from erosion, while established vegetation provides long-term stability.
- Should be tilted back if the system is built on a smooth, evenly sloped surface.
- May also be constructed in a stair-step fashion, with each successive course of timbers set back 6 to 9 inches toward the slope face from the previously installed course.

Figure 32. Live cribwall.



(iii) Construction guidelines:
Live material sizes—Live branch cuttings should be 1/2 to 2 inches in diameter and long enough to reach the back of the wooden crib structure.

Inert materials—Logs or timbers should range from 4 to 6 inches in diameter or dimension. The lengths will vary with the size of the crib structure. [If the cribwall will be inundated at high flows, unpeeled logs have the advantage of providing greater "roughness," and would help slow stream currents flowing against the cribwall. Plant stems sticking from the cribwall are even more effective in slowing stream velocities; if temporary inundation of the cribwall is likely, plants that can tolerate inundation should be used. Slower flows are both less erosive and provide more suitable conditions for immature salmon.]

Large nails or rebar are required to secure the logs or timbers together.

Installation:
- Starting at the lowest point of the slope, excavate loose material 2 to 3 ft below the ground elevation until a stable foundation is reached.
- Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.
- Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 ft apart and parallel to the slope contour.
- Place the next course of logs or timbers at right angles (perpendicular to the slope) on top of the previous course to overhang the front and back of the previous course by 3 to 6 inches.
- Backfill the newly created course ("box") and place live branch cuttings on the backfill perpendicular to the slope and with growing tips facing out of the crib. Some of the basal (bottom) ends of the live branch cuttings should reach undisturbed soil at the back of the cribwall. Growing tips should protrude slightly beyond the front of the cribwall. Cover the cuttings with backfill and compact. Then begin next course.
- Each course of the live cribwall is placed in the same manner and secured to the preceding course with nails or reinforcement bars.
- When the cribwall structure reaches the existing ground elevation [or designed height], place live branch cuttings on the final layer of backfill (perpendicular to the slope); then cover the cuttings with backfill and compact.
- Live branch cuttings should be placed as described at each course to the top of the cribwall structure.

[(7) Vegetated rock gabions and (8) Vegetated rock walls have been omitted because neither gabions nor rock walls are currently recommended on the Kenai River.]

(9) Joint planting (Figure 33)
(i) Description: Joint planting or vegetated riprap involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope. [Although additional riprap is not currently permitted below "ordinary high water" on the Kenai River, riprap already in place can be improved with this technique.]

(ii) Applications and effectiveness:
- Use where rock riprap is already in place.
- Roots improve drainage by removing soil moisture. Over time, they create a living root mat in the soil base upon which the rock has been placed. The root systems of this mat help bind or reinforce the soil to prevent washout of fines between and below rock units.

(iii) Construction guidelines:
Live material sizes—The cuttings must have side branches removed and bark intact. They should range in diameter from 1/2 to 1 1/2 inches and be sufficiently long to extend into soil below the rock surface.

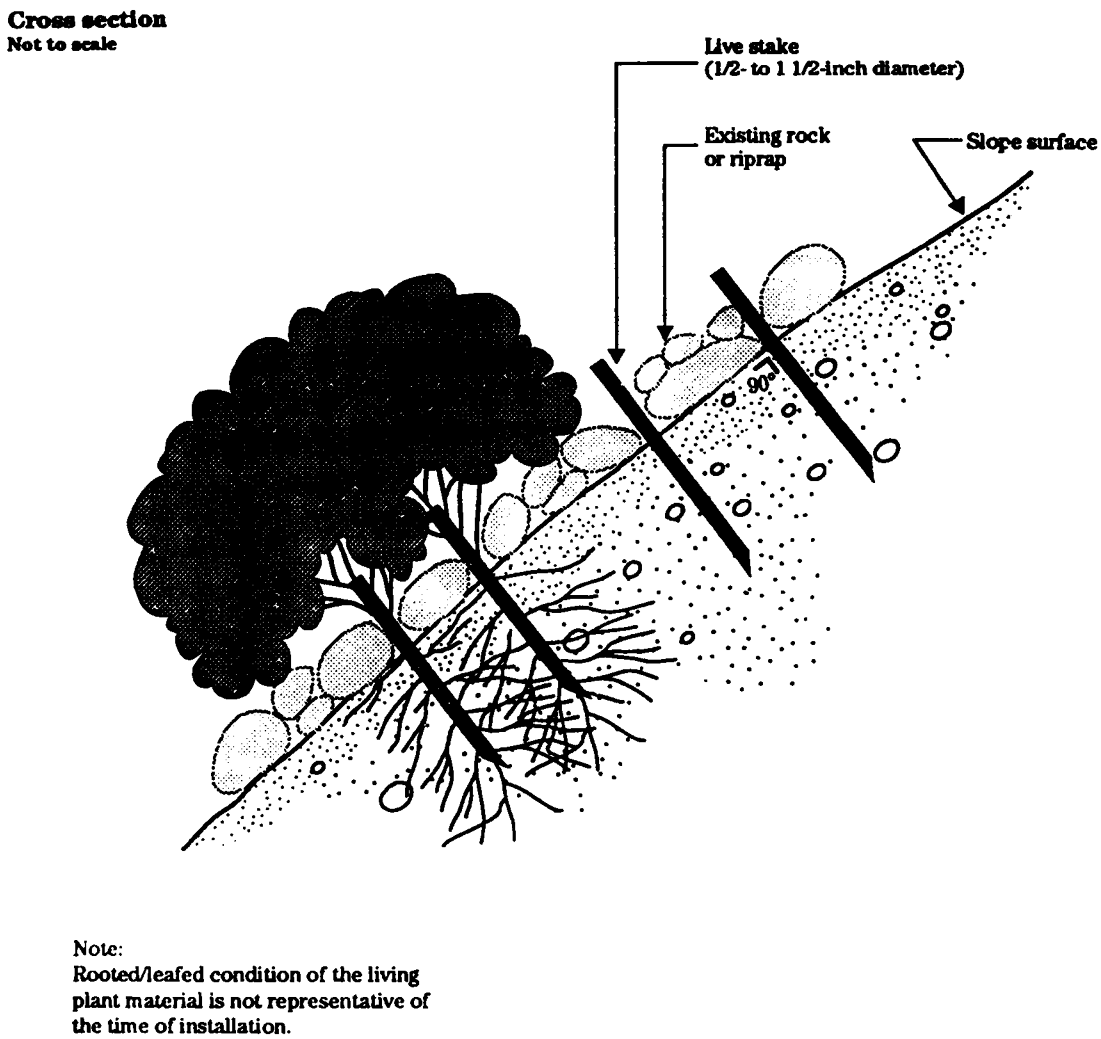
Installation:

- Tamp live branch cuttings into openings between rocks. The butt ends of the branches should extend into backfill or undisturbed soil behind the riprap.

- Orient the live branch cuttings perpendicular to the slope, with growing tips protruding slightly from the finished face of the rock.

End of text from Chapter 18 (SCS 1992)

Figure 33. Live joint planting.



Growing your own plants for bioengineering

Because bioengineering often requires large amounts of plant material, you may want to consider creating "production beds" in which to grow the material you'll need. The following article provides instructions for establishing *stooling beds* and beds of rooted cuttings. It is from the *Proceedings* of the 1991 meeting of the Intermountain Forest Nursery Association (USFS Rocky Mountain Forest and Range Experiment Station 1991). Also refer to information earlier in this chapter, in particular, <u>Propagating plants yourself</u> under <u>Obtaining plants</u>, and <u>Conventional plantings</u> earlier in this section on <u>Practical ways to promote bank stability</u>.

Although the following information was developed in the Northern Plains of the U.S., it should be generally applicable to the Kenai River study corridor. Local experimentation, however, will lead to better guidelines over time. Herbicide and insecticide instructions have been omitted from the article; if you develop willow or poplar production beds, contact the Plant Materials Center or local nurseries/greenhouses to find out what kinds of weed or insect pests occur locally and how to control them.

Vegetative propagation of poplar and willow

Greg Morgenson
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Introduction

Poplar and willow species and cultivars are used in the Northern Plains for farmstead plantings, field windbreaks, and for use in moisture retentive areas where other species would not survive due to saturation of the soil much of the year. Propagation is by hardwood cuttings which are rooted in the field, grown for one season, and harvested that fall or the following spring.

Clonal[1] selection and establishement

Clonal selection has been based upon: (1) growth rate, (2) insect and disease resistance, (3) form, (4) adaptibility to climate, and (5) long-term use within the region. An additional factor that needs to be considered in selection of cultivars is the ability to root in acceptable production percentages in the field. Clones of a species or hybrid may vary greatly in this factor.

The Agricultural Research Service Station, Mandan, ND, is currently evaluating in excess of 200 clones of poplar. The Soil Conservation Service Plant Materials Centers are evaluating and releasing vegetatively propagated willow cultivars for streambank stabilization, reclamation, and natural screening (*Conservation tree and shrub cultivars in the United States, Agriculture Handbook 692,* USDA SCS 1991, 50 pp.)

After clonal selections have been made and initial propagation completed, the rooted cuttings are planted into... soil at a 1 to 1.5 foot spacing within rows to establish *stooling blocks.* A differing species of another genus, such as willows within poplar, may be used to separate clones which would otherwise be very similar in appearance.

Stooling block maintenance

Once stooling blocks are established, the estimated life of the block is 10 to 15 years. After several years of harvesting, the plants grow together to make an almost continuous growth within the rows. Yearly inputs include:

1) Fertilization: 11-52-0 (N-P-K) at 300 lbs/acres. Straight N causes excessive vegetative growth.
2) Irrigation: as needed.
3) Herbicide and/or insecticide: as appropriate.

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1 A *clone* consists of all the descendents of a single individual that arose by asexual, or vegetative, reproduction.

Growth should average 8 to 12 feet on vigorous blocks. [In Alaska, average growth will probably be somewhat less.] After 10 to 15 years, growth rate decreases and blocks need to be rotated out and replaced.

Whip harvest

Harvest of the poplar and willow whips from the stooling blocks begins after natural defoliation and hardening of plant tissues in the fall. The whips are severed approximately 6 to 12 inches from ground level, this may be accomplished by hand pruners, brush saw, or mechanical harvesters.

Lincoln-Oakes Nurseries has developed a mechanical harvester to side-mount on a tractor. Utilizing the PTO and hydraulics of the tractor, the whips are severed by a 22-inch rotating blade, held by belts, and transported to an employee acting as catcher behind the belts. The whips are then placed into large wooden tree boxes, color coded, and moved to indoor storage until processing.

Cutting processing

Whips are held in unheated storage and processed into cuttings by cultivar. All side branches and oversized portions of the whips are removed to provide a uniform size. Using a band saw, whips are processed into 7 inch cuttings and stored in wooden boxes holding approximately 2200 cuttings. [Note, the cuttings described here are for use in creating beds of rooted cuttings. Bioengineering practices described earlier in this chapter frequently require much longer cuttings. If you plan to use cuttings from stooling blocks for a particular bioengineering practice, be sure to collect cuttings of appropriate size.] Cutting diameter ranges from 1/4 to 3/4 inches...

Cuttings should be stored at 24 degrees F. to 28 degrees F. to prevent fungal growth and prevent bud break in storage. (These recommendations are from "Refrigerated storage for hardwood cuttings of willow and poplar," Cram and Lindquist, 1982, in *Tree Planter's Notes* 33(4):3-5.)

Planting of dormant cuttings (for rooting)

Planting of processed cuttings begins approximately the third week of May. [In Alaska, planting could begin as soon as soil is sufficiently thawed.] Soil is prepared by roto-tilling to a depth of 10 to 12 inches, this allows easy insertion of cuttings. Cuttings may be planted by a number of methods... Many nurseries leave 1 to 2 inches of the cutting above ground level at planting, this may lead to moisture loss through the exposed cut end and multiple bud breaks.

After planting, the field is dragged with a harrow with teeth nearly horizontal to level ridges and lightly cover the tops of the cuttings to a depth of 1/2 to 1 inch...

Growth

Shoot emergence through the soil begins 1 to 2 weeks after planting. During this time, irrigation is as needed to keep the cutitngs in damp, but not wet, soil... [Watch for signs of disease or insect infestation and control as needed.] Fertilization consists of approximately 90 to 120 lbs actual nitrogen in 3 to 4 split applications through the growing season...

At the end of one growing season, the rooted cuttings are 3 to 6 feet in height. Our cuttings are topped at 20 inches to provide a uniform size rooted cutting with a good shoot to root ratio. [Alternatively, cuttings can be left to grow into additional stooling blocks.] The tops may then be processed into additional cuttings for field planting. Rooted cuttings may be fall dug after dormant and stored at 28 degrees F. in indoor storage, or spring dug before bud break. Rooted cuttings are color coded to cultivar before shipment.

(3) Structures

Many non-living (inert) structural approaches to stabilizing river banks have been developed over the years. These include structures that are laid on the face of bank slopes, structures that line the toe of banks, and structures built out into river channels. "Structures are generally capable of resisting much higher lateral earth pressures and shear stresses than vegetation" (SCS 1992, Chapter 18:5).

Although inert structures can be effective in particular situations, there are a number of **problems with their use**:

1. Inert structures generally require careful and **costly** design, installation, and maintenance. In particular, the costs of design, material, and equipment can be very high, and are often beyond the budgets of most Kenai River landowners.

MOST NON-LIVING STRUCTURES ARE BEST THOUGHT OF AS A LAST RESORT. HOWEVER, THREE CAN BE USED BOTH TO PROTECT RIVERBANKS AND TO IMPROVE FISH HABITAT: (1) BOARDWALKS, (2) FLOATING DOCKS, AND (3) ACCESS STAIRS DOWN SLOPES.

2. Because of the complexity of forces that interact in river channels (discussed in Chapter III), inert structures **may cause significant problems where they tie into the bank, in adjacent sections of the channel, and in areas upstream and/or downstream.** Failures of structures due to faulty design, poor installation, flooding, etc. are not uncommon and can lead to additional bank damage and high repair costs.

3. Inert structures **rarely provide bank-edge habitat for rearing salmon or other fish.** Instead, they often create conditions unsuitable for juvenile fish (e.g., increased velocity, lack of cover), and eliminate habitat areas from use. They also rarely benefit other fish or wildlife.

4. Getting **permits** for inert structures that will affect areas below "ordinary high water" is currently very difficult. Permitting agencies, particularly the Alaska Department of Fish and Game, are increasingly concerned about the cumulative impacts on fish of structures already installed along the Kenai River. The ADF&G has recently begun a study to: "identify primary, secondary, and cumulative impacts on fish habitat resulting from riparian zone development along the Kenai River." This study will lead to "...assessment methodology and management policies that will avoid and/or reduce future development impacts on fisheries habitats" (ADF&G 1992). Until new policies are developed, it's unlikey any inert structures will be permitted in the Kenai River (even riprap, which has been permitted in the past).

5. Many landowners and recreational river users consider inert structures **incompatible with the aesthetics of a recreational river**, particularly when long stretches of riverbank are treated this way.

For these reasons, most inert structures are best thought of as a last resort in stabilizing riverbanks. Nonetheless, there are three structures that rarely cause the problems listed above. They can be used both to protect riverbanks and to improve fish habitats. These are: (1) boardwalks, (2) floating docks, and (3) access stairs down slopes. You may want to consider using these structures as part of your riverbank management system.

Boardwalks

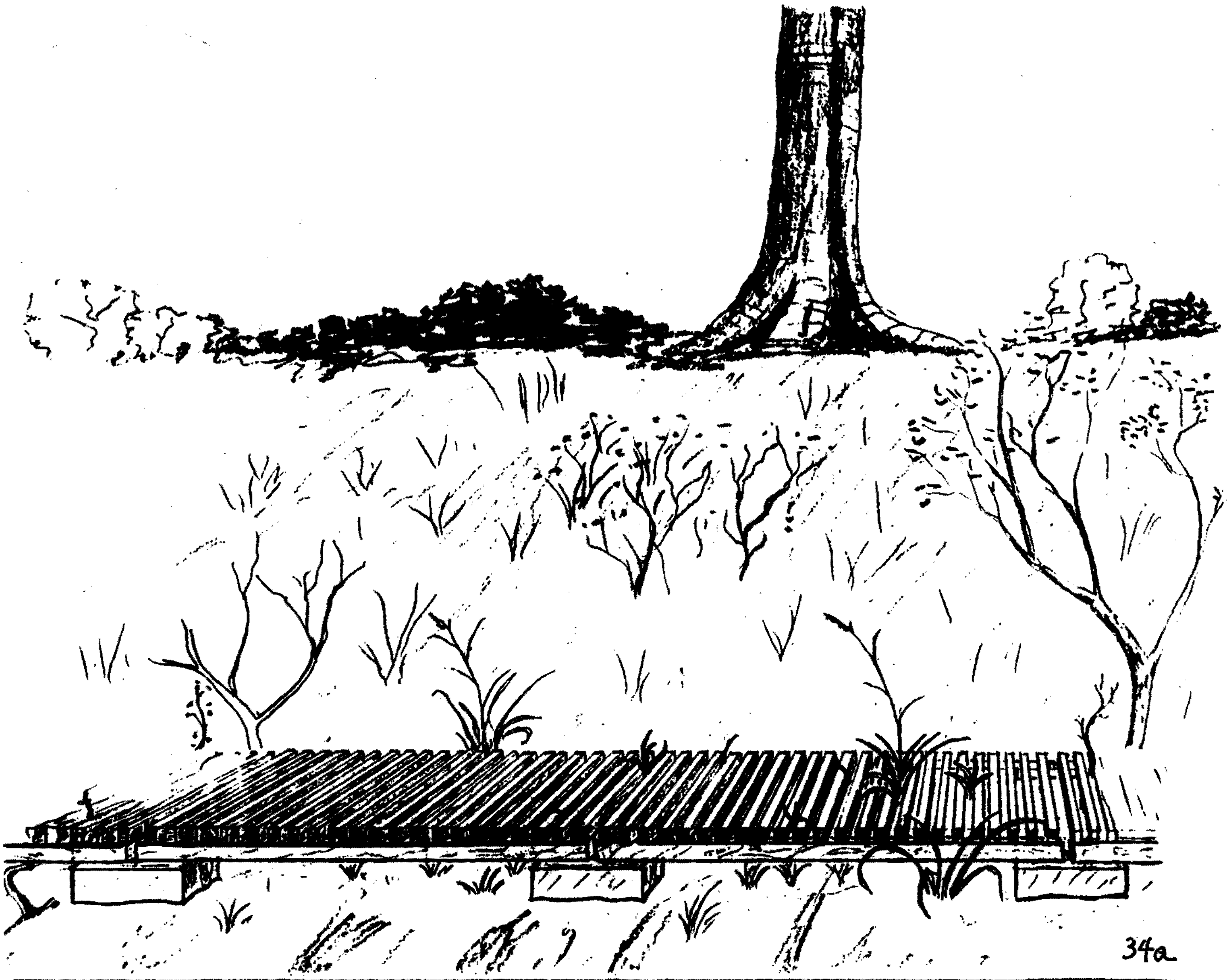
Figures 34, 35, 36, and 37 illustrate several kinds of boardwalks that could be used along the Kenai River. Figures 35 through 37 are self-explanatory. Figure 34a and b illustrate two boardwalks specifically designed to allow plant growth underneath. The techniques illustrated to promote plant growth (spacing between decking; staking of growing woody stems beneath the boardwalk) could also be applied to other boardwalk designs.

Figure 34a illustrates a "seasonal" boardwalk. The boardwalk rests on removable footings (blocks of wood or concrete) laid on top of the riverbank above ordinary high water. Footings blocks could be of any convenient size, but the higher the footings, the more light will reach beneath the boardwalk. The stringers (4 ft or 6 ft long boards that run from footing to footing to support surface decking) could be made of 4 inch by 4 inch lumber or other appropriate sizes. To allow plenty of light to reach plants beneath the boardwalk, surface decking could be made of 2 inch by 2 inch boards, 2 or 3 ft long, spaced 1 inch apart. The boardwalk could also be made in sections, hinged together if necessary. Sections could be removed before winter or if flooding were probable.

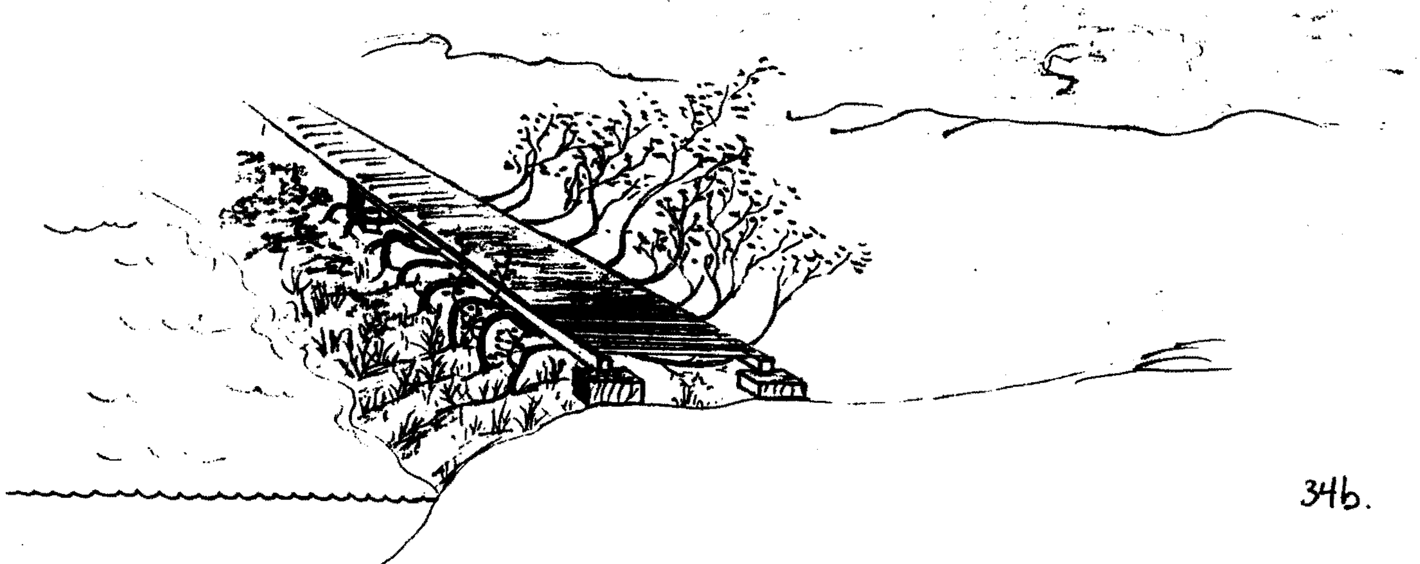
Figure 34b illustrates a more permanent boardwalk. *Before* it was built, long "whips" or "wands" of willows (or other suitable shrubs) were planted along the edge of the bank. When these stems were 4 or 5 ft long, they were laid horizontally along the ground and staked down. The boardwalk was then built over this ground-protecting surface of stems. Because leaves have access to sun *behind* the boardwalk, sunlight is not needed for plant growth beneath the boardwalk; decking boards can, therefore, be spaced close together. (Leave enough space between boards for rainfall to drain and for wet boards to swell.) Leafy growth behind the boardwalk can be "hedged" relatively short so it won't interfere with casting during fishing. Leafy growth in front of the boardwalk can also be pruned. Alternatively, the decking surface could be extended further towards the river ("cantilevered") entirely over the stems to discourage shrubby growth in front of the boardwalk. As long as foliage grows behind the walkway, roots will grow and bind the bank, even if stems are covered by the boardwalk itself.

Prefabricated vegetation-protecting surfaces are also available. One such product is called *Porta-path*. It's made from polypropylene, and consists of a system of "treads" and "connectors" that clip together to form a flexible pathway (or other surface) that can be laid out when needed and rolled up for storage. This product might provide adequate protection to riverbanks that receive relatively light use. In addition, a more permament "grass paving" system, called *Ilplus grassroad pavers* is also available. Vendors of these products are listed in Chapter VI under "walkways (prefab and/or portable)."

Figure 34. Boardwalks designed to encourage plant growth beneath (described in text).



34a



34b.

Figure 35. Double plank boardwalk (from USFS 1991).

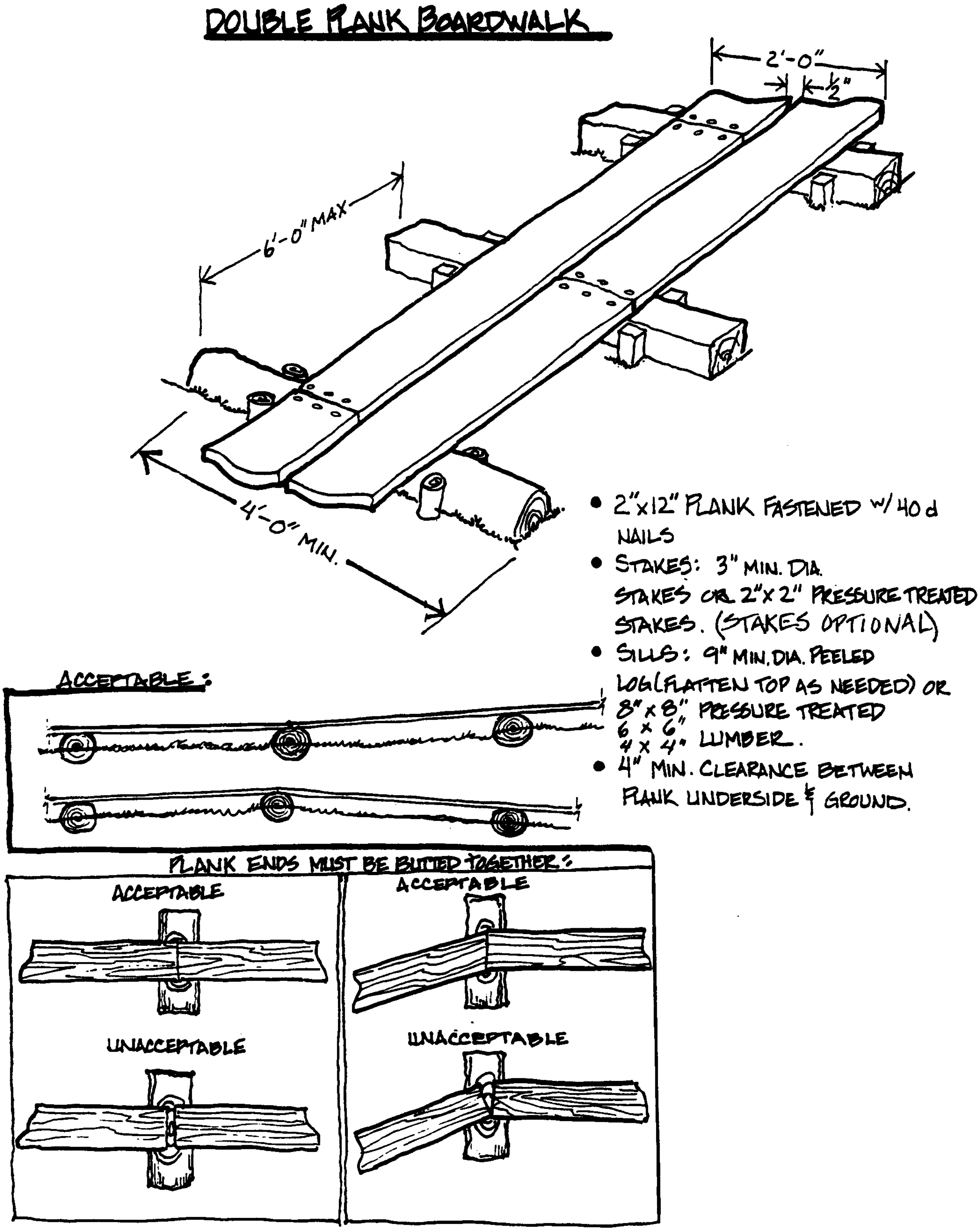


Figure 36. Single plank boardwalk (from USFS 1991).

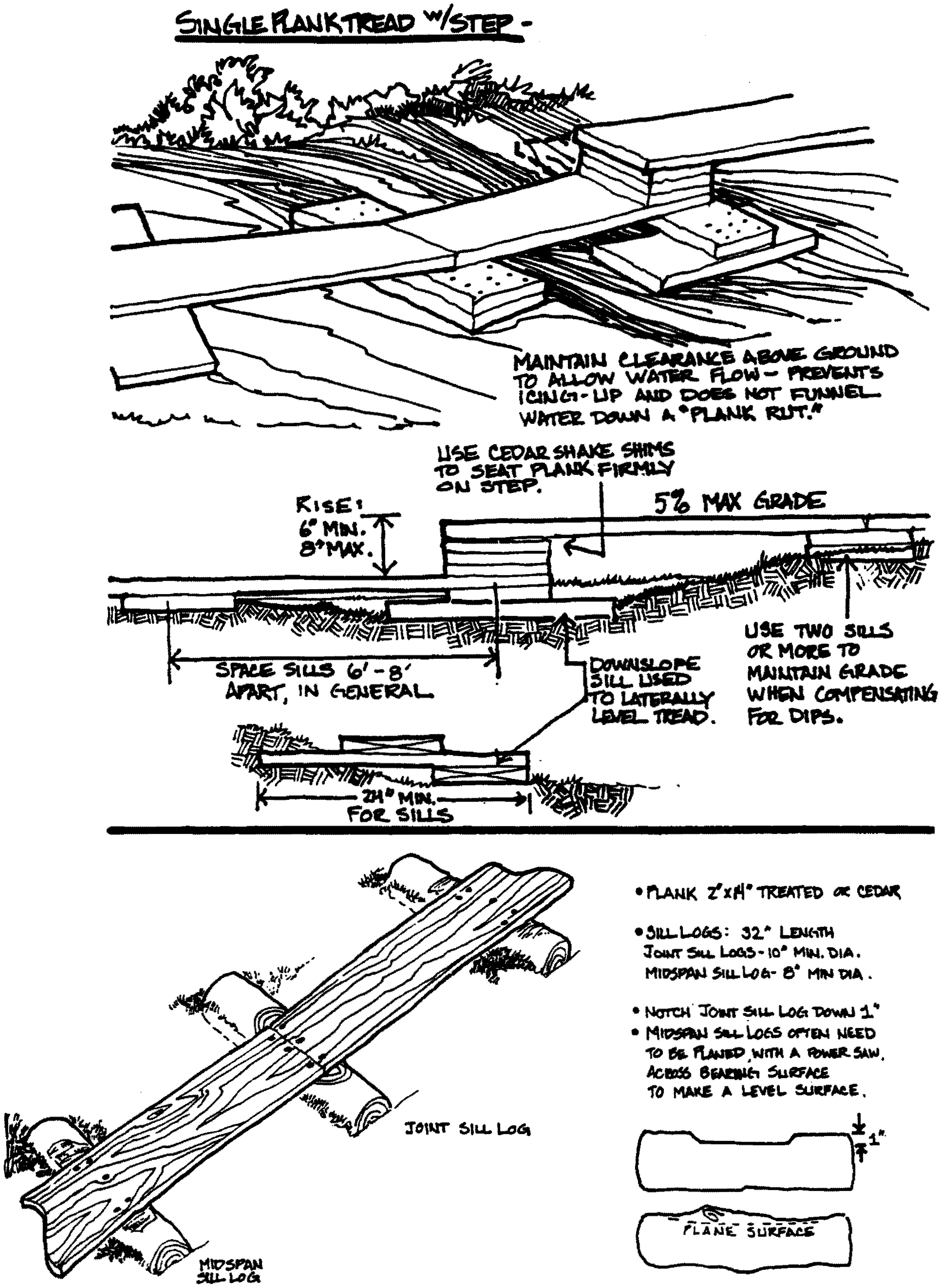
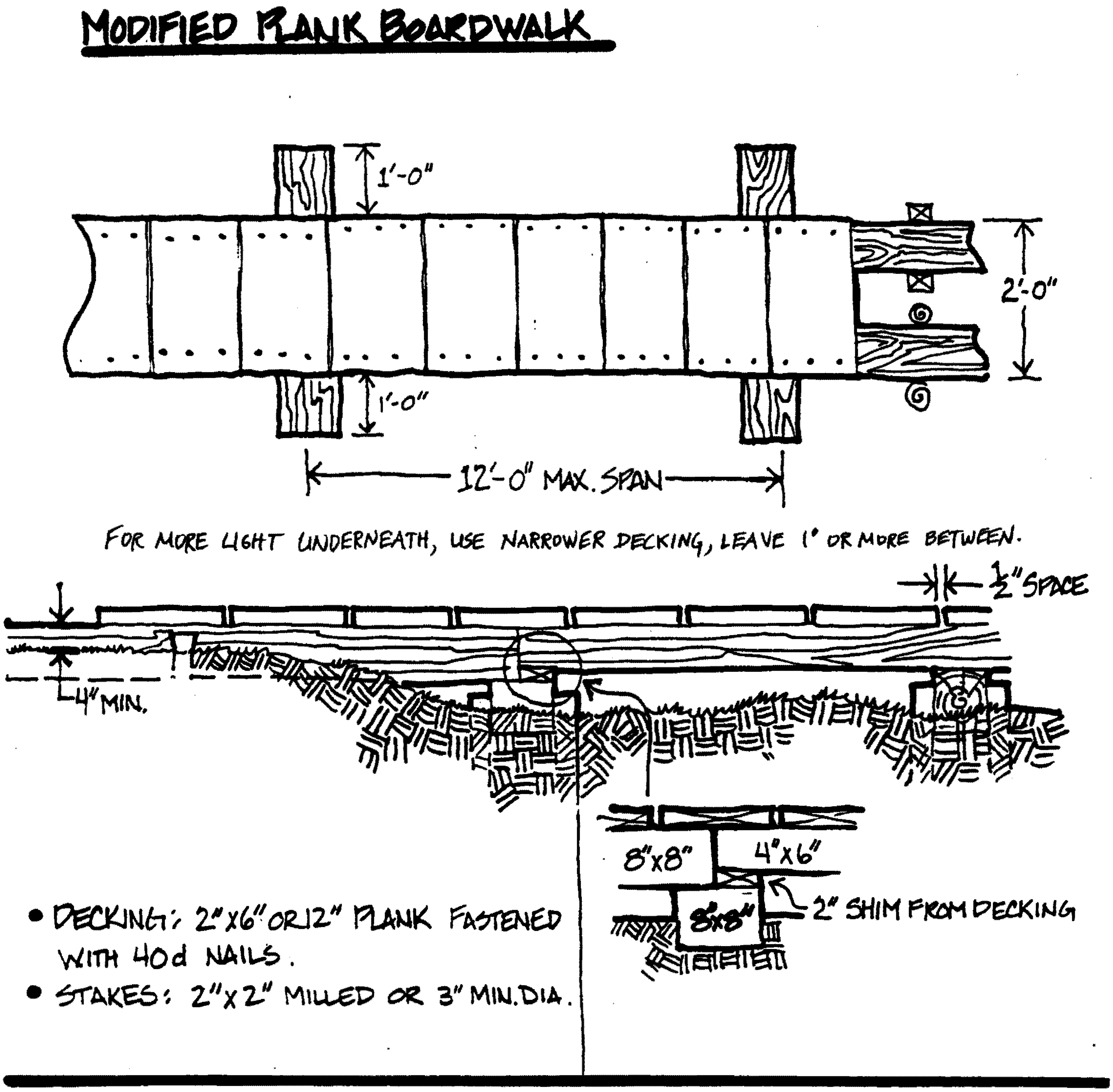


Figure 37. Modified plank boardwalk (from USFS 1991).



Floating docks

Figure 38 illustrates a design for a floating dock. Because docks affect areas below ordinary high water and may interfere with navigation, permits are required for their installation (see Chapter II, Section D). Docks serving individual parcels are restricted to a total surface area of 64 square ft. Docks serving a number of parcels may be larger, but designs must be reviewed on a case-by-case basis.

The following guidelines from the *Kenai River Comprehensive Management Plan* also apply to floating docks (ADNR 1986:259):

- Floating docks shall not extend more than 10 ft from the water's edge at any water level or river stage below the ordinary high water line.

- In no case shall floating docks extend more than 25 ft beyond the ordinary high water line.

- Walkways or ladders extending beyond the ordinary high water line for the purpose of connecting floating docks with the shoreline shall not exceed 4 ft in width.

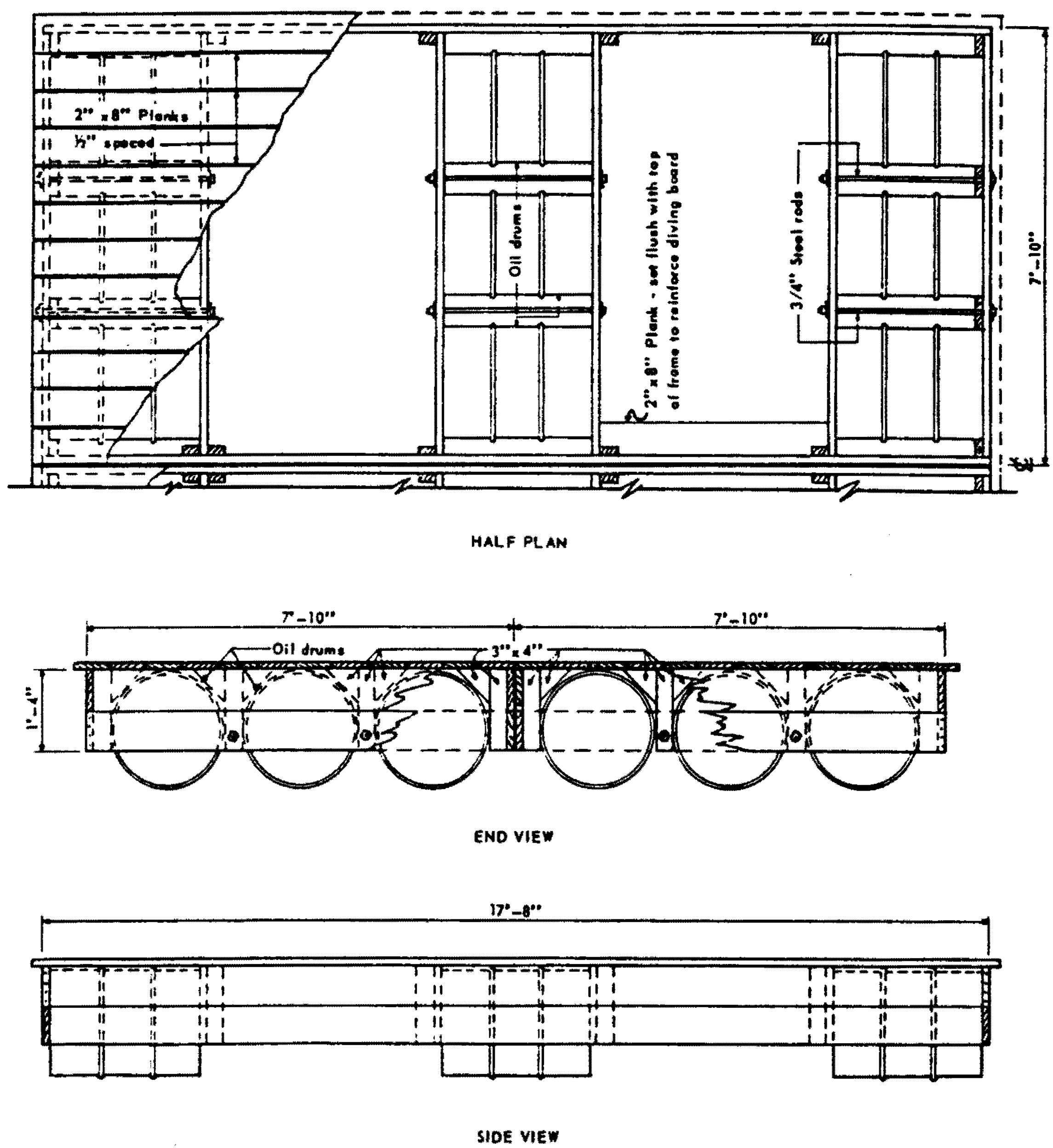
- Barrels used in the construction of floating docks shall be cleaned and sealed to prevent the escape of hazardous materials into the Kenai River.

Access stairs

Figure 39 illustrates stairs appropriate on gentle slopes. Figures 40, 41, and 42 illustrate stairs that can be built on somewhat steeper slopes with little or no modification of the slope surface and relatively little disturbance of vegetation.

Figure 38. Floating dock.

All wood parts should be pressure treated for long life, and all hardware should be coated. While oil drums are employed here for flotation, Styrofoam "planks" might be substituted. This plan relates to Boat Landing Dock, DESIGN index No. R-4855, (SCS-499).



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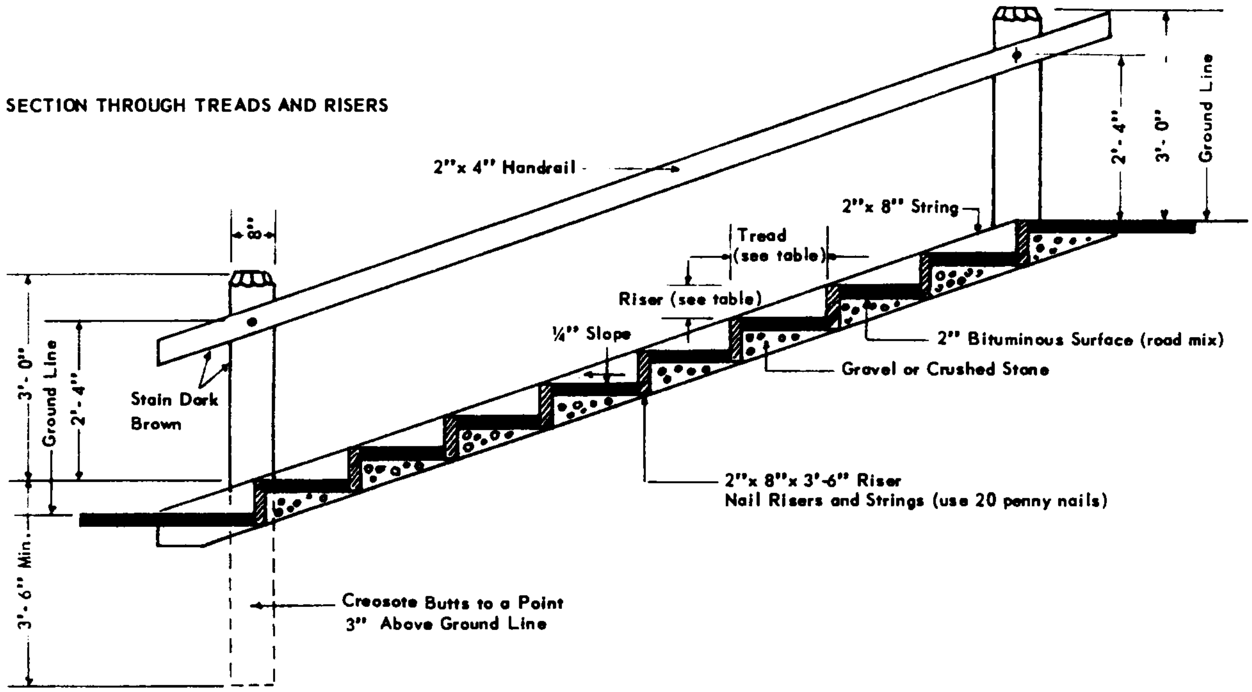
3-71

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

FLOAT DOCK

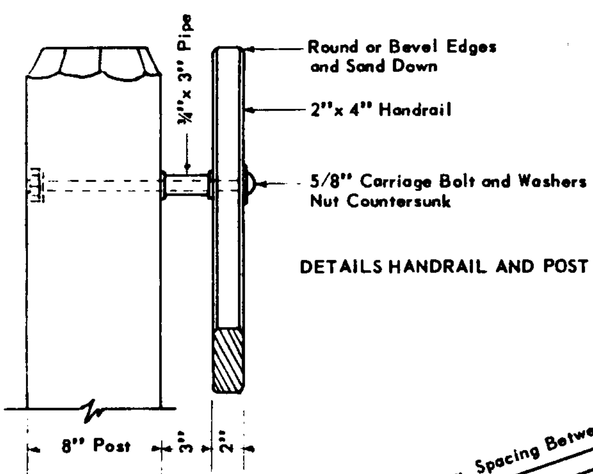
FROM DESIGN VOLUMES OF THE PARK PRACTICE PROGRAM
NATIONAL CONFERENCE ON STATE PARKS
DESIGN SHEET NO. R-4902

Figure 39. Steps and rail.

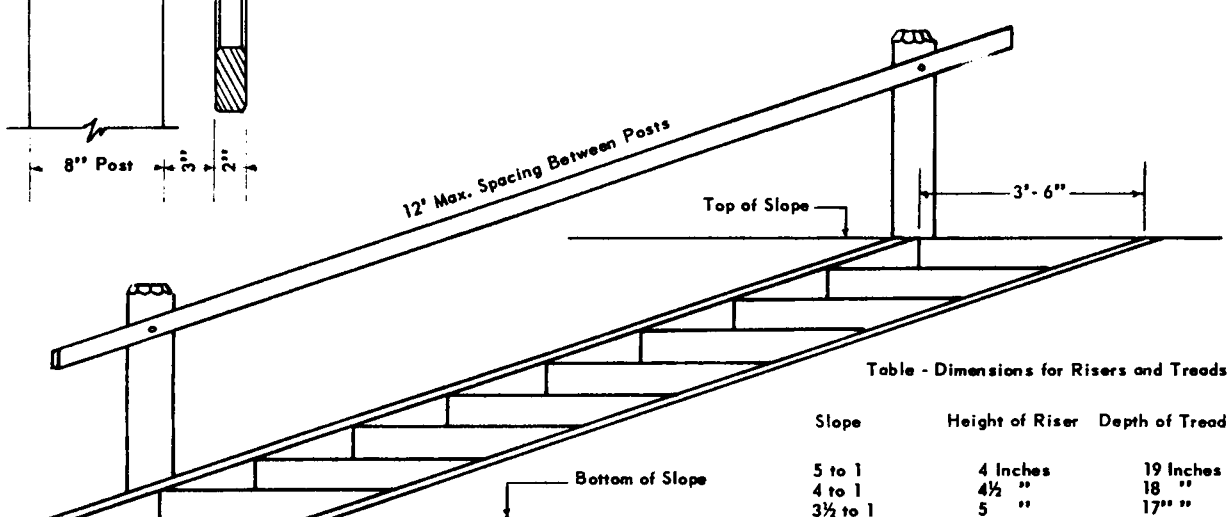


SECTION THROUGH TREADS AND RISERS

Short stairways are often required in the park situation. This is a practical design for such an installation from the Wisconsin Highway Commission.



DETAILS HANDRAIL AND POST



ORTHOGRAPHIC SKETCH

Table - Dimensions for Risers and Treads

Slope	Height of Riser	Depth of Tread
5 to 1	4 Inches	19 Inches
4 to 1	4½ "	18 "
3½ to 1	5 "	17" "
3 to 1	5½ "	16 "
2½ to 1	6 "	15 "
2 to 1	6½ "	13 "
1½ to 1	7 "	11 "

UNITED STATES DEPARTMENT OF THE INTERIOR, NATIONAL PARK SERVICE
The Park Practice Program
NATIONAL CONFERENCE ON STATE PARKS — AMERICAN INSTITUTE OF PARK EXECUTIVES

DATE	January 1968	PLATE	606 H
INDEX	B-3176	CONTROL	C-0907-B

STEPS AND RAIL

Contributed by WISCONSIN Highway Commission

Figure 40. Native log stairs (from USFS 1991).

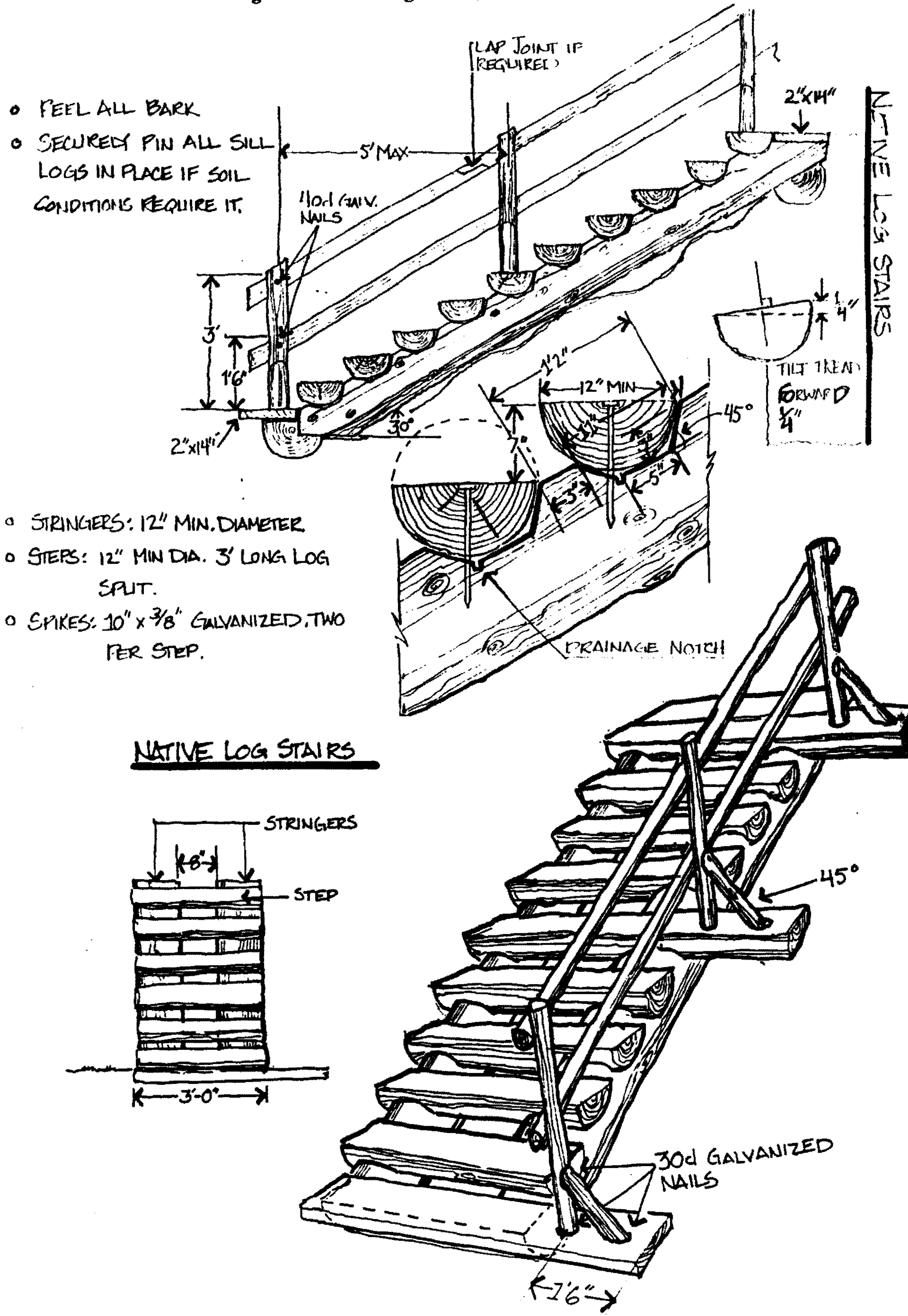


Figure 41. Log stairs with plank steps (from USFS 1991).

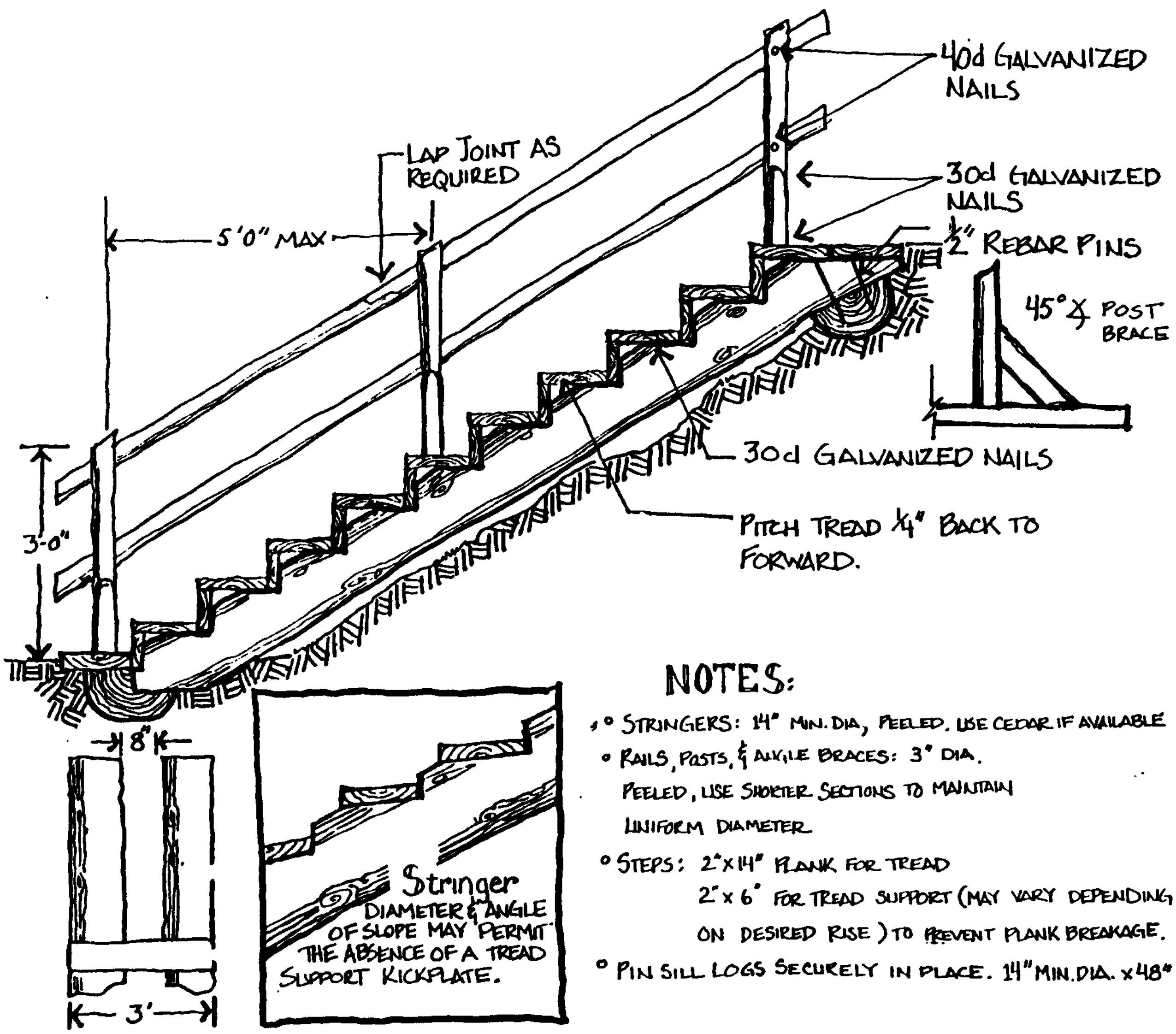
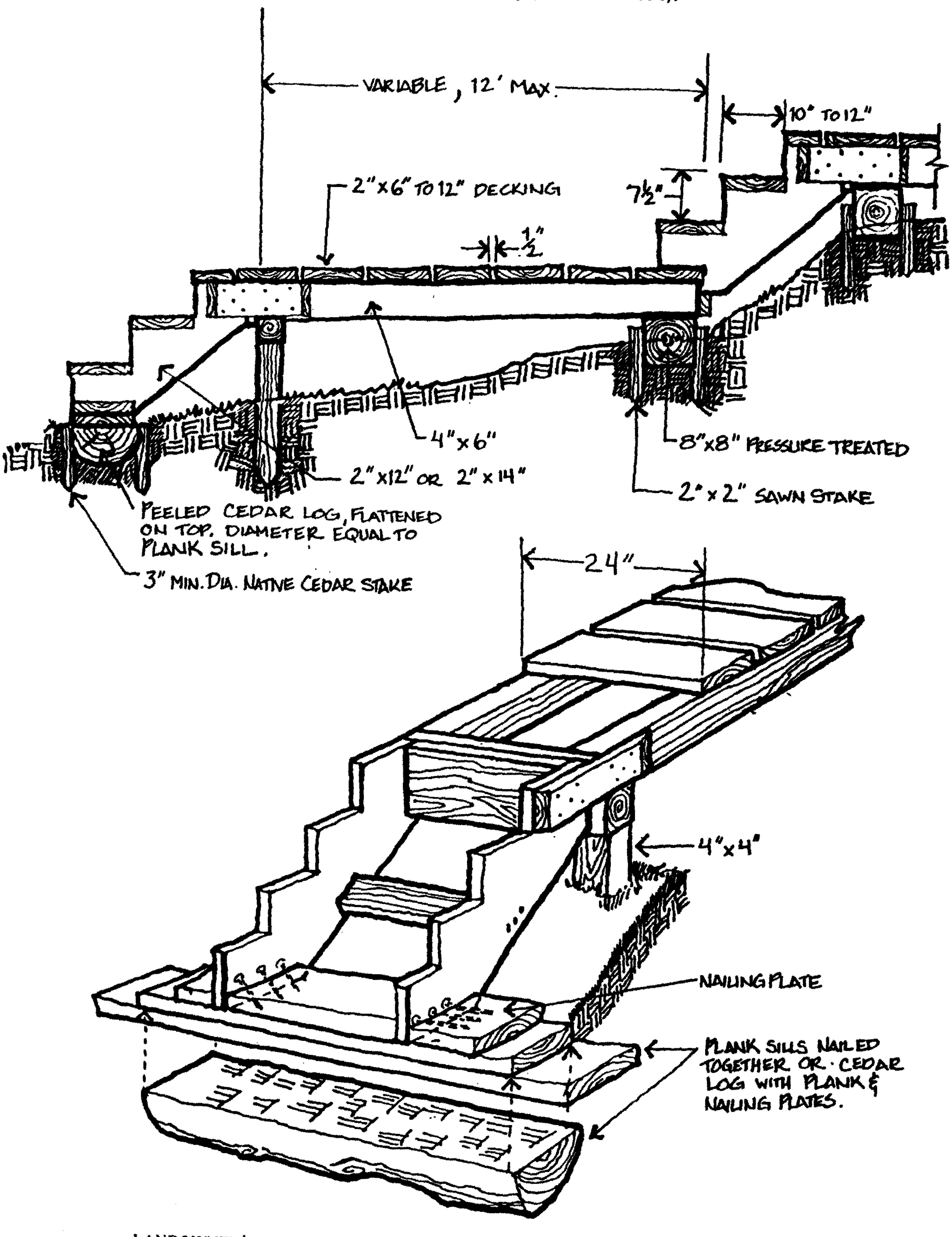


Figure 42. All plank stairway (from USFS 1991).



Riverbank data
(Currently available only for banks in the City of Soldotna)

Written with technical input from
Frank Reckendorf
SCS Sedimentation Geologist, Portland

What riverbank information was collected

When the Kenai River Study was first discussed, a riverbank[1] inventory was envisioned as part of the plan. Unfortunately, funding to cover the bank inventory never materialized. As a result, the Kenai River Study involved mapping soils and plant communities up to the river's edge, but the riverbanks themselves were not inventoried.

A number of Kenai River Study participants recognized lack of riverbank data as a serious shortcoming, and in 1989, the Soil Conservation Service developed and field tested a method to inventory Kenai River banks[2] in the hopes that funding for a bank inventory would be found. (A number of agencies helped develop the methodology, most notably the Alaska Department of Fish and Game.) In 1990, the City of Soldotna provided funding to the Kenai Soil and Water Conservation District to inventory riverbanks within Soldotna city limits, and the District contracted the SCS to do the project. The SCS conducted the City of Soldotna bank inventory in May 1990. Like other mapped data, bank inventory information was added to the Kenai Peninsula Borough's computerized geographic information system.

Nineteen riverbank characteristics were assessed during the inventory (Table 15). (These will make more sense if you read Chapter III.) On the basis of data about these characteristics, field crews distinguished 61 separate stream "reaches." A "reach" is a segment of riverbank that is relatively homogeneous (uniform) in terms of conditions found there. On the right bank (looking downstream), 35 reaches were inventoried, totaling 37,960 ft of riverbank (7.1 miles); on the left bank, 26 reaches totaled 39,640 ft of riverbank (7.5 miles). Solid dots on Map 1 show where each reach starts and ends (open dots indicate where streamflow velocities were measured). Table 16 shows the length and geomorphic surface of each reach. As each reach was assessed, field crews also took one or more color photographs of a typical segment of the riverbank in that reach. For more information about the bank inventory, refer to: *City of Soldotna Kenai River Bank Inventory Report* (Reckendorf and Saele 1991). For data or descriptions about particular reaches, contact the Soil Conservation Service Homer Field Office.

Using collected information to assess riverbank stability

To this point, the riverbank inventory has produced primarily "descriptive" data. To become more useful to Kenai River landowners, descriptive riverbank data need to be "interpreted," like soil and plant data have been in this *Guide*. But you can't "interpret" data till you answer the question: "interpreted in terms of what?" Soils data, for example, are used to interpret the *suitability* of soils for specific *uses*: will this soil function as a <u>leach field</u>, a <u>trail</u>, or a <u>foundation</u> site? Such uses suggest <u>criteria</u> for rating soils data: do these soils <u>drain</u> well enough to absorb leach field effluent? do they <u>compact</u> well enough to support the foundation of a single-family dwelling? For soils, suitability criteria and their relationship to particular land uses have evolved and been standardized over decades.

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1 The "riverbank" discussed here consists of the scarp, or sloping face, of the geomorphic surface adjacent to the river; in other words, the sloping-to-nearly-vertical face you see when looking at the bank from a boat. This scarp ranges in height from just a few ft on floodplains to 40 ft or more on old terraces.

2 Development of the bank inventory methodology is outlined in: *Kenai River Streambank Erosion, Special Report* (Reckendorf 1989). Contact the SCS for information about this report.

Currently only one criterion — bank stability — has been widely suggested as a basis for interpreting bank data. Put simply, the interpretation needed is: is this bank stable enough that a landowner won't find his property disappearing into the river at an alarming rate? As a Kenai River landowner, this question is critical to you. But it's also critical to others who value Kenai River fisheries because bank erosion can destroy essential fish habitats (see The relationship between riverbanks and fish earlier in this chapter).

The problem is, this is a complicated question to answer, in part because **erosion itself is not necessarily bad, and halting erosion is not necessarily good.** To begin with, as explained in Chapter III, riverbank erosion is a *natural* and *inevitable* part of river systems. "Normal" rates of erosion are critical to the "normal" functioning of natural rivers. Trying to stop "normal" (or "geologic") erosion can interfere with a river's long-term balance and productivity. Secondly, because **riverbanks are *naturally unstable* environments**, it's easy to *accelerate* bank erosion; and many of us contribute to the problem — landowners, anglers, boaters, developers. At the same time, none of us wants to curtail our activities, even when we *know* what we do may cause erosion. Thirdly, **once bank erosion is accelerated, it can be difficult, expensive, and potentially harmful to slow it back down.** One reason is the difficulty of dealing effectively with such complex, dynamic environments (see Chapter III). Another reason is that many approaches traditionally used to control bank erosion are as harmful to fish and other aquatic life as erosion iself (or more harmful). Examples include stone jetties, barrels, steel gratings, board revetments, even riprap. Finally, there are many techniques for slowing erosion that have never been tried on the Kenai River. Our knowledge of Kenai River erosion — its benefits and costs, causes and solutions — is still rudimentary.

IT'S SO EASY TO CAUSE STREAMBANK EROSION. WE ALL CONTRIBUTE TO THE PROBLEM — LANDOWNERS, ANGLERS, BOATERS, DEVELOPERS...

Evaluating riverbank stability is also hard because it can't be assessed with bank data alone. Many variables other than bank characteristics affect bank stability. Consider for example all the riverbank processes mentioned in Chapter III — flooding, bed scour, movement of meander loops, ice damming, etc., most of whose effects on a particular riverbank are hard to predict. In addition, consider all the ways that you, as landowners, affect bank stability: Do you protect or disturb the stabilizing mat of vegetation on your bank? Do you regularly drag your boat up your bank, or do you use a floating dock and spruce tree revetments to minimize damage from boats and boat wakes? Do you build your house as close as possible to the water's edge and cut down all the trees that "block" your view? Such human variables are critical: no matter what its inherent condition, with a little human effort, almost any bank can be made unstable.

Despite these concerns, bank data can indicate something about "relative" bank stability if we assume that other factors (flooding, ice dams, etc.) affect all banks equally. (This is, of course, not true in reality.) Making this assumption, we (F. Reckendorf and D. Lehner) developed a simple system for rating inventoried banks in terms of their relative stability. The system is based on ten bank characteristics that could be determined from riverbank data. Table 17 shows you the results.

Table 17 lists each inventoried stream reach and identifies factors that contribute to erosion (or failure) on that particular section of riverbank. The greater the number of "destabilizing" factors shown, the more susceptible that reach will generally be to erosion. Characteristics considered in Table 17 are as follows:

1) **Bank height** The higher the bank, the greater its potential for instability. Banks that are categorized as terraces 2 or 3 (which are

over 20 ft in height) are considered potentially most unstable.

2) **Streambank position** As you saw in Chapter III, banks on outside meander bends are generally subject to more erosion from river currents than other banks. Table 17 shows which banks are on outside curves and where along the curve they're located.

3) **Human disturbance** Trampling and other human activities can cause bank erosion. Banks that are relatively more disturbed are also relatively more prone to erosion and failure. If any part of a river reach showed significant disturbance, the whole reach is identified as disturbed in Table 17.

4) **Unstable material at base of scarp** As you saw in Chapter III, most banks inventoried along the Kenai River consist of unconsolidated sediments. If these sediments occur at the base of the bank face (scarp), they are vulnerable to the erosive effects of river currents, boat wakes, etc. If the toe of a slope erodes, the bank above starts collapsing.

5) **No horizontal toe** Some banks have a narrow horizontal toe, usually gravelly, which attenuates (weakens the force of) river currents and boat wakes that reach the vertical bank face behind it (except at high water levels when the river overtops the toe). Where present, this horizontal toe provides some protection to the bank face.

6) **Bare (plant cover gone)** Earlier in this chapter you saw how important plants are to bank stability. Banks without plant cover are much more susceptible to erosion than well-vegetated banks.

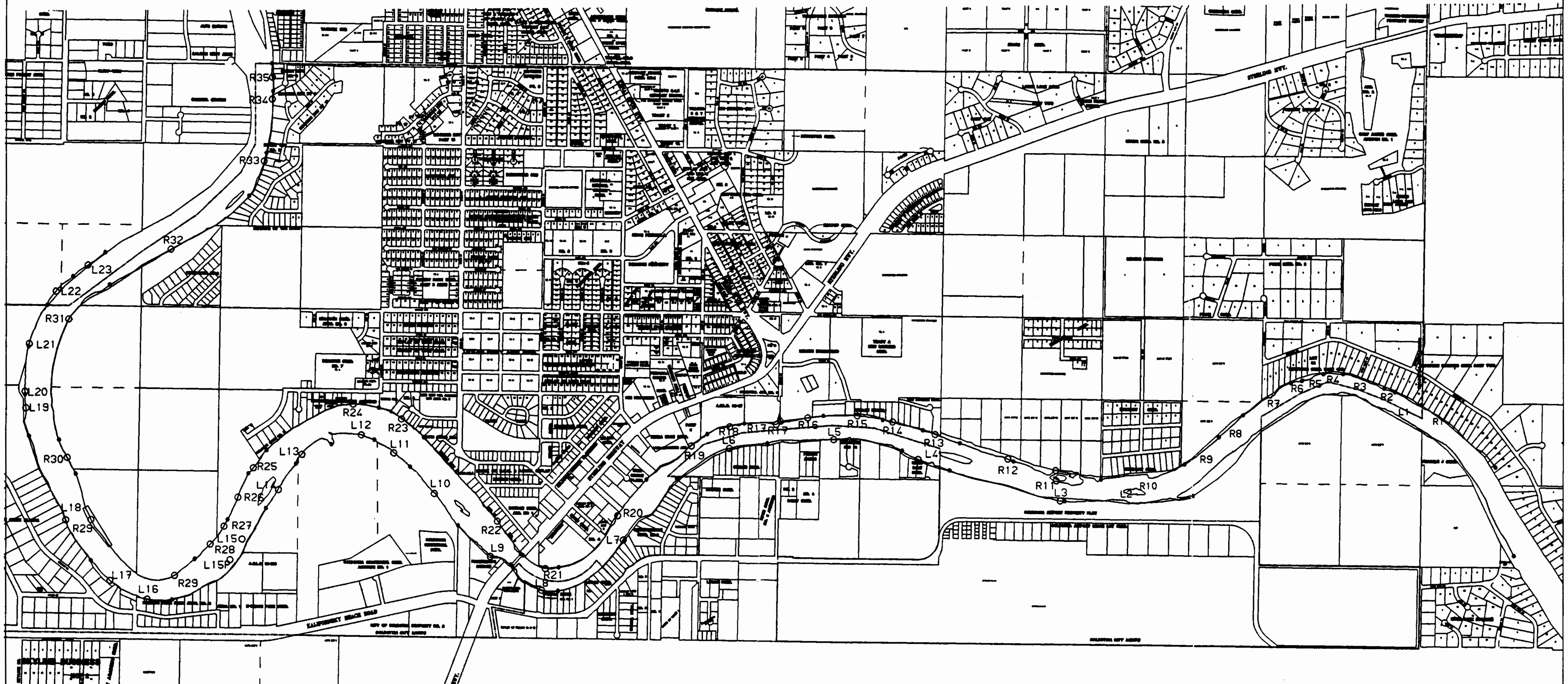
7) **High ratio of bank height to bankfull flow height** When the river flows high ("bankfull"), it saturates the bottom portion of bank slopes. If the bank above this saturated zone is a *high* bank (and therefore heavy), it increases stress on the saturated material below, encouraging it to fail. A high ratio, therefore, means a potentially less stable bank than a low ratio.

8) **Low percent of total bank height with roots** This is another way of recognizing the stabilizing effects of plants. If much of a bank is penetrated by roots, the bank will be more stable than if it has only a thin layer of roots near the surface.

9) **High nearshore velocities** We saw in Chapter III that much of a river's erosive energy is a function of streamflow velocity; fast rivers are more erosive than slower rivers. As a result, banks adjacent to fast flows are subject to more erosive energies than banks next to slow flows. River currents tend to be fastest against outside meander curves, but other areas may also have fast flows. For example, obstacles that constrict the river channel also increase local flow velocity.

10) **Prone to flooding** Most of the factors listed in Table 17 increase with bank height: in general, high banks are less stable than low banks. But low banks are more susceptible to flooding. During a flood, low banks may be overtopped by fast flood flows, and large chunks may be eroded, particularly if the bank is not well vegetated. In addition, seepage from banks, particularly as flood waters drop, decreases bank stability, causing banks to fail. Seepage washes out fine sediments from between gravels. This causes the gravel matrix to lose grain-to-grain contact and then collapse. Also, as illustrated in Figure 27, low banks that get saturated at ordinary high water are very susceptible to erosion along devegetated footpaths.

Section D, Using Riverbank Information, has suggested many ways to prevent and minimize riverbank erosion along the Kenai River. In addition, Table 10 in Chapter III provides a handy index to *all* the ways covered in this *Guide* to protect Kenai River resources. Taking care of river resources is the best way to ensure that we will always have them to use and enjoy.



NOTE: L & R ON REACH LABELS REFER TO LEFT AND RIGHT RIVER BANKS WHILE FACING DOWNSTREAM

LEGEND

● END OF REACH

○ STUDY SITE

R13 REACH LABEL (TYPICAL)

REVISION BLOCK

NORTH

KENAI PENINSULA BOROUGH
Planning Department
GIS Division

KENAI RIVER BANK REACHES

SCALE:

DATE: MARCH 4, 1991

Table 15. Kenai River streambank inventory legend (from Reckendorf and Saele 1991).

Geomorphic surface	(LF) low floodplain; (HF) high floodplain; (T1) terrace 1; (T2) terrace 2; (T3) terrace 3; (MO) moraine
Surface condition	(wv) well vegetated; (vt) partially vegetated and trampled; (tb) trampled and bare or almost bare; (uv) naturally unvegetated
Streambank height from toe	(A) 0–4 ft; (B) 4–7 ft; (C) 7–20 ft; (D) 20–50 ft; (E) >50 ft
Streambank position	(I) inside curve (O) outside curve (X) crossover modifiers: u=upstream end of reach, d=downstream end of reach, m=mid-point (highest velocity position within curve reach)
Graphic	Draw approximate bank cross-section showing shape, slope breaks, relative thickness of strata, etc. The following five data categories should correspond with sketch.
Slope (by strata)	(V) vertical; (1) vertical 1:1 (100%); (2) 1:1 to 2:1 (50%) (3) 2:1 to 3:1 (33%); (4) 3:1 to 4:1 (25%); (5) >4:1 (25%)
Strata material	(U) unstratified; (GW/GP with sand), etc., Refer to National Soils Handbook (NSH Table 603–1); Other modifiers: Sd = sandstone, gr = gravelly, cm = cemented, cb = cobbly, om = organic matter
Torvane (by strata)	Measure vane stress with Torvane, record in Tons per sq. ft;
Strata stability	(st) stable; (ps) partially stable; (ls) loose sloughing; (bl) block slumping; (ov) overhanging; (hm) hummocky; (sl) slumping
Slope cover	(t) trees; (s) shrubs; (h) herbaceous; (g) grass; and (b) bare; and use modifier pb = partially bare (give % bare)
Toe width	(0) no toe "floodplain"; (e) edge, <5 ft; (n) narrow, 5 ft – 10 ft; (m) medium, 10 ft – 50 ft
Toe texture	use same material codes as Strata material (NSH 603–1)
Large Woody debris	(ln) leaners; (sr) sweepers; (oc) occasional large woody debris
Bed Material d50 w/in 10 ft	Estimate d50 in cm or d50 in cm from pebble count
Bed material d50 beyond 10 ft	Estimate d50 in cm or d50 in cm from pebble count
Velocity	(VI) <1 ft/sec; (V2) 1–2 ft/sec; (V3) 2–3 ft/sec; (V4) >3 ft/sec
Velocity location	(D1) 2.5 ft from toe; (D2) 5 ft from toe; (D3) 10 ft from toe
Cultural features	(st) stairs; (RR) large riprap; (rr) small riprap; (tr) tires; (wd) wood cribbing or boards; (cn) concrete wall; (rg) rock groins; (ca) canals; (bd) boat dock; (tv) tree revetments; (ot) other
Houses (number and setback)	(cb) on bank; (vc) very close within 10 ft of bank; (cl) close within 10 – 50 ft of bank; (sb) set back 50 – 100 ft of bank; (mt) more then 100 ft from bank

Table 16. Kenai River streambank reaches within the City of Soldotna (from Reckendorf and Saele 1991).

Reach	Length (ft)	Geomorphic Surface	Reach	Length (ft)	Geomorphic Surface
R-1	2,610	T1	L-1	7,000	HFP
R-2	120	T2	L-2	1,800	T2
R-3	1,120	T2	L-3	2,000	T2
R-4	360	T1	L-4	800	T1
R-5	400	T1	L-5	2,280	HFP
R-6	200	T2	L-6	1,680	T2
R-7	1,040	T2	L-7	2,760	HFP
R-8	560	T2	L-8	1,000	T2
R-9	680	T2	L-9	1,040	T2
R-10	1,520	T1	L-10	1,200	T2
R-11	1,480	HFP	L-11	760	T2
R-12	960	T2	L-12	1,160	HFP
R-13	600	T2	L-13	1,120	HFP
R-14	640	T1	L-14	800	T1/HFP
R-15	600	T2	L-15	2,240	HFP/LFP
R-16	640	T2	L-16	840	T3
R-17	600	LFP	L-17	720	T3
R-18	600	LFP/HFP	L-18	2,320	HFP
R-19	1,240	T1	L-19	720	HFP
R-20	2,080	T2	L-20	760	T2
R-21	600	HFP	L-21	760	T3
R-22	2,560	T2	L-22	600	T3
R-23	920	T2	L-23	440	T3
R-24	2,000	T3	L-24	1,880	T2
R-25	440	T2	L-25	240	T1
R-26	800	T2	L-26	2,720	HFP
R-27	280	T2			
R-28	560	T1			
R-29	3,000	HFP			
R-30	600	T1			
R-31	2,800	HFP			
R-32	2,720	HFP			
R-33	720	T3			
R-34	960	T3			
R-35	680	T1			

T1 = terrace 1 LFP = low floodplain
T2 = terrace 2 HFP = high floodplain
T3 = terrace 3

Table 17. Factors that may contribute to bank instability on inventoried reaches of riverbank (see related map). Streambanks with the most factors are the most vulnerable to erosion or failure. (A blank space means the factor does not characterize that river reach, "--" means no data; further explanations in text.)

reach number (facing downstream, "R" means right bank, "L" means left bank)	terraces 2 and 3 (T1 and T2, both over 20 ft high)	position on outside meander bend	relatively disturbed by human activities	relatively unstable material at base of scarp (slope)	no horizontal toe at base of scarp (slope)	bare (plant cover gone)	high ratio of bank height to bankfull-flow height	low % of total bank height with roots	high near-shore stream velocities	prone to flooding; L = low H = high FP = floodplain
R-1		middle	yes	yes	--			yes	yes	
R-2	T2	middle			--		yes	yes	--	LFP remnant
R-3	T2	middle	yes	yes			yes	yes	yes	LFP remnant
R-4		middle		yes					--	LFP remnant
R-5		middle	yes	yes	--			yes	--	
R-6	T2	downstream		yes			yes	yes	--	
R-7	T2	downstream		yes			yes	yes	--	HFP remnant
R-8	T2	downstream		yes			yes	yes		HFP remnant
R-9	T2			yes	yes		yes	yes	yes	HFP remnant
R-10			yes	yes						HFP remnant
R-11			yes	yes					--	HFP
R-12	T2		yes	yes		partly	yes	yes	yes	
R-13	T2		yes	yes			yes	yes	yes	HFP remnant
R-14	T2/T1	upstream		yes	yes					HFP remnant
R-15	T2	middle		yes			yes	yes	yes	

reach number (facing downstream, "R" means right bank, "L" means left bank)	terraces 2 and 3 (T1 and T2, both over 20 ft high)	position on outside meander bend	relatively disturbed by human activities	relatively unstable material at base of scarp (slope)	no horizontal toe at base of scarp (slope)	bare (plant cover gone)	high ratio of bank height to bankfull-flow height	low % of total bank height with roots	high near-shore stream velocities	prone to flooding; L = low H = high FP = floodplain
R-16	T2	middle	yes	yes			yes	yes	yes	LFP/HFP remnants
R-17		downstream	yes							LFP
R-18		downstream	yes	partly	partly					LFP/HFP
R-19				yes	yes					HFP remnant
R-20	T2		yes	yes	partly		yes	yes		
R-21			yes	yes	yes				--	HFP
R-22	T2		yes	yes	partly		yes	partly	yes	
R-23	T2	upstream	yes	yes	partly		yes	yes	--	HFP remnant
R-24	T3	middle	yes	yes	partly	one area	yes	yes	yes	some FP remnant
R-25	T2	downstream	yes	yes	partly		yes	yes	yes	some FP remnant
R-26	T2		yes	yes			yes	yes	yes	some FP remnant
R-27	T2		yes	yes			yes	partly	--	some FP remnant
R-28			yes	yes		in areas		yes		some FP remnant
R-29			yes	yes	partly					HFP

reach number (facing down-stream, "R" means right bank, "L" means left bank)	**terraces 2 and 3 (T1 and T2, both over 20 ft high)**	**position on outside meander bend**	**relatively disturbed by human activities**	**relatively unstable material at base of scarp (slope)**	**no horizontal toe at base of scarp (slope)**	**bare (plant cover gone)**	**high ratio of bank height to bankfull-flow height**	**low % of total bank height with roots**	**high near-shore stream velocities**	**prone to flooding; L = low H = high FP = flood-plain**
R-30			yes	yes		in areas		yes	yes	
R-31			yes		yes					HFP
R-32					yes					HFP
R-33	T3	middle		yes			yes	partly	yes	HFP remnant
R-34	T3	downstream		yes	yes		yes	yes		
R-35		downstream	yes	partly	partly			--		
L-1			yes							HFP
L-2	T2	upstream	yes				partly	partly		LFP/HFP remnants
L-3	T2	downstream	yes	yes			yes	yes		FP remnant
L-4			yes	yes	yes			yes	--	
L-5			yes	yes	partly				--	HFP
L-6	T2					yes	yes	yes	yes	
L-7			yes		partly					HFP
L-8	T2	middle	yes	yes	partly		yes	yes	--	HFP remnant
L-9	T2		yes		partly		yes	yes		FP remnant
L-10	T2		yes			partly	yes	yes		

reach number (facing downstream, "R" means right bank, "L" means left bank)	terraces 2 and 3 (T1 and T2, both over 20 ft high)	position on outside meander bend	relatively disturbed by human activities	relatively unstable material at base of scarp (slope)	no horizontal toe at base of scarp (slope)	bare (plant cover gone)	high ratio of bank height to bankfull-flow height	low % of total bank height with roots	high near-shore stream velocities	prone to flooding; L = low H = high FP = flood-plain
L-11	T2		yes			yes	yes	yes		
L-12			yes	yes		partly			yes	HFP
L-13			yes		partly	yes				HFP-fill
L-14			yes	yes	yes				--	T1/HFP
L-15		upstream	yes		partly				yes	HFP/LFP
L-16	T3	middle	yes	yes	partly		yes	yes	--	
L-17	T3	middle	yes	yes	yes	partly	yes	yes		
L-18		downstream	yes	yes	yes					HFP
L-19		downstream	yes	yes		partly				HFP
L-20	T2	downstream	yes	yes	--	mostly	yes	yes		
L-21	T3	downstream	yes	yes	yes	mostly	yes	yes		
L-22	T3	downstream		yes	yes	partly	yes	yes	--	
L-23	T3	downstream		yes	yes	partly	yes	yes	--	
L-24	T2	downstream	yes	yes	partly	mostly	yes	yes		
L-25			yes	yes	partly	mostly		yes		
L-26			yes		yes					HFP

V. SHARING AND PROTECTING THE KENAI RIVER

CHAPTER CONTENTS

A.	**Linked by the Kenai River**	**2**
B.	**Brainstorming for the future** ***(Programs to help landowners protect Kenai River resources)***	**3**
C.	**"Streamwatching"** ***(Citizens' programs to keep an eye on Kenai River resources)***	**12**

V. SHARING AND PROTECTING THE KENAI RIVER

A. LINKED BY THE KENAI RIVER

At the time this *Guide* is being written, there are over 4,000 platted parcels adjacent to the lower Kenai River. We estimate that within the Kenai River study corridor (which encompasses lands within 1/4 mile of the river on each side), there are three or four times as many lots: 12,000 to 16,000. A relatively small percentage of these lots are developed. Many more lots will be developed in the future, and additional large parcels will be subdivided.

The thousands of individuals, families, and organizations with land along the Kenai River represent a very diverse group of people. For one thing, they live in a huge variety of places: along the Kenai River; in Homer, Soldotna, Sterling, Kenai, and other Peninsula communities; in Anchorage, Fairbanks, and other towns across Alaska; and in cities scattered throughout the Lower 48 states. Some even live in other countries. For another thing, Kenai River landowners represent a huge variety of backgrounds and experiences, values and goals, ages and occupations. Some have barely seen their piece of Kenai River land and don't know much about it; others belong to families who've lived along the Kenai River for hundreds of years and have a deep knowledge of the river's places, seasons, and moods.

KENAI RIVER LANDOWNERS <u>AS A GROUP</u> WILL HELP SHAPE WHAT HAPPENS TO THE RIVER.

Whatever their differences, however, all Kenai River landowners are linked by one strong thread: the Kenai River. This link isn't just metaphorical, it's also a literal, physical reality: **what one Kenai River landowner does can affect landowners (and river users) up and down the river**. This is true whether effects are obvious (for example, cutting down mature trees along the riverbank) or invisible (allowing sewage or other contaminants to leak into the river). Rivers carry things and move them from one place to another. And rivers are travel routes along which people (and animals) move; and both of these facts mean that **rivers *connect*, linking what happens at one place to what happens upstream or down.**

What this means is that Kenai River landowners *as a group* will help shape what happens to the river. The "good deeds" of some aren't enough to protect the river's productivity if the "bad deeds" of others reduce water quality or destroy fish habitats. As described in Chapter III, the river is a *system*: its parts and processes intertwine. Landowners as a group are a huge part of this system; their cumulative actions can have dramatic effects on the river's parts and processes.

This, of course, means that, *as a group*, Kenai River landowners have the potential to shape the future of the river in significant beneficial ways. Many landowners already know this and have established organizations like the Kenai River Property Owners Association and the Kenai River Habitat Protection Association (both listed in Chapter VI) to help them accomplish positive goals. But what goals should these groups (or others concerned with the river) pursue?

Possibilities are as diverse as the landowners themselves. At this point in time, however, with the Kenai River still — to all appearances — in pretty good health, programs that encourage *prevention* make a lot of sense. The following sections discuss some positive, prevention-oriented programs underway in Alaska or other states. These may suggest directions worth pursuing on the Kenai River. At a minimum, these programs should help landowners brainstorm their own directions for the Kenai River's future.

B. BRAINSTORMING FOR THE FUTURE
(*Programs to help landowners protect Kenai River resources*)

If the Kenai River Study had had more time and money available, a valuable addition to its *Plan of Work* would have been to compile a catalogue of programs that could *help* private landowners take care of Kenai River resources. That didn't happen. But as it turns out, something very like that did happen in Oregon.

The University of Oregon's Community Planning Workshop helped the U. S. Forest Service compile an **inventory of incentive programs and policies available to river managers and private landowners along Wild and Scenic Rivers.** In other words, the Community Planning Workshop put together information on ways to *help* and *encourage* private landowners to take care of the rivers on which they live. This information was published in: *Promoting Voluntary Landowner Cooperation: Private Landowner Incentives on Wild and Scenic Rivers* (University of Oregon 1991). Because much of this information is relevant to the Kenai River, several discussions from the report are excerpted below. Tables 1 and 2 summarize some of this information, and are derived from the report. Table 3 lists selected incentive programs that are now applicable on the Kenai River or that could be models for future Kenai River programs. (Descriptions of most non-Alaskan programs are from *Promoting Voluntary Landowner Cooperation*.) Table 4 lists several programs that landowners themselves can implement if they want to help keep an eye on the health of Kenai River resources.

The following material is excerpted from: *Promoting Voluntary Landowner Cooperation: Private Landowner Incentives on Wild and Scenic Rivers* (University of Oregon 1991:pp 7-18).

Theory of Incentives as a public policy tool for voluntary landowner participation

Over time a variety of management strategies have evolved to encourage landowners to voluntarily participate in programs and policies that help protect and conserve natural resources... [T]hese environmental strategies can be grouped into four main types: **Information, Facilitation, Regulation, and Incentives.**

- *Information Strategies* are designed for use in situations where a lack of sufficient and/or accurate data is the main impediment to ecologically and socially desirable results[1].

- *Facilitation Strategies* encourage ecologically and socially desirable actions by removing barriers to and/or creating the infrastructure that enables such activities.

- *Regulatory Strategies* serve to coerce the adoption of desired courses of action by threatening punishment and sanctions which suppress undesired activity.

- *Incentive Strategies* come in two forms: Positive and Negative Incentives. Positive incentives use a variety of mechanisms and forms to attribute positive value to desired courses of action and behavior. Raising the positive value of an action tends to increase the attractiveness of engaging in such behavior for the target individuals or groups. Increased attractiveness may promote voluntary compliance, which may be more effective and generate less hostility than regulatory strategies...

1 Obviously, this *Landowner's Guide* illustrates application of an "information strategy." Once information is available, incentive strategies can be used to encourage people to use it.

Positive Incentives

Land Trusts

[A land trust is usually a private, non-profit entity that acquires and holds lands and/or conservation easements (see below) for the good of society and the ecosystem. Local and state agencies may also hold lands and/or conservation easements for the same purposes, and in that respect function like land trusts.] Land trusts have been used since the late nineteenth century to protect and conserve land threatened by urban sprawl. The major types of land trust include:

- Multi-resource
- Agricultural and Forest
- Community
- Riverbank Protection
- Scenic Area
- Historic Preservation

Many tax incentives also become available to landowners whose land becomes part of a land trust.

Conservation Easements

A conservation easement is a legal agreement made by a property owner and another party [such as a Land Trust] to protect a particular resource. Conservation easements are used to protect a piece of land or historic building from inappropriate development while allowing the property owner to retain private ownership. The property owner forgoes specific rights which are set forth in the easement. The conservation easement gives the easement holder the right to enforce the restrictions set forth in the easement. The easement holder must be a qualified conservation recipient, such as a land trust, historic preservation organization, or a public agency.

The easement restricts the property's use to the degree necessary to protect the significant resource. Restrictions can prohibit all development, or allow development compatible with the existing land use. Generally, the landowner is allowed to continue traditional uses of the land. Public apathy and opposition have occurred from misconceptions regarding benefits and impacts of the easements. Tax incentives such as reduced income taxes, estate taxes, and property taxes are commonly associated with Conservation Easements.

Cooperative Management

Cooperative Management of a resource involves the active and combined efforts to insure that each party's interests and actions are compatible and mutually reinforcing of each other. The developmental process is based on voluntary agreement by all parties. Many Coordinated Resource Management Plans (CRMP's) illustrate how agencies and communities can work together to develop and implement cooperative plans. The goals of all parties and the plan must be concise and simply understood.

Dispute mechanisms that allow parties to resolve conflicts in a positive manner are an integral element in the success of cooperative management. Monitoring and review processes should also be part of the program.

Financial Incentives

Loans, grants, and subsidies are direct financial incentives used to stimulate activities that conserve or protect a resource by lowering the cost of doing so. These financial incentives function best when conditionally linked to a desired change in behavior. Cash incentives provide those affected with a sense of empowerment and control over their own destiny. However, financial incentives should not create a dependency on the outside source of money. They require regulations, enforcement, monitoring and feedback to function effectively... The following are examples of currently used programs:

- Government Low Interest Loans
- Low Interest Loans to Contractors
- Home Improvement Loans Tied to Current Government Assisted Housing
- Low or Zero Interest Loans
- Deferred Payment Loans
- Graduated Payment Loans

Tax Incentives

Many different federal and state tax benefits can be used as positive incentives for environmental protection. All tax incentives aim to lower the costs of conservation to a particular target group, thus making it more attractive. The major types of tax incentives include:

- Property Tax Reductions
- Sales and Use Tax Exemptions

Table 1. Types of positive incentives available for environmental management (from University of Oregon 1991).

Incentive Model	Purpose	Target Group
Land Trusts	Private non-profit entities participate in land transactions to protect and preserve land-related resources.	Conservation organizations, concerned citizens, community leaders
Conservation easements	Restrict use of properties and/or enable others to use them for specific purposes.	Landowners, charitable organizations, Land Trusts
Cooperative Management	Public and private sectors jointly manage ecosystems or resources in compatible or mutually reinforcing ways.	Private property owners, public agencies and land managers
Loans, grants, and subsidies	Encourage protection of resources and ecosystems by lowering or perhaps eliminating costs of such protection.	Land Trusts, property owners, communities, local governments
Tax reductions	Adjustments, reductions, credits, and elimination of specific taxes to encourage conservation and protection of resources.	Taxpayers
Insurance rate reductions	Special rates encourage conservation and protection.	Property owners

- Adjusted Sales Taxes
- Income Tax Deductions
- Income Tax Credits
- Conservation Tax Rebate
- Investment Tax Credits
- Accelerated Depreciation
- Tax Incentives to Local Governments
- Progressive Taxes
- Multiple Tax Credits

Tax incentives generally require no new agency to administer the programs. No direct budget allocations are required beyond the estimation of revenue from taxes collected, but tax incentives represent a real cost to the government through reduced tax revenues. The interaction between state and federal taxes should also be considered...

Insurance

Government assistance in meeting landowner insurance requirements (i.e. flood insurance) helps overcome an obstacle in adoption of some types of conservation policies such as limiting development in flood plains. However, there is a need for administration of federal insurance programs. Administration can be performed by the Federal government, or through contract with a private organization. Help in meeting the high costs of insurance can be provided as an incentive to comply with regulations and policies.

The Community Planning Workshop also provided criteria for evaluating positive incentive programs. These are summarized in Table 2. The Workshop pointed out: "Evaluative criteria should include not only an assessment of whether or not the goals were achieved (e.g., were... rivers actually protected?), but should also answer the following questions: is the program fair to landowners? and is the implementation process feasible?" (University of Oregon 1991:16).

Table 3 lists some positive incentive programs that are applicable on the Kenai River or that could provide models for future Kenai River programs.

Table 2. Evaluation criteria essential for successful implementation of economic incentives (from University of Oregon 1991).

Criteria	Defining Characteristics
Ease of participation	Programs should use in-place and broad-based administrative systems.
Significant monetary incentives	Monetary incentives must be large enough to attract participants.
Extensive information diffusion	Programs should be well publicized through public informational campaigns utilizing all media.
Consultation and participation of industry and community leaders	This broadens participatory base and increases perceived acceptability and legitimacy of conservation programs.
Ease of enforcement	Enforcement of mandatory elements must not lead to excessively complex bureaucracies nor encourage avoidance.
High coverage/impact	Programs should have high participation rates from target groups, thus producing significant impacts.
Complementary mandatory element	This element establishes rules and parameters by which conduct can be regulated.
Follow up monitoring	Monitoring provides information on the usefulness and success of the program.
Quality control	Programs must incorporate techniques that will minimize problems associated with the quality of inputs into the program.

Table 3. Selected incentive programs available on the Kenai River or that could serve as models for future Kenai River programs. (Descriptions of programs not specific to the Kenai River are generally from University of Oregon 1991).

Clean Water Act (as amended in 1987) 319 Projects

Section 319 of the Clean Water Act provides for federal grants to states to help them implement programs to protect water quality from *nonpoint source pollution. Nonpoint source pollution* refers to wastes and pollutants that are spilled, leaked, leached, eroded, or dumped onto the ground or into waters, as opposed to wastes and pollutants discharged through a pipe under National Pollutant Discharge Elimination System (NPDES) Permits. Nonpoint source pollution is usually caused by resource-based industries, such as agriculture, mining, oil and gas, forestry, etc., or by urban development. Alaska's *Nonpoint Source Pollution Control Strategy* (DEC 1990) has been approved by the Environmental Protection Agency (EPA), making Alaska eligible for "319" implementation funds. 319 grants are obtained through annual work plans submitted to EPA, and must be matched by the State at a ratio of two non-federal dollars to three grant dollars (40% state cost share); or for groundwater projects, on an even dollar-for-dollar basis (50% state cost share).

In addition, the Alaska Department of Environmental Conservation administers an annual program that provides federal grant funding to cities and local groups for local water quality projects (205(j) funding for these projects ended in 1991; 604(b) funding continues). Projects may address water quality monitoring, stream cleanup, structural controls, public information and education, and related objectives. EPA 319 grants can provide additional funding for these local water quality projects.

Contact: Alaska Department of Environmental Conservation/Water Quality Management or Pollution Prevention Programs, P.O. Box O, Juneau, AK 99811
465-2653, 465-2671, or 789-6785

Coastal America Program

A Federal pogram to improve the coastal environment of the U. S. It allows state and local governments and organizations to identify local environmental needs and obtain Federal funds and technical help to meet those needs. Coastal America will not pay all the costs of a project, but it can combine with local money to make a project possible. It is intended to help with local coastal projects that would do one or more of the following:

a. Prevent habitat degradation or repair past habitat degradation.

b. Prevent nonpoint source pollution or repair past damage from nonpoint source pollution.

c. Prevent contamination of sediment material and repair damage by past contamination.

Contact: Coastal America, 722 Jackson Place, N. W., Washington, D.C. 20503
(202) 395-5750
or
U. S Army District, Alaska, ATTN: CENPA-EN-PL-ER, P. O. Box 898, Anchorage AK, 99506-0898

Conservation Easements

Land Trusts such as The Nature Conservancy acquire and manage lands and conservation easements (through outright purchase, donations, etc.) to protect rare species or communities or other resources of public significance.

Contact: The Nature Conservancy, 601 W. 5th Ave., Suite 550, Anchorage, AK 99501
276-3133

Kenai River Habitat Protection Association

An incentives program sponsored by Kenai River Sportfishing, Inc. to encourage Kenai River landowners to protect and/or enhance salmon habitat and to recognize those that do.

Contact: Ben Ellis, Kenai River Sportfishing, Inc., P. O. Box 1228, Soldotna, AK 99669
262-8588

King Salmon Fund

A fund established by the Kenai Peninsula Fishermen's Association to support habitat-related projects on the Kenai River.

Contact: Ken Tarbox, President, Board of Directors, King Salmon Fund, 34824 Kalifornsky Beach Rd., Suite E, Soldotna, AK 99669

Land and Water Conservation Fund (LWCF)

A fund created by the 1965 Land and Water Conservation Fund Act to assist state and federal agencies in meeting present and future outdoor recreation needs. LWCF grants are available through the Alaska Division of Parks and Outdoor Recreation for the acquisition and/or development of land to be used for outdoor recreation. Any land acquired or developed with these funds must be held in perpetuity for outdoor recreation or, with approval from the Division of Parks and Outdoor Recreation and the National Park Service, be replaced with land of equal or higher fair market value, recreation utility and location.

Contact: Division of Parks and Outdoor Recreation, Administrative Services Section, P. O. Box 107001, Anchorage, AK 99510-7001
762-2607 or 2608

National Estuary Program

A program to develop comprehensive Conservation and Management Plans for "designated" estuaries. (The process for designating estuaries occurs every few years.) Funds are available for resource management programs, including programs to protect and restore coastal resources in estuaries which have national significance and to reduce basin-wide point and non-point sources of pollution.

Contact: U.S. Environmental Protection Agency, Oceans and Coastal Protection Division, (Donna Nickerson) Washington, D.C. 20460
202-260-6467
or
U. S. Environmental Protection Agency, Region 10 (Jack Gakstatter) 1200 6th Ave.
Seattle, WA 98101
206-553-0966

Pollution Prevention Incentives for States

A program that supports innovative state and regional pollution prevention. Programs are designed to reduce pollutants across air, land, surface, and groundwaters; the prevention programs reflect comprehensive and coordinated planning and implementation. Examples include: demonstration projects, planning, recycling projects, curriculum development, educational projects, data collection and dissemination, and technical assistance.

Contact: U. S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, PM-222B, 401 M. St., S.W., Washington, D.C. 20460
202-245-4167 or 382-2237

REI Seed Grant Program

This program provides support (seed grants) to state and local conservation groups from the National Rivers Coalition to assist grassroots lobbying efforts that: (1) add rivers for study or designation in the National Wild and Scenic Rivers System or improves management of designated rivers, (2) improve state river programs through efforts on legislation, regulations and/or implementation of statewide river assessment, (3) promote passage of state or federal legislation that facilitates federal, state, or local river protection, and accomplishes other related goals.

Contact: National Rivers Coalition, 801 Pennsylvania Ave., S.E., Suite 400, Washington, D.C. 20003
202-547-6900

REI Environmental Committee Corporate Contribution Program

A program to improve the quality of life through environmental protection. Projects focus on protection and enhancement of natural resources needed for muscle-powered sports, including: preserving wildlands and open space and educating the public on conservation issues. REI provides up to $2,000 for group efforts.

Contact: Public Affairs Department, Recreational Equipment, Inc. (REI), P. O. Box 88126, Seattle, WA 98138
206-395-3780

Riparian Tax Incentive Program

An Oregon tax incentive program designed to encourage and reward protection of privately owned riparian habitat; a similar program might be applicable along the Kenai River. Landowners and the Oregon Department of Fish and Wildlife together formulate management plans for private riparian lands. The landowner agrees to manage riverbanks and protect natural values under approved management programs. Individuals can get an income tax deduction and property taxes may also be reduced.

Contact: Oregon Department of Fish and Wildlife, 506 S. W. Mill St., P. O. Box 59, Portland, OR 97207
503-229-5400, ext. 439

Rural Development Administration

A loan and grant program to provide basic human amenities, alleviate health hazards, and promote the orderly growth of rural areas by meeting the need for new and improved rural water and waste disposal facilities. (This program was formerly operated by the Farmers Home Administration (FmHA). Since the newly created RDA does not yet have its field structure in place, FmHA continues to administer the program.) Funds may be used for the installation, repair, improvement, or expansion of rural water facilities, including distribution lines, well pumping facilities, and related costs; as well as for installation, repair, improvement, or expansion of rural waste disposal facilities, including the collection and treatment of sanitary, storm, and solid wastes. Eligible entities include: municipalities, counties, and other political subdivisions of a state; associations, cooperatives, and corporations operated on a not-for-profit basis; and federally recognized Indian tribes. The service area must not include an area in a city or town having a population in excess of 10,000 inhabitants. This program is considered suitable for joint funding such as commercial/private lenders, Federal agencies, state and local governments.

Contact: Farmers Home Administration State Office, 634 S. Bailey, Suite 103, Palmer, AK 99645
745-2176

Sport Fish Partnership Program

A program administered by the Alaska Department of Fish and Game, Division of Sport Fish, to provide cost-share (up to 75 percent of cost) for development of angling opportunities accessible to the public. Funding comes from Federal Aid in Sport Fish Restoration and projects must be approved by the U. S. Fish and Wildlife Service.

Contact: Dave Nelson, Alaska Department of Fish and Game, Division of Sport Fish, 34828 Kalifornsky Beach Rd., Soldotna, AK 99669
262-9368

Stewardship Incentive Program (part of the "Forest Stewarship Act" of 1990)

A federal incentives program administered by the states. Cost-sharing is provided to private nonindustrial landowners for tree planting and improvement, windbreak establishment, soil and water protection, riparian and wetland protection, fish and wildlife enhancement, aesthetics, forest recreation, and other practices recommended in site-specific "Forest Stewardship Plans" developed with technical assistance from state foresters. To qualify, a landowner must (1) be a private forest landowner, and (2) own no more than 1,000 acres of eligible forest land (or 5,000 acres with a waiver from the State forester).

Contact: Ric Plate, Stewardship Forester, Alaska Department of Natural Resources, Division of Forestry, HC1 Box 107, Soldotna, AK 99603
262-4124

Wetlands Restoration Program

A program designed to restore or create wetlands on private lands. In addition to wetlands, projects benefitting migratory birds, endangered species, anadromous fish, and waterfowl may also qualify for funding. The program provides direct financial assistance, in addition to cost sharing agreements with other government agencies and landowners. Grants have traditionally ranged from $10,000 to $25,000, although larger amounts have been awarded.

Contact: U. S. Fish and Wildlife Service, Alaska Regional Office, 1011 E. Tudor Rd., Anchorage, AK 99503
786-3486

C. "STREAMWATCHING"
(Keeping an eye on the Kenai River)

If this *Guide* has given you the impression that the future of the Kenai River is in your hands, you're absolutely right. We hope that the background and "how-to" information in previous chapters will help you consider the river's future as you develop your Kenai River lands and enjoy what the river provides you and your family. In addition to the many "river-conscious" development alternatives we've already discussed, there's another way you can promote the river's healthy functioning: you can be a "streamwatcher" and help keep an eye on the river.

A "streamwatcher" is someone who is: (a) concerned about the condition of the Kenai River, (b) alert to any telltale signs that something might be wrong, particularly with water quality, and (c) willing to contact appropriate authorities so they can correct the problem.

There are a number of programs that can help citizens educate themselves so they can better monitor their local streams and rivers and become effective "streamwatchers." Some of these programs are listed in Table 4. In addition, Table 5 lists signs you can watch for when you're on the Kenai River. These signs indicate that something might be happening that could damage the river's health. Table 5 also tells you whom to contact if you see one of these signs. If you want more information about stream monitoring, the following references are very helpful:

Adopting a Stream, a Northwest Handbook (Yates 1988) and

The Monitor's Handbook (LaMotte Company Staff 1992).

Table 4. Citizens' programs to monitor and protect river health.

Adopt-a-Stream Program

A volunteer program to help citizens learn about and care for local streams. "Since every one of us lives in a watershed, each of us directly affects the health of a nearby creek. Everyone can help restore, protect, or enhance a stream at the local level... By monitoring streams that flow by our houses, farms, and schools, we can see what is happening to the entire watershed upland of us. And we can make sure that we ourselves are not degrading water for the people who live downstream" (Yates 1988:ix).

The five steps of stream adoption are: (1) investigate your stream (learn everything you can about it), (2) establish a streamkeeper group (share the process), (3) establish short- and long-term goals, (4) create an action plan, and (5) become a streamkeeper.

Contact: The Adopt-A-Stream Foundation, P. O. Box 5558, Everett, WA 98206
or
Alaska Department of Fish and Game, 34828 Kalifornsky Beach Rd., Soldotna, AK 99603
262-9368

Alaska Water Watch and Citizens for Clean Water

"Alaska Water Watch" is a program designed to promote citizen "stewardship" of aquatic resources, including water quality and quantity, habitat, and fish and water-dependent wildlife. The Alaska Department of Environmental Conservation participates in Alaska Water Watch through its "Citizens for Clean Water" volunteer program, which is designed to maintain or improve water quality through public participation and education.

Contact: Department of Environmental Conservation (Bob Krogseng or Scott Forgue),
35390 Kalifornsky Beach Rd., Suite 11, Soldotna, AK 99669
262-5210

Streamwalk Program

A self-directed citizens' monitoring program to assess the health of local streams.

Information and free copy of *Streamwalk Manual* available from:
U. S. Environmental Protection Agency, Region 10, (Susan Handley), 1200 6th Ave., Seattle, WA 98101
206-553-1287

Instream Flow Protection Program

Private individuals, organizations, and agencies can secure "instream flow water rights" from the Alaska Department of Natural Resources. Applications for instream flow water rights can be filed to protect one or more of the following uses: fish and wildlife migration and production; navigation (e.g., boating, rafting, kayaking); water quality and sanitary characteristics; and recreational activities, aesthetics, and parks. Applicants can request that a volume or depth of water be left in individual segments (reaches) of streams, rivers, or lakes for specificed times of the year. (Applications for instream flow water rights on two segments of the Kenai River are in the process of adjudication by the Department of Natural Resources.)

Contact: Statewide Instream Flow Coordinator (Christopher Estes), Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services Section, 333 Raspberry Rd., Anchorage, AK 99518-1599
267-2142
or
Chief of Water Rights Adjudication (Gary Prokosch), Alaska Department of Natural Resources, Pouch 10-7005, Anchorage, AK 99510
762-2571

Table 5. Signs of a situation that could potentially damage Kenai River resources; whom to contact if you see one of these signs.

Sign of problem	Contact (see Chapter VI for more information)
visual sign/smell of raw sewage	Alaska Department of Environmental Conservation
garbage or junk in river	Alaska Department of Environmental Conservation
sediment runoff into river	Alaska Department of Environmental Conservation
vehicles or equipment in river	Alaska Department of Environmental Conservation Alaska Department of Fish and Game
dredging or other alterations in river	Alaska Department of Fish and Game U. S. Army Corps of Engineers, Regulatory Branch
manure piles near waterways	Alaska Department of Environmental Conservation
sewer covers overflowing	Alaska Department of Environmental Conservation city Public Works Departments
discharge from a pipe that smells or looks like chemicals or petroleum	Alaska Department of Environmental Conservation
signs of hazardous material spill (e.g., oil sheen on water)	Alaska Department of Environmental Conservation
foam on water	Alaska Department of Environmental Conservation
clogged storm drains	Alaska Department of Environmental Conservation city Public Works Departments
perched or eroded culverts	Alaska Department of Environmental Conservation Alaska Department of Fish and Game city or borough Public Works Departments or Alaska Department of Transportation and Public Facilities
material dumped in wetlands	U.S. Army Corps of Engineers, Regulatory Branch

VI. GETTING MORE HELP — SOURCES OF HELP AND INFORMATION

CHAPTER CONTENTS

A.	**How to use this Chapter**	**2**
B.	**Sources of help by category**	**2**
C.	**Directory of agencies, organizations, and businesses**	**8**

VI. GETTING MORE HELP -- SOURCES OF HELP AND INFORMATION

A. HOW TO USE THIS CHAPTER

This chapter indicates where to go for additional help if you'd like more information than you find in this *Guide* (or if you'd like help understanding anything discussed in this *Guide*). The chapter is divided into two parts. **In Section B, information is listed alphabetically by category**, for example: "forestry assistance," "permitting," "planning assistance," "water quality testing," etc. Under each topic, you'll find names of agencies, organizations, commercial businesses, or other entities that can provide information or help on that topic. **Once you've decided who to contact, refer to Section C. There you'll find all agencies, organizations, commercial businesses, etc. listed alphabetically with their addresses and phone numbers.** (Go straight to Section C if you just need the address or phone number of an agency referenced elsewhere in this *Guide*.)

These lists are by no means all-inclusive, but they should get you started in the right direction. As you come across additional sources of help and information, we suggest you record them in the spaces provided at the end of each section.

Inclusion in these lists, or absence from them, is not intended to imply any endorsement or lack of endorsement by the Soil Conservation Service or any other participant in the Kenai River study. Businesses included under specific topics were identified by looking in the Kenai Peninsula Yellow Pages. All businesses listed under relevant topics in the 1992 Peninsula Directory Yellow Pages were included here. Anchorage businesses listed in the Anchorage Yellow Pages were also included if no local Peninsula businesses were found under the same category in the Peninsula Directory. Businesses not listed in the Yellow Pages were included if made known to us by other agencies or landowners.

B. SOURCES OF HELP BY CATEGORY

(Look in Section "C" for phone numbers and addresses of listed agencies, organizations, etc.)

Aerial photographs
- Aeromap US, Inc.
- U. S. Geological Survey, Earth Science Information Center — Public Inquiry

Archaeological sites (where to report sites)
- Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation, Office of History and Archeology

Archaeology information
- Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation, Office of History and Archeology
- University of Alaska, Kenai Peninsula College, Anthropology Department

Bioengineering contractors
- Interfluve, Inc.
- Robbin B. Sotir and Associates
- Wildland Hydrology Consultants

Bioengineering information
- Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation, Kenai Area Office

City of Soldotna (information about their bioengineering projects)
Interfluve
Plant Materials Center
Robbin B. Sotir and Associates
U. S. Soil Conservation Service
Wildland Hydrology Consultants (Dave Rosgen)

Citizens' water quality monitoring programs
see **Monitoring programs carried out by citizens** (also Chapter V, Table 4)

Coastal Zone Management/Coastal Projects Consistency Review
Alaska Division of Governmental Coordination (DGC)
Kenai Peninsula Borough

Climate data
National Weather Service (U. S. Department of Commerce)
State Climatologist, University of Alaska
U. S. Soil Conservation Service (snow survey data)

Conservation easements
Kachemak Heritage Land Trust
Nature Conservancy

Contractors who have completed multiple riverbank projects along the Kenai River
D and L Construction Co., Inc.
Merkes Builders, Unlimited
Specialty Excavating
Ward Landscaping

Emergency/Natural disasters information and coordination
Alaska Department of Military and Veterans Affairs, Division of Emergency Services
Kenai Peninsula Borough, Office of Emergency Management

Engineers, Civil-Kenai/Soldotna area
McLane and Associates
Nelson, William J. and Associates
Robson Engineering (Walter)
Rozak Engineering
Tauriainen, Mike, PE Consulting Engineers
Wince-Corthell-Bryson

Engineers, Civil Sanitary-Kenai/Soldotna area
McLane and Associates
Nelson, William J. and Associates
Robson Engineering (Walter)
Rozak Engineering
Tauriainen, Mike, PE Consulting Engineers
Wince-Corthell-Bryson

Engineers, Consulting-Kenai/Soldotna area
Bonebrake Engineering
McLane and Associates
Petro-CAD
Robson Engineering (Walter)
Rozak Engineering
Tauriainen, Mike, PE Consulting Engineers
Wince-Corthell-Bryson
see also: "Engineers-Environmental" in the Anchorage Yellow Pages

Erosion control
D and L Construction Co., Inc.
Merkes Builders, Unlimited
Soil Stabilization Products Co.
Specialty Excavating
U. S. Soil Conservation Service
Ward Landscaping

Erosion control matting and geotextiles — vendors
Akzo Industrial Systems Co.
American Excelsior Co. (Richard Guzy)
Phillips Fiber Corp.
Soil Stabilization Products
Ward Landscaping

Excelsior blankets
see: **Erosion control matting-vendors**

Fertilizer recommendations
Cooperative Extension Service
Greenhouses/Nurseries
Plant Materials Center
U. S. Soil Conservation Service
Landscape contractors

Fish habitat information
Alaska Department of Fish and Game, Sport Fish Division (Soldotna Office); Sport Fish Division, Research and Technical Services Section
U. S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center
U. S. Fish and Wildlife Service, Kenai Fishery Assistance Office

Fish population information

Alaska Department of Fish and Game, Sport Fish Division (Soldotna Office)
U. S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center
U. S. Fish and Wildlife Service, Kenai Fishery Assistance Office

Floating docks

Acme Park and Playground Co.
Alaska Department of Fish and Game, Habitat Division (permits for floating docks)
Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation (floating dock guidelines for the Kenai River)
Superdeck Marketing

Flood height information

see: **Riverflow information**

Flood information

Alaska Department of Community and Regional Affairs, Municipal and Regional Assistance Division
Kenai Peninsula Borough, Planning Department
U. S. Army Corps of Engineers
U. S. Geological Survey, Water Resources Division

Flood insurance information

Alaska Department of Community and Regional Affairs, Municipal and Regional Assistance
Kenai Peninsula Borough, Planning Department

Floodplain determination/maps

Kenai Peninsula Borough, Planning Department
U. S. Army Corps of Engineers

Floodplain permitting

Kenai Peninsula Borough, Planning Department

Flood preparedness information

Alaska Department of Military and Veterans Affairs, Division of Emergency Services
Kenai Peninsula Borough, Office of Emergency Management

Forestry assistance

Alaska Department of Natural Resources, Division of Forestry
Cooperative Extension Service, Forester
U. S. Forest Service, State and Private Forestry
U. S. Soil Conservation Service

Funny River Rd. Bridge information

Alaska Department of Transportation and Public Facilities, Division of Preliminary Design and Environmental

Geotextiles

see: **Erosion control matting and geotextiles-vendors**

Grasses

see: **Plant materials**

Greenhouses/nurseries

see **Greenhouses/nurseries** in Section B

Groundwater information

Alaska Department of Environmental Conservation
Kenai Peninsula Groundwater Task Force
U. S. Environmental Protection Agency

Group planning (assistance to groups)

U. S. Soil Conservation Service
Kenai Soil and Water Conservation District

Hazardous waste management

Alaska Department of Environmental Conservation
U. S Environmental Protection Agency

Historic sites information

Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation, Office of History and Archeology

Hydrology information

Alaska Department of Natural Resources, Division of Water or Alaska Hydrologic Survey
U. S. Geological Survey, Water Resources Division

Hydraulic engineers
CH2M Hill, Inc.
Interfluve, Inc.
U. S. Soil Conservation Service
Wildland Hydrology Consultants (Dave Rosgen)
see also: "Engineers-Environmental" in the Anchorage Yellow Pages

Instream flow water rights
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
Alaska Department of Natural Resources, Division of Water
(for recreation: National Park Service, Outdoor Recreational Planning)

Kenai River hydrology
see **Hydrology information**

Landowner's Association
Kenai River Property Owner's Association

Landscape contractors
Booth's Landscaping
Ward Landscaping
Woodland Landscaping

Landscape plant materials
see **Plant materials — sources**

Land use planning assistance
see **Planning assistance**

Land use regulations
see also: **Permitting and Local governments**
Alaska Department of Fish and Game (fish habitat)
Alaska Division of Governmental Coordination (coastal zone management)
Alaska Department of Environmental Conservation (water quality)
City of Soldotna (Kenai River Overlay District)
Kenai Peninsula Borough, Planning Department (floodplains)
U. S. Army Corps of Engineers (wetlands, navigable rivers)
U. S. Environmental Protection Agency (water quality, waste management)
U. S. Fish and Wildlife Service (on Kenai National Wildlife Refuge)

Local governments
City of Kenai
City of Soldotna
Kenai Peninsula Borough
see also: Chambers of Commerce

Maps
Commercial book, map, or outdoor equipment stores
Kenai Peninsula Borough, Geographic Information System (GIS)
U. S. Fish and Wildlife Service, Kenai National Wildlife Refuge, Visitor's Information Center
U. S. Geological Survey, Earth Science Information Center — Public Inquiry
U. S. Soil Conservation Service (soils maps)

Monitoring programs carried out by citizens
Adopt-A-Stream
Alaska Water Watch (Citizens for Clean Water Program)
LaMotte Co. (*The Monitor's Handbook*)
Streamwalk
(see Chapter V, Table 4 for contacts)

Mulch matting
see **Erosion control matting-vendors**

Native organizations
Cook Inlet Region, Inc.
Kenai Native Association
Kenaitze Indian Tribe
Salamatof Native Association

Permitting

Actions that affect navigability of rivers:
U. S. Army Corps of Engineers

Activities in the Coastal Zone:
Kenai Peninsula Borough, Planning Department
Alaska Division of Governmental Coordination

General assistance related to the Kenai River:
Alaska Division of Parks and Outdoor Recreation
Permit Information Referral Center
Alaska Division of Governmental Coordination

Habitat: see Riverbank and instream activities

Hazardous waste management:
- Alaska Department of Environmental Conservation
- U. S. Environmental Protection Agency

Floodplain developments
- Kenai Peninsula Borough, Planning Department

Riverbank and instream activities (actions that affect the river below "ordinary high water" or fish habitats):
- Alaska Department of Fish and Game, Habitat Division
- Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation (information about permitting and permitted activities)

Water quality:
- Alaska Department of Environmental Conservation
- U. S. Environmental Protection Agency

Wetlands:
- U. S. Army Corps of Engineers, Regulatory Branch

Photographs
- see **Aerial Photographs**

Planning assistance
- Environmental Engineering firms (see **Engineers-Kenai/Soldotna area)**
- Kenai Soil and Water Conservation District
- U. S. Soil Conservation Service
- Cooperative Extension Service
- see also: specific kinds of assistance (e.g., forestry, water quality, etc.)

Plant community data
- Environmental Engineering firms (see **Engineers-Kenai/Soldotna area)**
- U. S. Forest Service
- U. S. Soil Conservation Service

Plant materials — assistance with handling and care
- Alaska Department of Natural Resources, Division of Forestry (trees)
- Greenhouses/Nurseries
- Landscape contractors
- Plant Materials Center
- U. S. Forest Service, State and Private Forestry (trees)
- U. S. Soil Conservation Service

Plant materials — sources
- Alaska Department of Natural Resources Division of Forestry, Forest Regeneration Center and Soldotna Office
- Alaska Department of Transportation and Public Facilities, Highway Maintenance (to request permission to collect plants in state road rights-of-way)
- Greenhouses/Nurseries
- also contact the Plant Materials Center for information on other possible sources

Property owner's Association
- Kenai River Property Owner's Association

Rainfall data
- see **Climate data**

Riverflow information
- U. S. Geological Survey, Water Resources Division

River monitoring programs
- see: **Monitoring programs carried out by citizens**

Sawmills and sawmill operators-Kenai/Soldotna area (from Alaska Department of Natural Resources, Division of Forestry, Soldotna Office)
- Burt, Al
- Clucas, Robert
- Crescent Timber Co.
- D and L Construction
- Habighorst Lumber
- Hakala, Mike
- Mahan, Alfred "Bud"
- Paymont, Ted
- Spruce Works (Gale Horgenson operator)

Sediment control assistance
- U. S. Soil Conservation Service

Septic systems assistance
- Alaska Department of Environmental Conservation
- Septic system installers (certified)

Septic systems design
see: **Engineers, Civil Sanitary-Kenai/Soldotna area**

Septic systems installers
Septic systems installers (certified)

Silviculture
see: **Forestry assistance**

Site planning assistance
see: specific topics, for example: "soils," "plant communities," "climate data," etc.

Snow data
see: **Climate data**

Soils information
Environmental Engineering firms (see **Engineers-Kenai/Soldotna area**)
U. S. Soil Conservation Service

Soils testing
Cooperative Extension Service (soil fertility testing)
Environmental Engineering firms (see **Engineers-Kenai/Soldotna area**)

Spruce bark beetle prevention
Alaska Department of Natural Resources, Division of Forestry
U. S. Forest Service, State and Private Forestry

Stage (water level) information
see: **Riverflow information**

Surveyors-Kenai/Soldotna
Economy Surveys
Integrity Surveys
Johnson Surveying
McLane and Associates
Swan Surveying
Whitford Surveying

Walkways (prefab and/or portable)
Portapath, sold by Teletek Industries, Inc. and Mountain Green Marketing
II Plus Grassroad Pavers, sold by Bartron Corporation

Waste management
Alaska Department of Environmental Conservation
U. S. Environmental Protection Agency
U. S. Soil Conservation Service
see also: **Septic systems assistance**

Water quality information
Alaska Department of Environmental Conservation
Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division (Kenai River Water Quality Investigation)
Kenai Peninsula Groundwater Task Force
U. S. Environmental Protection Agency

Water quality monitoring
see: **Monitoring programs carried out by citizens**

Water quality testing
Northern Test Lab
Alaska Department of Environmental Conservation

Water rights
Alaska Department of Natural Resources Division of Water

Wetlands information
U. S. Army Corps of Engineers
U. S. Fish and Wildlife Service, Alaska Regional Office
U. S. Soil Conservation Service

Wetlands permitting
U. S. Army Corps of Engineers
U. S. Fish and Wildlife Service, Alaska Regional Office
see also: **Permitting**

Wildlife information
Alaska Department of Fish and Game, Division of Wildlife Conservation
U. S. Fish and Wildlife Service, Alaska Fish and Wildlife Research Center and Kenai National Wildlife Refuge Office
U. S. Soil Conservation Service

Windbreak assistance
Landscape contractors
Plant Materials Center
U. S. Soil Conservation Service

Woodland management
see: Forestry assistance

C. DIRECTORY OF AGENCIES, ORGANIZATIONS, AND BUSINESSES

Acme Park and Playground Co.
10360 Nigh Rd.
Anchorage, AK 99502
522-1155

Aeromap US, Inc.
2014 Merrill Field Dr.
Anchorage, AK 99501
272-4495

Akzo Industrial Systems Company
One North Pack Square
P. O. Box 7249
Asheville NC 28802
704-258-5050

Alaska Department of Community and Regional Affairs, Municipal and Regional Assistance Division
333 W. 4th Ave., Suite 220
Anchorage, AK 99501-2341
269-4500

Alaska Department of Environmental Conservation (DEC)
35390 Kalifornsky Beach Rd., Suite 11
Soldotna, AK 99669
262-5210

Alaska Department of Fish and Game (ADF&G)

Anchorage Office (all Divisions)
333 Raspberry Rd.
Anchorage, AK 99518-1599
344-0541

Habitat Permits (in Anchorage Office)
267-2346 or 267-2284

Soldotna Office (all Divisions)
34828 Kalifornsky Beach Rd.
Soldotna, AK 99669
262-9368

Fisheries Rehabilitation, Enhancement, and Development Division (FRED)
P. O. Box 25526
Juneau, AK 99802-5526
465-4160

Alaska Department of Military and Veterans Affairs,
Division of Emergency Services
P.O. Box 5750
Fort Richardson, AK 99505-5750
1-800-478-2337

Alaska Department of Natural Resources (DNR)

Division of Agriculture,
Plant Materials Center (PMC)
see: Plant Materials Center

Division of Forestry,
Alaska Forest Regeneration Center
(Forest Nursery)
HC 85 Box 9001
Highland Rd.
Eagle River, AK 99577
694-5880

Area Forester and
Stewardship Forester
Soldotna Office
HC 1 Box 107
Soldotna, AK 99669
262-4124

Division of Lands
3601 C. St.
Anchorage, AK 99508
762-2692

Division of Parks and Outdoor Recreation (DPOR)
Kenai Area Office
P.O. Box 1247
Soldotna, AK 99669
(35850 Lou Morgan Rd., Sterling)
262-5581

Office of History and Archeology
P.O. Box 107001
Anchorage, AK 99510-7001
762-2622

Division of Water
3601 C. St.
Anchorage, AK 99508
762-2145

Division of Water and Hydrologic Surveys
P. O. Box 77-2116
Eagle River, AK 99577
696-0070

Alaska Department of Transportation and Public Facilities

Division of Preliminary Design and Environmental
4111 Aviation Ave.
P. O. Box 196900
Anchorage, AK 99519-6900
266-1508

Highway Maintenance Soldotna/Kenai
44109 Sterling Highway, Suite D
Soldotna, AK 99669
262-4413

Alaska Division of Governmental Coordination (DGC) (in the Office of the Governor)
3601 C. St., Suite 370
Anchorage, AK 99503-2798
561-6131

Alaska Forest Regeneration Center (see Alaska Department of Natural Resources, Division of Forestry)

Alaska State Government Information
561-4226

Alaska Water Watch
contact Alaska Department of Environmental Conservation, which participates in Alaska Water Watch through its "Citizens for Clean Water" program

American Excelsior Co. (Richard Guzy)
3807 Lunar Drive
Anchorage, AK 99504
333-7419

Bartron Corporation
29911 Aventura, Suite D
Rancho Santa Margarita, CA 92688
714-589-7763

Bonebrake Engineering
P. O. Box 2497
Soldotna, AK 99669
262-1671

Burt, Al (David)
P. O. Box
Sterling, AK 99672
262-8554

Chambers of Commerce

Funny River
HC 1 Box 1478
Soldotna, AK 99669
262-1871

Kenai
402 Overland
Kenai, AK 99611
283-7989

Soldotna
Sterling Hwy.
Soldotna, AK 99699
262-9814 or 262-1337

City of Kenai
210 Fidalgo
Kenai, AK 99611
283-7530

City of Soldotna
177 N. Birch
Soldotna, AK 99669
262-9107

CH2M Hill, Inc.
2550 Denali
Anchorage, AK
278-2551

Clucas, Robert
HC 2 Box 900
Clam Gulch AK 99568
567-3359

Cook Inlet Aquaculture Association (CIAA)
HC 2 Box 849
Soldotna, AK 99669
283-5761

Cook Inlet Region, Inc. (CIRI), Lands Office
P. O. Box 93330
Anchorage, AK 99509-3330
(2525 C. St.)
274-8638

Cooperative Extension Service (CES)
34820 College Dr.
Soldotna, AK 99669
262-5824 or
toll free, 1-800-478-5824

Corps of Engineers (COE)
see: U. S. Army Corps of Engineers

Crescent Timber Co. (Ed Ellis, owner)
Box 824
Cooper Landing, AK 99572
595-1288

D and L Construction Co., Inc. (Larry Smith)
Box 680
Cooper Landing, AK 99572
595-1278
35348 Kalifornsky Beach Rd.
Soldotna, AK 99669
262-6160

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

Economy Surveys (Terry Eastham)
P. O. Box 289
Soldotna, AK 99669
262-1951

Greenhouses/Nurseries (Kenai and Soldotna area)

Kenai River Nursery
47705 Kalifornsky Beach Rd.
Kenai, AK 99611
283-7843

Nu-State Nursery and Flower Shop
202 N. Forest Dr.
Kenai, AK 99611
283-7742

Ridgeway Farms (Abby Ala)
Box 1863
Soldotna AK, 99669
262-4616

Sterling Greenhouse
Mi 81 Sterling Hwy.
Sterling, AK 99672
262-3845

Trinity Greenhouse
P. O. Box 882
Soldotna, AK 99669
(Milepost 18 1/2 Kalifornsky Beach Rd.)
262-9242

Habighorst Lumber (Roger Habighorst)
SR 1 Box 3929
Sterling, AK 99672
262-5482 (Roger)
262-9232 (Mark)

Hakala, Mike
317 Diane Lane
Soldotna, AK 99669
262-4784

Integrity Surveys
Mile 104.5 Sterling Highway
Kasilof, AK
262-9461

Interfluve, Inc.
P. O. Box 773
Hood River, OR 97031
503-478-3035

Johnson Surveying
Mile 1.2 S. Cohoe Loop Rd.
P. O. Box 27
Clam Gulch, AK 99568
262-5772

Kachemak Heritage Land Trust
P. O. Box 2400
Homer, AK 99603
235-5263

Kenai National Wildlife Refuge (KNWR)
see: U. S. Fish and Wildlife Service, Kenai National Wildllife Refuge

Kenai Native Association
215 Fidalgo
Kenai, AK 99611
283-4851

Kenai Peninsula Borough (KPB)
144 N. Binkley
Soldotna, AK 99669
262-4441 or
toll free, 1-800-478-4441

Kenai Peninsula Groundwater Task Force
contact: Mike Swan
P. O. Box 987
Soldotna, AK 99669
262-1014

Kenai River Habitat Protection Association
P. O. Box 1228
Soldotna, AK 99669
262-8588

Kenai River Property Owner's Association
P. O. Box 3070
Soldotna, AK 99669

Kenai River Sportfishing, Inc.
P. O. Box 1228
Soldotna, AK 99669
262-8588

Kenai Soil and Water Conservation District (KSWCD)
Mike Swan, Chairman
Box 987
Soldotna, AK 99669
262-1014

Kenaitze Indian Tribe
P. O. Box 988
Kenai, AK 99611

Landscape contractors

Booth's Landscaping
Mi. 4.2 Kenai Spur Hwy.
Soldotna, AK 99669
283-4302

Ward Landscaping
P. O. Box 290
Soldotna, AK 99669
262-5135

Woodland Landscaping
HC 3 Box 903X
Soldotna, AK 99669
262-6091

McLane and Associates
Box 468
Soldotna, AK 99669
283-4218

Merkes Builders, Unlimited
Box 404
Soldotna, AK 99669
262-6031

Mountain Green Marketing (Gary Holcomb)
1621 196th St., S.E.
Bothell, WA 98012
206-485-3585

National Weather Service (U. S. Department of Commerce)
see also: State Climatologist

long-term data:
Data Acquisition Office
222 W. 7th Ave. #23
Anchorage, AK 99513
271-5116

recent weather:
Weather Service Forecast Office
(same address)
271-5105

Native Organizations
see: Cook Inlet Region, Inc.
Kenai Native Association
Kenaitze Indian Tribe
Salamatof Native Association

Nature Conservancy (The)
601 W. 5th Ave., Suite 550
Anchorage, AK 99501
276-3133

Northern Test Lab
35186 Kenai Spur Hwy.
Soldotna, AK 99699
262-4624

Nurseries/Greenhouses
see: Greenhouses/Nurseries

Paymont, Ted
Nikiski
776-5435

Permit Information Referral Center
3601 C. St.
Anchorage, AK 99508
563-6529

Petro-CAD
2730 Watergate Way
Kenai, AK 99611
283-6010

Phillips Fiber Corp.

Alex Custin (distributor)
23032 77th Ave., S.E.
Woodinville, WA 98072
206-486-6432

Engineered Geotextiles
1900 Point West Way, Suite 261
Sacramento, CA 95815
916-224-3151 or
1-800-437-6600

Plant Materials Center (PMC)
HC 02 Box 7440
Palmer, AK 99645
745-4469

Robbin B. Sotir and Associates
434 Villa Rica Rd.
Marietta, GA 30064
(404) 424-0719

Robson Engineering (Walter)
P. O. Box 1791
Soldotna AK 99669
262-3178

Rosgen (Dave)
1 Stevens Lake Rd.
Pagosa Springs, CO 81147
303-731-4424

Rozak Engineering
P. O. Box 350
Kenai, AK 99611
283-5640

Salamatof Native Association
P. O. Box 2682
Kenai, AK 99611
283-7864

Septic System Installers (Certified)
Request list from Alaska Department of Environmental Conservation

Soil Conservation Service (SCS)
see: U. S. Soil Conservation Service

Soil Stabilization Products Co.
P. O. Box 2779
Merced, CA 95344
209-383-3296

Specialty Excavating
Box 365
Soldotna, AK 99669
262-5175

Spruce Works (Gale Jorgenson)
Box 8038
Nikiski, AK 99635
776-3436

State Climatologist
University of Alaska, Environment and Natural Resource Institute, Climate Center
707 A. St.
Anchorage, AK 99501
257-2737 or 279-4523

Superdeck Marketing (floating docks and walkways)
7753 Beech St., N. E.
Minneapolis, MN 55432
612-571-2247

Swan Surveying (Mike Swan)
P. O. Box 987
Soldotna, AK 99669
262-1014

Teletek Industries, Inc.
400 Madison Ave., Suite 1011
New York, NY 10017

U. S. Army Corps of Engineers (COE), Alaska District, Regulatory Branch
P. O. Box 898
Anchorage, AK 99506-0898
753-2712
or toll free, 1-800-478-2712

U. S. Environmental Protection Agency (EPA), Region 10 (includes Alaska)
Public Information
Mail Stop S.O. 143
1200 6th Ave.
Seattle, WA 98101
1-800-424-4372

U. S. Fish and Wildlife Service (USFWS)

Alaska Fish and Wildlife Research Center (Alaska Regional Office)
1011 E. Tudor Rd.
Anchorage, AK 99503
786-3486

Ecological Services
605 W. 4th Ave., Rm. G62
Anchorage, AK 99501
271-2797

Kenai Fishery Assistance Office
P. O. Box 1670
Kenai, AK 99611
262-9863

Kenai National Wildlife Refuge (KNWR)
P. O. Box 2139
Soldotna, AK 99669
(2139 Ski Hill Dr.)
262-7021

U. S. Forest Service (USFS)
State and Private Forestry
201 E. 9th Ave.
Anchorage, AK 99501
271-2571

U. S. Geological Survey (USGS)
Earth Science Information Center — Public Inquiries Office
4230 University Dr.
Anchorage, AK 99508-4664
786-7011

Water Resources Division (WRD)
1209 Orca St.
Anchorage, AK 99501
786-7100

U. S. Soil Conservation Service (SCS)

Anchorage State Office
949 E. 36th, Suite 400
Anchorage, AK 99508-4362
271-2424

Homer Field Office
Box 400
Homer, AK 99603
235-8177

University of Alaska, Cooperative Extension Service

see: Cooperative Extension Service

Ward Landscaping

P. O. Box 290
Soldotna, AK 99669
262-5135

Whitford Surveying

1902 Wyatt Way
Kenai, AK 99611
283-4928

Wildland Hydrology Consultants (Dave Rosgen)

1 Stevens Lake Rd.
Pagosa Springs, CO 81147
303-731-4424

Wince-Corthell-Bryson

609 Marine
Kenai, AK 99611
283-4672

VII. MAPS OF THE KENAI RIVER STUDY CORRIDOR

CHAPTER CONTENTS

A.	**Before using maps...** *(What is map scale? Why is it so important?)*	p. 2
B.	**Tables related to lower Kenai River maps**	
	Soil connotative legend	Table 1
	Names of plants identified during mapping of plant communities along the lower Kenai River (common and scientific names)	
	mosses	Table 2a
	lichens	Table 2b
	forbs	Table 2c
	grasses	Table 2d
	shrubs	Table 2e
	trees	Table 2f
	Overstory ("land cover") map codes used along the lower Kenai River	Table 3
	Mapping codes for understory plant communities	Table 4
	Suitability interpretations for overstory plant communities; overstory communities were interpreted in terms of: spruce beetle hazard moose habitat goshawk habitat willow abundance cottonwood abundance wood volume	Table 5
	Suitability interpretations for understory plant communities; understory communities were interpreted in terms of: wild berry abundance willow abundance cottonwood abundance	Table 6
C.	**Maps of soils along the lower Kenai River** **Maps of plant communities along the lower Kenai River** Index map Soil maps Plant community maps	

VII. MAPS OF THE KENAI RIVER STUDY CORRIDOR

A. BEFORE USING MAPS...

(What is map scale? Why is it so important?)

(Before reading this section, you might want to review Using soils information on your land, Chapter IV, Section B.)

Maps (and aerial photographs from which maps are often made) generally portray 3-dimensional reality on a 2-dimensional (flat) surface from a bird's eye view. Map or photo *scale* indicates how much smaller features are on the map or photograph than they are in reality. A map showing features "life size," for example, has a scale of 1:1 (read "1 to 1"). With a 1:1 scale, mapped features are the same size as the real features they represent, so 1 inch (or foot or cm or whatever) on the map equals 1 inch (or foot or cm or whatever) on the ground. If you mapped a room that was 12 ft long and 12 ft wide at a 1:1 scale, your map would also be 12 ft x 12 ft in size.

Obviously maps are rarely "life size" — some shrinking or *reduction* of reality is usually necessary. If you map a 12 ft x 12 ft room on a 1 ft x 1 ft sheet of paper, 1 ft of distance on your map equals 12 ft of distance in the room (on the ground), so your map scale equals 1:12. Mapped distances are, therefore, 1/12th as long as real distances. Note however that we're talking about **linear** distance. What does this 1/12th reduction in distance do to **area**? You've taken 144 square ft of real area in your room (12 ft x 12 ft equals 144 square ft) and reduced it to 1 square foot of area on your 1 ft x 1 ft map. In other words, the relationship of mapped area to real area is 1:144. This means that your map **area** is now 1/144th the size of the real area even though your map **distances** are 1/12th the length of real distances. Your bed on the map would be only 1/144th the size of your real bed, even though it would be 1/12th as long and 1/12th as wide. Figure 1 illustrates these relationships with a compass "mapped" at 1:1 scale ("life size") and then at a number of smaller scales.

These relationships mean that:

> as a map reduces **distance** by some amount (by 12 in our example), it reduces **area** by that same amount *squared* (multiplied by itself; 12 x 12, or 144 in our example).

Therefore, **changing map scale affects area much more than it affects linear distance.**

Let's look at why this is critical to understanding and using the soil and plant community maps provided in this *Guide*.

The maps made by the Soil Conservation Service along the Kenai River were compiled on aerial photographs printed at a scale of 1:4800 (see back cover for an example of the photography used). This means that 1 inch (or foot or cm or whatever) on the photo equals 4800 inches (or ft or cm or whatever) on the ground[1]. Representing 4800 inches of real distance (or 400 ft) in 1 inch of photo distance means that the photos show a lot less detail than really exists on the ground. (Note: In order to save space, computer-generated **digitized maps**

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1 Sometimes people mix units of measurement when they tell you the photo or map scale — they'll say, "this photo has a scale of 1 to 400," when they mean, "this photo has a scale in which 1 *inch* on the photo equals 400 *feet* on the ground." If you want to express scale accurately, you can't mix units of measurement like inches and feet. Since 400 ft equals 4800 inches, the photo actually has a scale of 1:4800.

included in this chapter are printed at a scale of 1:8400. That means, 1 inch equals 8400 inches, or 700 ft; and 7 1/2 inches equals about 1 mile. Since *photographs* used to make these *digitized maps* have a scale of 1:4800, the maps you see here are only about half the size of the actual photographs (about 57% of photo size, to be more precise). In the "Technical Report" for the Kenai River Study, computer-generated maps will be printed at the actual photo scale, namely, at 1:4800, so the information will be somewhat larger and easier to read.)

How much "life-size" detail can you see on a 1:4800 photo? You can get a sense of how much (or how little) when you realize that the **area** covered by a feature in the photo (say, a house) is 1/4800 x 1/4800, or 1/23,040,000th, the size of the actual feature on the ground! In other words, aerial photographs like those used for this study inevitably leave out a lot of detail.

IN THE KENAI RIVER STUDY, MAPS WERE MADE TO HELP LANDOWNERS UNDERSTAND: (1) WHAT AREAS ARE BEST SUITED FOR PARTICULAR LAND USES, AND (2) WHAT KINDS OF PROBLEMS THEY MIGHT FIND TRYING TO DEVELOP DIFFERENT AREAS.

In order to make soil or plant community maps, SCS soil scientists and botanists looked at the 1:4800-scale aerial photographs and stripped away *even more* detail in order to outline areas containing particular kinds of soils or plant communities. Stripping away *irrelevant* detail is what making maps is all about. By stripping away details that don't give you useful information, you can see more clearly those details that *are* useful, along with useful patterns. But because selected details are stripped away in making maps, map *users* must be careful to use maps the way map *makers* meant them to be used.

Let's recall the purpose for which maps were made during the Kenai River study. In this study, maps were made (and data were collected) to help Kenai River landowners: (1) identify what areas are best suited for particular kinds of land uses, and (2) understand what kinds of problems (e.g., soil limitations) they might find when trying to develop different areas.

Because of the density of platted lots along the Kenai River (see Figure 2, for example), the Soil Conservation Service knew that maps would have to be quite detailed to provide information useful to landowners. In other words, maps would need to have a relatively high *resolution.* In 1987, SCS "test mapped" about 110 acres to find out what kinds of detail and accuracy were possible using three different mapping intensities and how long different levels of mapping would take. On the basis of that test, SCS chose the 1:4800 mapping scale because they determined that a larger scale (say, 1:2500) would <u>not</u> provide significantly more useful information to landowners but <u>would</u> cost considerably more.

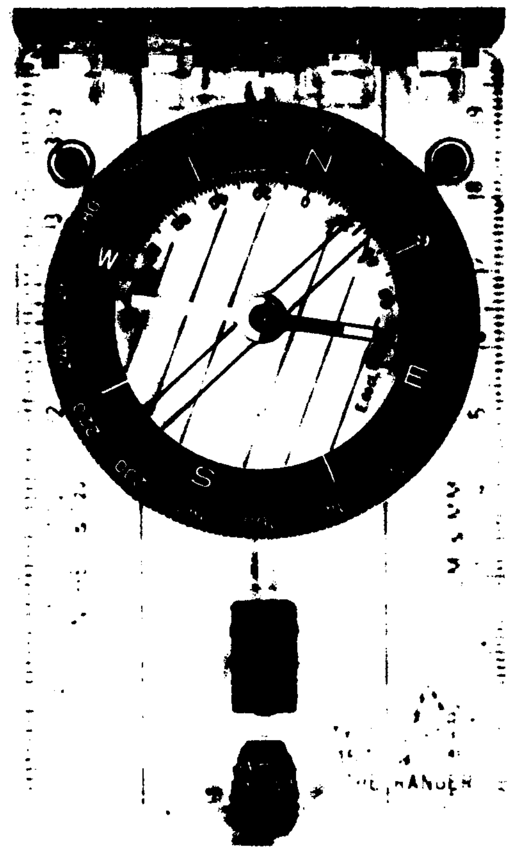
The 1:4800 mapping scale provides a "minimum mapping unit" of about an acre. That means that features less than an acre or so in size are generally too small to outline. With a scale of 1:4800 and a minimum mapping unit of about an acre, **what SCS soil maps are very good at showing is the *likelihood* of finding particular soil conditions on an area an acre or larger in size.** That means that if you walk out to a spot on a 1-acre parcel, find your location on one of the soil maps, and then look up the *map unit symbol* for your soil polygon (see Table 1), the chances are about 85% that the spot where you're standing has the soil properties identified by the map unit symbol, or very similar properties.

Those are good odds for most ***planning*** purposes, but they also mean that there's a 15% chance that the ***exact spot*** on which you want to build your house has soil conditions completely different from those shown on the soil map. These **scattered areas of contrasting soils too small to map are called "inclusions,"** and they're unavoidable in mapping. (Figure 5 in Chapter IV illustrates what a soil inclusion looks like.) That's why SCS always **urges landowners to get <u>onsite</u> inspections before deciding where precisely to locate developments on their land.** Without "point-specific" information, landowners are playing the odds when they decide where to locate buildings or other improvements — and although an 85% chance of success is pretty high, you probably don't want to gamble on whether or not your foundation will crack or your septic system fail.

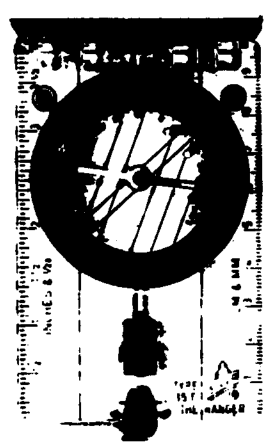
As this discussion implies, **serious problems can arise by taking a map drawn at one scale, *enlarging* it, and then using it in ways not intended by the map makers.** This danger is particularly high when data are digitized in a computerized geographic information system (like the Borough's), which makes it very easy to change scale. Remember that enlarging a map (increasing its scale) just 5 times will enlarge mapped *areas* 25 times. If you took a soil map made at one scale and enlarged it five times, you would seriously misrepresent mapped reality. Many features that could have been mapped at the larger scale were too small to outline when they were only 1/25th as large (see Figure 1 again).

Here's an example of how mapping scale affects what gets drawn on a soil map: Boundaries around soil polygons are seldom abrupt (unless they reflect an abrupt geologic control, like a cliff). Instead, soils change gradually over some horizontal transition zone. (This is also usually true of plant communities.) At a scale of 1:4800, most soil transition zones are not much wider than the tip of the pen used to outline soil polygons, so transition areas get lumped in with adjacent polygons. If the mapping scale (and the photographs used for mapping) had been significantly larger than 1:4800, say 1:2000, many transition zones would have been large enough to map as individual units. So if you enlarge a digitized soil map from 1:4800 to 1:2000, the polygons shown on the enlarged map will not represent reality as accurately as the scale suggests they should.

Figure 1. Comparison of five scales (1:1 to 1:16) and their effects on area.



1:1 scale (life size)



1:2 scale,
1/4 life size

1:4 scale,
1/16 life size

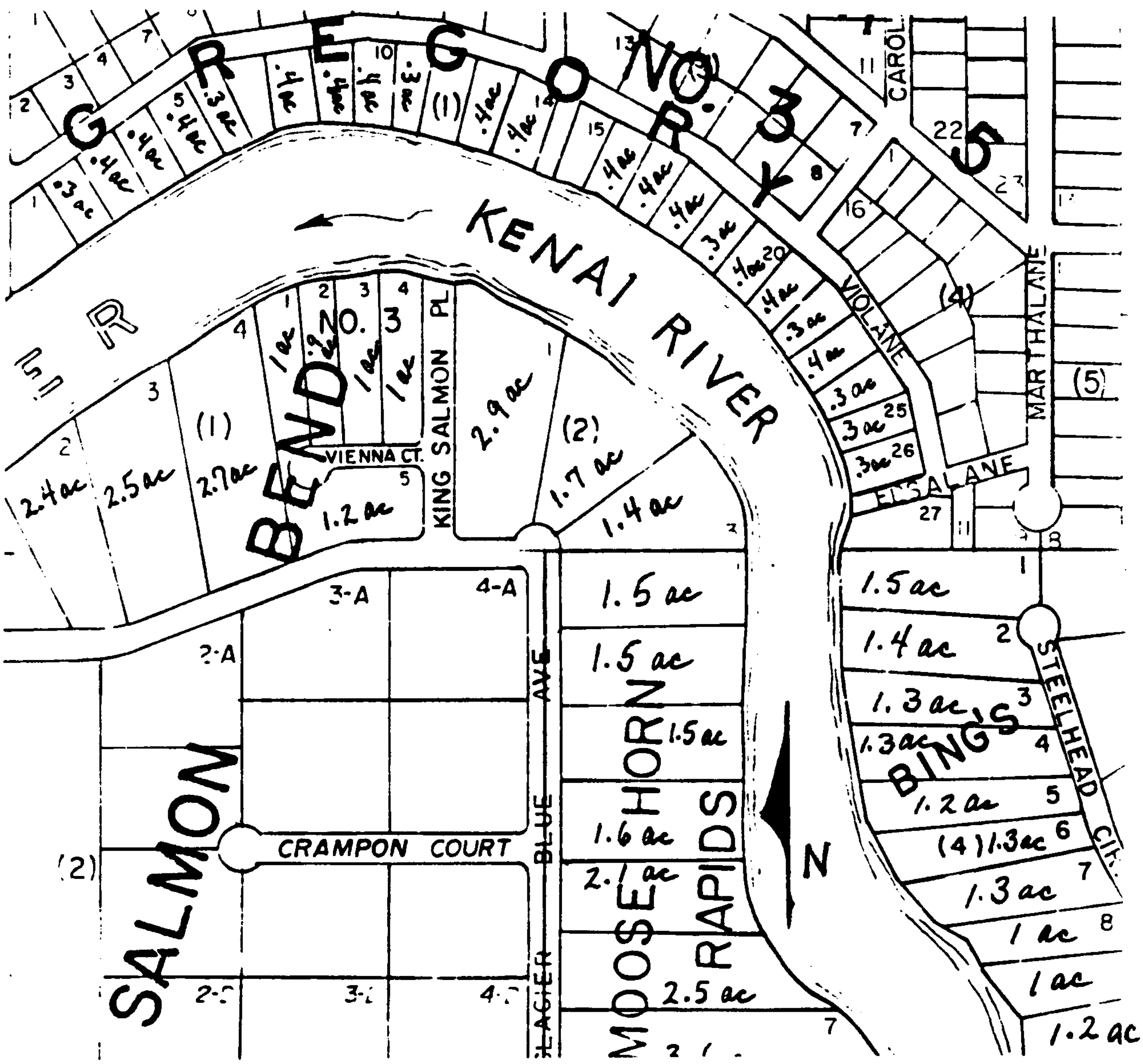
1:8 scale,
1/64 life size

1:16 scale,
1/256 life size

To put this all in perspective, let's look at a typical lot on the Kenai River as it appears on a 1:4800-scale map (Figure 2). Many Kenai River lots are about 1-acre in size. (The Borough requires that any lot with onsite water and septic be at least 40,000 square ft in size; an acre is 43,560. Variances to this minimum size requirement have been granted in many areas.) Many lots are also long and narrow, or "piano-key" in shape, because subdividers can fit more "riverfront" lots along a given stretch of river if each lot is as narrow as possible. At the scale of Figure 2 (or the photograph on the back cover), a mature spruce tree seen from above is about the size of a pin head, and a house is barely discernible. The pen used to outline polygons on a map this size makes a line that would be tens of feet wide if a line of equal proportion were drawn on the ground. And on-the-ground features hundreds of square feet in size are too small to outline on the map.

Despite these cautionary comments, maps included here allow you to identify with a high degree of accuracy the soil conditions and plant communities you're likely to find on your parcel. All you need to do is use the maps as the map makers intended.

Figure 2. Kenai River subdivision lots at a scale of 1:4800. (Acreages of several lots are marked.)



B. TABLES RELATED TO LOWER KENAI RIVER MAPS

Table 1. "Connotative legend" for understanding soil map unit symbols.

Surface texture	(PSC) 1/ (10-60")	Texture 3/ (24-60")	Watertable	Slope %
1 = SIL, VFSL	1 = <15% cos frags >3" by vol	1 = S, FS, LS, LFS	0 = 0-1'	A = 0-4
2 = COS, S, FS	2 = 15-35% cos frags >3"	2 = SL, FSL	1 = 1-2'	B = 4-8
3 = SIC, C, SC	3 = >35% cos frags >3"	3 = L, SIL, SCL, VSFL	2 = 2-4'	C = 8-15
4 = ALL others (FSL, SL, etc.)	4 = high shrink-swell	4 = SICL, SC, SIC,C	4 = 4-6'	D = 15-25
5 = Pt (>8")	5 = OL, OH, Pt 2/	5 = Pt	6 = >6'	E = >25
6 = Gravelly (15-35% by vol)			7 = ponded 4/	
7 = Very gravelly (35-50%) by vol			8 = perched 4/	
8 = >50% coarse fragments				

Map unit examples:

1210A = Silt loam surface, cobbly PSC, sandy (rapid permeability), watertable 0-1', 0-4% slope.

2326B = Sandy surface, very cobbly PSC, sandy loam (moderately rapid permeability), 4-8% slope.

Texture terms: (USDA)

COS	Coarse sand	VFSL	Very fine sandy loam
S	Sand	L	Loam
FS	Fine sand	SIL	Silt loam
VFS	Very fine sand	SI	Silt
LCOS	Loamy coarse sand	SCL	Sandy clay loam
LS	Loamy sand	CL	Clay loam
LFS	Loamy fine sand	SICL	Silty clay loam
LVFS	Loamy very fine sand	SC	Sandy clay
COSL	Coarse sandy loam	SIC	Silty clay
SL	Sandy loam	C	Clay
FSL	Fine sandy loam	Pt	Peat
<	less than (e.g., 1<2)	>	greater than (e.g., 2>1)

Footnotes:

1/ Particle size control section; "cos frags" = coarse fragments
2/ Restrictive feature (O = organic): subsidence and/or low strength
3/ For permeability determination
4/ Ratings same as 0-1' watertable group (not used throughout survey)

Table 2a. Mosses identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Hylocomium	splendens	ladder moss
Mnium	marginatum	marginate mnium
Pleurozium	schreberi	wall moss
Polytrichum	spp.	hairy caps
Polytrichum	juniperinum	juniper hairy caps
Ptilium	spp.	knights plume
Ptilium	crista-castrensis	knights plume
Sphagnum	spp.	peat moss

Table 2b. Lichens identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Cetraria	spp.	fruiticose lichen
Cladina	spp.	reindeer lichen
Cladonia	spp.	fruiticose lichen
Nephroma	spp.	alpine lettuce
Peltigera	spp.	three is company
Stereocaulon	spp.	fruiticose lichen

Table 2c. Forbs identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Achillea	millefolium	common yarrow
Aconitum	delphinifolium	monkshood
Actaea	rubra	red baneberry
Angelica	lucida	wild celery
Antennaria	rosea	rose pussytoes
Arabis	Drummondii	Drummond rockcress
Arabis	hirsuta	hairy rockcress
Aster	sibiricus	Siberian aster
Athyrium	filix-femina	lady fern
Calla	palustris	water arum
Caltha	palustris	marsh marigold
Cardamine	pratensis	cuckoo flower
Cerastium	Beeringianum	Bering chickweed
Chenopodium	album	lambsquarters
Chrysanthemum	arcticum	arctic daisy
Cicuta	Douglasii	western water hemlock
Cicuta	mackenzieana	Mackenzie water hemlock
Conioselinum	chinense	western hemlock parsley
Corallorrhiza	trifida	early coralroot
Crassula	aquatica	water pygmy-weed
Cystopteris	fragilis	fragile fern
Delphinium	glaucum	glaucous larkspur
Dianthus	repens	northern pink
Dryopteris	dilatata	spreading wood fern
Epilobium	angustifolium	fireweed
Epilobium	Hornemannii	Hornemann's willow-herb
Epilobium	latifolium	dwarf fireweed
Epilobium	palustre	swamp willow-herb
Equisetum	arvense	field horsetail
Equisetum	fluviatile	water horsetail
Equisetum	palustre	marsh horsetail
Equisetum	pratense	meadow horsetail
Equisetum	sylvaticum	woodland horsetail
Erigeron	peregrinus	peregrine fleabane
Galium	boreale	northern bedstraw
Galium	trifidum	small bedstraw
Galium	triflorum	sweet scented bedstraw
Geranium	erianthum	wild geranium
Geocaulon	lividum	northern comandra
Geum	macrophyllum	largeleaf avens
Goodyera	repens	rattlesnake plantain
Gymnocarpium	dryopteris	oak fern
Hedysarum	alpinum	alpine sweet vetch
Heracleum	lanatum	cow parsnip
Hippuris	vulgaris	marestail

Honkenya	peploides	seabeach sandwort
Impatiens	noli-tangere	western touch me not
Lathyrus	palustris	wild pea
Lemna	minor	lesser duckweed
Listera	cordata	heartleaved twayblade
Ligusticum	scothicum	Scotch lovage
Lupinus	nootkatensis	Nootka lupine
Lupinus	polyphyllus	largeleaf lupine
Lycopodium	alpinum	alpine clubmoss
Lycopodium	annotinum	stiff clubmoss
Lycopodium	clavatum	running clubmoss
Lycopodium	complanatum	ground cedar
Mertensia	paniculata	tall bluebells
Menyanthes	trifoliata	buckbean
Moneses	uniflora	single-flowered wintergreen
Oxytropis	campestris	field oxytrope
Oxytropis	deflexa	deflexed oxytrope
Parnassia	palustris	northern grass of parnassus
Petasites	frigidus	arctic sweet coltsfoot
Pedicularis	sudetica	sudetan lousewort
Pedicularis	verticillata	whorled lousewort
Plantago	maritima	goosetongue
Platanthera	obtusata	small northern bog orchid
Poa	spp.	bluegrass
Polemonium	acutiflorum	tall Jacob's ladder
Polemonium	pulcherrimum	pretty Jacob's ladder
Polygonum	alaskanum	wild rhubarb
Polygonum	aviculare	knotweed
Polygonum	bistorta	meadow bistort
Potentilla	egedii	silverweed
Potentilla	palustris	marsh five finger
Primula	cuneifolia	wedgeleaf primrose
Pyrola	asarifolia	liverleaf wintergreen
Pyrola	chlorantha	greenflowered wintergreen
Pyrola	grandiflora	largeflowered wintergreen
Pyrola	minor	lesser wintergreen
Pyrola	secunda	one-sided wintergreen
Ranunculus	hyperboreus	arctic buttercup
Ranunculus	lapponicus	lapland buttercup
Ranunculus	Macounii	Macoun buttercup
Rhinanthus	minor	yellow rattle
Rumex	arcticus	arctic dock
Rubus	pedatus	fiveleaf bramble
Sanguisorba	canadensis	Canada burnet
Salicornia	europaea	slender glasswort
Saxifraga	hirculus	yellow marsh saxifrage
Senecio	congestus	marsh fleabane
Senecio	pseudo-Arnica	seabeach senecio
Senecio	vulgaris	common groundsel
Sisymbrium	altissimum	tall tumble mustard

Solidago	spp.	goldenrod
Spergularia	canadensis	Canadian sandspurry
Spiranthes	Romanzoffiana	contential ladiestresses
Streptopus	amplexifolius	twisted stalk
Stellaria	calycantha	calyxeye starwort
Stellaria	crispa	crisp starwort
Stellaria	humifusa	low starwort
Stellaria	longifolia	longleaf starwort
Taraxacum	officinale	common dandelion
Thalictrum	sparsiflorum	few flower meadowrue
Trientalis	europaea	arctic starflower
Triglochin	maritimum	maritime arrowgrass
Triglochin	palustre	marsh arrowgrass
Urtica	dioica	Lyall nettle
Valeriana	capitata	capitate valerian
Viola	epipsila	marsh violet
Viola	Langsdorfii	Alaska violet
Viola	renifolia	white violet

Table 2d. Grasses identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Agropyron	smithii	western wheatgrass
Alopecurus	pratensis	meadow foxtail
Calamagrostis	spp.	reedgrass
Calamagrostis	canadensis	bluejoint (reedgrass)
Calamagrostis	deschampsioides	circumpolar small reedgrass
Carex	spp.	sedge
Carex	aquatilis	water sedge
Carex	Kelloggii	Kellogg sedge
Carex	limosa	shore sedge
Carex	loliacea	rye-grass sedge
Carex	Lyngbyei	Lyngbye sedge
Carex	pluriflora	manyflower sedge
Carex	podocarpa	shortstalk sedge
Carex	Ramenskii	Ramenski sedge
Carex	spectabilis	showy sedge
Elymus	arenarius	sea lymegrass
Eleocharis	spp.	spikerush
Eriophorum	spp.	cottongrass
Festuca	altaica	altai fescue
Festuca	ovina	sheep fescue
Festuca	rubra	red fescue
Hierochloe	odorata	vanilla grass
Juncus	spp.	rush
Luzula	spp.	woodrush
Luzula	multiflora	manyflowered woodrush
Poa	spp.	bluegrass
Poa	alpigena	low bluegrass
Poa	eminens	largeflower speargrass
Puccinellia	hultenii	Hulten alkaligrass
Puccinellia	nutkaensis	nutka alkaligrass
Puccinellia	phryganodes	creeping alkaligrass
Trisetum	spicatum	downy oatgrass

Table 2e. Shrubs identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Alnus	crispa	American green alder
Alnus	sinuata	Sitka alder
Alnus	tenuifolia	thinleaf alder
Andromeda	polifolia	bog rosemary
Arctostaphylos	rubra	redfruit bearberry
Betula	nana	dwarf arctic birch
Chamaedaphne	calyculata	leatherleaf
Cornus	canadensis	dwarf dogwood
Dryas	drummondii	Drummond mountainavens
Empetrum	nigrum	crowberry
Ledum	groenlandicum	Labrador tea
Ledum	palustre	narrowleaf Labrador tea
Linnaea	borealis	twinflower
Menziesia	ferruginea	rusty menziesia
Myrica	gale	sweet gale
Oplopanax	horridus	devilsclub
Oxyococcus	microcarpus	bog cranberry
Potentilla	fruticosa	bush cinquefoil
Ribes	glandulosum	skunk currant
Ribes	hudsonianum	northern black currant
Ribes	lacustre	prickly currant
Ribes	laxiflorum	trailing black currant
Ribes	triste	red currant
Rosa	acicularis	prickly rose
Rubus	arcticus	nagoon berry
Rubus	chamaemorus	cloud berry
Rubus	idaeus	raspberry
Salix	spp.	willow
Salix	alaskensis	feltleaf willow
Salix	arbusculoides	littletree willow
Salix	arctica	arctic willow
Salix	Barclayi	Barclay willow
Salix	commutata	undergreen willow
Salix	fuscescens	Alaska bog willow
Salix	planifolia	diamondleaf willow
Salix	reticulata	netleaf willow
Salix	stolonifera	sproutingleaf willow
Sambucus	racemosa	red elderberry
Sorbus	scopulina	Greene mountainash
Spiraea	beauverdiana	Beauverd spirea
Vaccinium	uliginosum	bog blueberry
Vaccinium	vitis-idaea	lowbush cranberry
Viburnum	edule	highbush cranberry

Table 2f. Trees identified during mapping along the lower Kenai River.

GENUS	SPECIES	COMMON NAME
Alnus	crispa	American green alder
Alnus	tenuifolia	thinleaf alder
Betula	papyrifera	paper birch
Picea	glauca	white spruce
Picea	mariana	black spruce
Populus	balsamifera ssp. trichocarpa	black cottonwood
Populus	tremuloides	quaking aspen
Salix	alaxensis	feltleaf willow
Salix	bebbiana	Bebb willow

Table 3. Overstory ("land cover") map codes used along the lower Kenai River.

KENAI RIVER BASIN LAND COVER MAP CODES

Conifer Forest[1]

Closed[2]

1	Black Spruce
2	White Spruce
3	Black Spruce-White Spruce

Open[2]

6	Black Spruce
7	White Spruce
8	Black Spruce-White Spruce

Woodland[2]

11	Black Spruce
12	White Spruce
13	Black Spruce-White Spruce

Deciduous Forest

Closed

16	Cottonwood
17	Paper Birch
18	Quaking Aspen
19	Birch-Aspen

Open

20	Cottonwood
21	Paper Birch
22	Quaking Aspen
23	Birch-Aspen

Woodland

26	Cottonwood
27	Paper Birch
28	Quaking Aspen
29	Birch-Aspen

Shrubland[3]

Tall Closed

60	Willow
61	Alder
62	Alder-Willow

Tall Open

65	Willow
66	Alder
67	Alder-Willow

Low Closed

70	Mixed (Dwarf Birch/Willow/Ericaceous)

Low Open

71	Mixed (Dwarf Birch/Willow/Ericaceous)

Herbaceous

Dry

75	Bluejoint-Herb

Moist (seasonally flooded)

77	Sedge-Grass
78	Bluejoint-Herb

Wet

79	Sedge-Grass
80	Peat Moss Bog

Aquatic

82	Emergent Vegetation
85	Lakes/Ponds
86	Lakes/Ponds w/floating vegetation
88	Rivers and Streams

Barren-Natural

90	Intermittent Stream Channels
91	Sand and Gravel Bars
92	Rock
94	Bare Ground

Cultural

95	Urban-Suburban
96	Agricultural
97	Gravel Pits, Mines, Quarries
98	Roads
99	Pipelines & Powerlines

Descriptors

Forests - (Tree size class)
- R - Dwarf forests (Scrub: <20', mature) Reproduction (<5"DBH)
- P - Pole size (5 to 9" DBH)
- S - Sawtimber size (>9" DBH)

Other descriptors
- W - Wetland
- BR - Burned recently

[1]Forest - 10-100% tree canopy cover

Categories

Coniferous - Over 75% tree canopy is coniferous species

Broadleaf Deciduous - Over 75% tree canopy is broadleaf deciduous species

Mixed Coniferous/Broadleaf - Each contributes between 25-75% of the forest canopy cover

Species Classes

One species call - Over 75% of forest canopy cover is one species

Two species call - Each species contributes 25-75% of forest canopy cover

[2]Canopy Classes Closed/60-100% tree canopy cover; Open/25-60% tree canopy cover; Woodland/10-25% tree canopy cover

[3]Shrubland 25-100% of mapped polygon area is shrub canopy cover, but less than 10% forest canopy cover

Shrubland Categories:
Tall shrub - shrub species over 1.5 meters high
Low shrub - shrub species over 0.2/less than 1.5 meters

[4]Canopy classes -
Closed - 75-100% shrub canopy cover
Open - 25-75% shrub canopy cover

[5]Herbaceous — Over 5% of mapped polygon area is herbaceous canopy cover but less than 25% canopy cover of shrubs & less than 10% canopy cover of trees.

[6]Categories -
Dry - area is never flooded/saturated during the growing season
Moist - area is seasonally/periodically flooded/saturated during growing season
Wet - area has standing/flowing water most of the growing season

Table 4. Mapping codes for understory plant communities.

DRY PLANT COMMUNITIES	
Code Number	**Description**
d1	Feathermoss: simple, early successional community, often moss cover is less than 30%, little diversity.
d2	Feathermoss - lowbush cranberry - (northern commandra, horsetail): still moss-dominated but a later successional stage than d1, greater moss cover, greater species diversity.
d3	Feathermoss - dwarf dogwood - lowbush cranberry - (crowberry, twinflower, dwarf arctic birch, rose): similar to the very common community below, d11, but simpler, perhaps drier community.
d11	Feathermoss - lowbush cranberry - dwarf dogwood (twinflower, grass, highbush cranberry, willow, northern commandra, dwarf arctic birch, rose, crowberry, horsetail): considerable diversity among dominant spp.
d5	Feathermoss - lichen - lowbush cranberry - crowberry - (Labrador tea, dwarf arctic birch, grass, willow, blueberry): similar to d11, but much drier, high fruticose lichen component, altai fescue often present.
d42	Oak fern - rose - bluejoint - feathermoss - variety of dwarf shrubs - variety of forbs - (highbush cranberry, willow, horsetail): similar to d11, but earlier successional stage, drier, with more oak fern and less feathermoss, very lush, productive community.
d45	Bluejoint.
d21 (ed33)	Bluejoint - willow - (fireweed, horsetail, alder, variety of forbs): grass-tall shrub community.
d26	Bluejoint - dwarf dogwood - feathermoss - rose - lowbush cranberry - (nagoon berry): grass-dwarf shrub community.
d47	Fireweed - horsetail - highbush cranberry - bluejoint - (feathermoss): young white spruce stand.
d48	Horsetail: mostly field horsetail.
d16	Willow - (dwarf arctic birch - grass - feathermoss).
d30	Alder - horsetail - bluejoint - (rose, oak fern, canoda burnet, fireweed, feathermoss): riparian zone alder community

WET PLANT COMMUNITIES	
Code Number	**Description**
w47	Feathermoss: simple community, low cover values, little diversity. Similar to d1, but with wetland indicator plants as minor components.
w27	Feathermoss - bluejoint - horsetail (peat moss, marsh five-finger, willow, sedge, sweet gale near Birch Island).
w46	Peat moss - marsh five-finger - (horsetail, bluejoint, cloudberry).
w40	Peat moss - cottongrass - (bog cranberry, bog rosemary).
w33	Peat moss - bog rosemary - sedge.
w7	Peat moss - feathermoss - (lowbush cranberry, crowberry, horsetail, bluejoint, cloudberry, dwarf dogwood): simple black spruce bog community, dominated by mosses.
w11	Peat moss - feathermoss - dwarf arctic birch - willow - marsh five-finger - (bluejoint, Labrador tea, sedge, alder, horsetail, blueberry, cloudberry): black spruce bog, more complex than w7.
w39	Buckbean - cottongrass - (emergent vegetation)
w23	Horsetail: dominated by one or more spp. of horsetail; remainder of community may be either simple or diverse.
w41	Horsetail - peat moss - feathermoss.
w45	Sedge - (from one to three species, little diversity).
w30	Sedge - Willow.
w10	Sedge - marsh five-finger - horsetail.
w31	Sedge - marsh five-finger - tundra rose - blueberry - sweet gale - (dwarf arctic birch - willow - bluejoint - bog rosemary): Sedge and marsh five-finger with a variety of low shrubs, found on the lower river, upstream from Warren Ames Bridge.

WET PLANT COMMUNITIES	
Code Number	**Description**
W35	Cottongrass - willow - peat moss - bluejoint - (dwarf arctic birch, marsh five-finger): often scattered dead spruce, found on the lower river, upstream from Warren Ames Bridge.
w1	Bluejoint.
w6	Bluejoint - oak fern.
w29	Bluejoint - Willow - (marsh five-finger, sedge, feathermoss, blueberry, horsetail).
w9	Bluejoint - horsetail - (canada burnet, willow, nettle).
w38	Crowberry - sedge - peat moss (often dead) - willow - (cloudberry): near mouth of Kenai River, dead peat moss probably due to relatively recent brackish water inundation. Found on the lower river, upstream from Warren Ames Bridge.
w3	Alder - bluejoint - (willow, horsetail, sedge, feathermoss, nettle): simple community, dominated by 2 or 3 species.
w4	Alder - bluejoint - horsetail - (marsh five-finger, willow, peat moss): more complex than w3.

TIDAL PLANT COMMUNITIES	
Code Number	**Description**
T1	Mud - shallow ponds - bare ground - sand.
T2	Creeping alkaligrass, with lesser amounts of maritime arrowgrass, marsh arrowgrass, slender glasswort, Canadian sandspurry (P. nutkaensis, near mouth of Kenai).
T3	Carex ramenskii - [or Carex lyngbyaei (short variety), especially downstream of the Warren Ames Bridge], silverweed, maritime arrowgrass, (goosetongue, nutka alkaligrass, largeflower speargrass, arctic daisy, manyflower sedge). (T11).
T4	Sea lymegrass (with some nutka alkaligrass near mouth).
T5	Lyngbye sedge.
T6	Bluejoint.

TIDAL PLANT COMMUNITIES	
Code Number	**Description**
T7	Circumpolar small reedgrass, manyflower sedge, Alaska bog willow (marsh five-finger).
T8	Nutka alkaligrass - maritime arrowgrass.
T9	Lyngbye sedge (short variety) - manyflower sedge.
T10	Beach pea - nutka alkaligrass - (arctic daisy, sea lymegrass, Scotch lovage).
T12	Manyflower sedge.
T13	Similar to T3, but includes crowberry and often dead or dying black spruce.
T14	Water horsetail.

NOTES:

The species that appears first is generally the most abundant, with those that follow in decreasing abundance. If one or more species are of about equal abundance, the shortest species will be listed first followed by those that are taller. The plants listed generally make up at least 20% cover. Those species listed in parentheses do not consistently reach 20%, but do on occasion, and are often, but not always, present.

The plant communities listed as "DRY" are considered to be upland, those listed as "WET" wetland, and those listed as "TIDAL" are affected by tidal action, near the mouth of the river. A Kenai River plant list has been developed with the more common species identified during this project (see Table 2).

Underlined plant communities have at least one field plot documenting species cover values. Those that are not underlined were not sampled, usually due to limited occurrence, but are known to occur.

T4 and T5 are almost identical on the photography, and may occur in similar areas, i.e., along river banks from about the Warren Ames Bridge upstream.

Table 5. Suitability interpretations for overstory plant communities.

LEGEND

S	= Suitable	H	= High
LS	= Low Suitability	M	= Moderate
NS	= Not Suitable	L	= Low
ND	= No Data	N	= None

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
1D closed dwarf black spruce	N	ND	NS	L	L	L
1R closed reproduction black spruce	N	LS	NS	L	L	L
1P closed pole black spruce	N	S	NS	L	L	M
2R closed reproduction white spruce	L	S	NS	M	M	L
2P closed pole white spruce	L	LS	LS	M	M	M
2S closed sawtimber white spruce	L	ND	LS	M	M	H
3R closed reproduction black/white spruce	L	S	NS	L	L	L
3P closed pole black/ white spruce	L	S	LS	L	L	M
6D open dwarf black spruce	N	S	NS	M	L	L
6R open reproduction black spruce	N	S	NS	M	L	L
6P open pole black spruce	N	LS	NS	M	L	L
7R open reproduction white spruce	L	S	NS	M	M	L
7P open pole white spruce	L	S	LS	M	M	M
7S open sawtimber white spruce	M	S	LS	M	M	H

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
8D open dwarf black/ white spruce	N	ND	NS	M	L	L
8R open reproduction black/white spruce	L	S	NS	M	L	L
8P open pole black/ white spruce	L	S	LS	M	L	M
11D woodland dwarf black spruce	N	S	NS	M	L	L
11R woodland reproduction black spruce	N	S	NS	M	L	L
12R woodland reproduction white spruce	L	ND	NS	M	M	L
12P woodland pole white spruce	L	S	LS	M	M	L
12S woodland sawtimber white spruce	L	ND	LS	M	M	M
13D woodland dwarf black/white spruce	N	ND	NS	M	L	L
13R woodland reproduction black/white spruce	L	S	NS	M	L	L
13P woodland pole black/white spruce	L	ND	LS	M	L	L
16R closed reproduction cottonwood	N	ND	NS	H	H	L
16P closed pole cottonwood	N	ND	NS	H	H	M
16S closed sawtimber cottonwood	N	ND	LS	H	H	H

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
17R closed reproduction paper birch	N	LS	NS	L	M	L
17P closed pole paper birch	N	LS	S	L	M	M
17S closed sawtimber paper birch	N	ND	S	L	M	H
18R closed reproduction aspen	N	LS	NS	L	M	L
18P closed pole aspen	N	ND	LS	L	M	M
18S closed sawtimber aspen	N	LS	S	L	M	H
19R closed reproduction birch/aspen	N	LS	NS	L	M	L
19P closed pole birch/ aspen	N	ND	S	L	M	M
19S closed sawtimber birch/aspen	N	ND	S	L	M	H
20R open reproduction cottonwood	N	ND	NS	H	H	L
20P open pole cottonwood	N	ND	NS	H	H	M
20S open sawtimber cottonwood	N	ND	LS	H	H	H
21R open reproduction paper birch	N	ND	NS	M	M	L
21P open pole paper birch	N	LS	S	M	M	M

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
21S open sawtimber paper birch	N	ND	S	M	M	H
22R open reproduction aspen	N	ND	NS	M	M	L
22P open pole aspen	N	LS	LS	M	M	M
22S open sawtimber aspen	N	ND	S	M	M	H
23R open reproduction birch/aspen	N	ND	NS	M	M	L
23P open pole birch/ aspen	N	LS	S	M	M	M
23S open sawtimber birch/aspen	N	LS	S	M	M	H
26R woodland repro- duction cottonwood	N	ND	NS	H	H	L
26P woodland pole cottonwood	N	ND	NS	H	H	M
26S woodland sawtimber cottonwood	N	ND	LS	H	H	M
27R woodland repro- duction paper birch	N	ND	NS	M	M	L
27P woodland pole paper birch	N	LS	S	M	M	L
27S woodland sawtimber paper birch	N	LS	S	M	M	M
28R woodland repro- duction aspen	N	ND	NS	M	M	L

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
28P woodland pole aspen	N	ND	LS	M	M	M
28S woodland sawtimber aspen	N	ND	S	M	M	M
29R woodland reproduction birch/aspen	N	ND	NS	M	M	L
29P woodland pole birch/aspen	N	ND	S	M	M	L
29S woodland sawtimber birch/aspen	N	ND	S	M	M	M
30R closed reproduction black spruce/birch	N	LS	NS	M	L	L
30P closed pole black spruce/birch	N	LS	LS	M	L	M
31R closed reproduction white spruce/birch	L	S	NS	M	M	L
31P closed pole white spruce/birch	L	S	LS	M	M	M
31S closed sawtimber white spruce/birch	L	S	S	M	M	H
32R closed reproduction black/white spruce/birch	L	S	NS	M	L	L
32P closed pole black/ white spruce/birch	L	S	LS	M	L	M
32S closed sawtimber black/white spruce/birch	L	ND	LS	M	L	H
33R closed reproduction black spruce/aspen	N	LS	NS	M	L	L

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
34R closed reproduction white spruce/aspen	L	LS	NS	M	M	L
34P closed pole white spruce/aspen	L	ND	LS	M	M	M
34S closed sawtimber white spruce/aspen	L	ND	LS	M	M	H
35R closed reproduction black/white spruce/aspen	L	S	NS	M	M	L
35P closed pole black/ white spruce/aspen	L	S	LS	M	M	M
37R closed reproduction white spruce/birch/aspen	L	LS	NS	M	M	L
37P closed pole white spruce/birch/aspen	L	S	LS	M	M	M
37S closed sawtimber white spruce/birch/aspen	L	LS	LS	M	M	H
38R closed reproduction white spruce/birch/ cottonwood	L	ND	NS	H	H	L
38P closed pole white spruce/birch/cottonwood	L	LS	LS	H	H	M
38S closed sawtimber white spruce/birch/ cottonwood	L	S	LS	H	H	H
39R closed reproduction white spruce/birch/ cottonwood	L	ND	NS	H	H	L
39P closed pole white spruce/birch/cottonwood	L	LS	LS	H	H	M
39S closed sawtimber white spruce/birch/ cottonwood	L	LS	LS	H	H	H

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
40R open reproduction black spruce/birch	N	S	NS	M	L	L
40P open pole black spruce/birch	N	ND	LS	M	L	L
41R open reproduction white spruce/birch	L	S	NS	M	M	L
41P open pole white spruce/birch	L	LS	LS	M	M	M
41S open sawtimber white spruce/birch	Moderate	LS	LS	M	M	H
42R open reproduction black/white spruce/birch	L	ND	NS	M	L	L
42P open pole black/ white spruce/birch	L	LS	LS	M	L	M
43R open reproduction black spruce/aspen	N	S	NS	M	L	L
43P open pole black spruce/aspen	N	S	LS	M	L	L
44R open reproduction white spruce/aspen	L	S	NS	M	M	L
44P open pole white spruce/aspen	L	S	LS	M	M	M
44S open sawtimber white spruce/aspen	L	ND	LS	M	M	H
45R open reproduction black/white spruce/aspen	L	LS	NS	M	M	L
45P open pole black/ white spruce/aspen	L	S	LS	M	M	M
47R open reproduction white spruce/birch/aspen	L	S	NS	M	M	L

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
47P open pole white spruce/birch/aspen	L	S	LS	M	M	M
47S open sawtimber white spruce/birch/aspen	L	S	LS	M	M	H
48R open reproduction white spruce/cottonwood	L	ND	NS	H	H	L
48P open pole white spruce/cottonwood	L	ND	LS	H	H	M
48S open sawtimber white spruce/cottonwood	L	ND	LS	H	H	H
49R open reproduction white spruce/birch/ cottonwood	L	ND	NS	H	H	L
49P open pole white spruce/birch/cottonwood	L	ND	LS	H	H	M
49S open sawtimber white spruce/birch/ cottonwood	L	LS	LS	H	H	H
50R woodland repro-duction black spruce/ birch	N	ND	NS	M	L	L
51R woodland repro-duction white spruce/ birch	L	ND	NS	M	M	L
51P woodland pole white spruce/birch	L	S	LS	M	M	L
51S woodland sawtimber white spruce/birch	L	LS	LS	M	M	M
52R woodland repro-duction black/white spruce/birch	L	ND	NS	M	L	L
52P woodland pole black/white spruce/birch	L	ND	LS	M	L	L

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
53R woodland reproduction black spruce/ aspen	N	LS	NS	M	L	L
54R woodland reproduction white spruce/ aspen	L	LS	NS	M	M	L
54P woodland pole white spruce/aspen	L	LS	LS	M	M	L
54S woodland sawtimber white spruce/aspen	L	ND	LS	M	M	M
57R woodland reproduction white spruce/ birch/aspen	L	ND	NS	M	M	L
57P woodland pole white spruce/birch/aspen	L	S	LS	M	M	L
57S woodland sawtimber white spruce/birch/aspen	L	ND	LS	M	M	M
58R woodland reproduction white spruce/ cottonwood	L	ND	NS	H	H	L
58P woodland pole white spruce/cottonwood	L	ND	LS	H	H	L
58S woodland sawtimber white spruce/cottonwood	L	ND	LS	H	H	M
59R woodland reproduction white spruce/ birch/cottonwood	L	ND	NS	H	H	L
59P woodland pole white spruce/birch/ cottonwood	L	ND	LS	H	H	L
59S woodland sawtimber white spruce/birch/ cottonwood	L	ND	LS	H	H	M
60 tall closed willow	N	ND	NS	H	H	N

Type/Description	Spruce Beetle Hazard	Moose Habitat	Goshawk Habitat	Willow Abundance	Cottonwood Abundance	Wood Vol.
61 tall closed alder	N	LS	NS	M	H	N
62 tall closed alder/ willow	N	LS	NS	H	H	N
65 tall open willow	N	LS	NS	H	H	N
66 tall open alder	N	LS	NS	M	H	N
67 tall open alder/ willow	N	LS	NS	H	H	N
70 low closed mixed dwarf birch/willow/ ericaceous	N	LS	NS	M	L	N
71 low open mixed dwarf birch/willow/ ericaceous	N	LS	NS	M	L	N
75 dry bluejoint/herb (hill top)	N	LS	NS	M	L	N
76 dry midgrass/herb/ sedge	N	ND	NS	M	L	N
77 moist wetland sedge/ grass/seasonally flooded	N	LS	NS	L	L	N
78 wet bluejoint reed-grass/forb	N	LS	NS	L	L	N
79 wet wetland wet sedge/grass	N	LS	NS	L	L	N
80 wet sphagnum bog	N	ND	NS	L	L	N
91 para-riverine (sand and gravel bars)	N	ND	NS	H	H	N
94 bare ground	N	ND	NS	L	L	N
97 gravel pits/mines/ quarries	N	ND	NS	H	H	N
98 roads	N	ND	NS	H	H	N
99 pipelines and powerlines	N	ND	NS	H	H	N

Table 6. Suitability interpretations for understory plant communities.

LEGEND

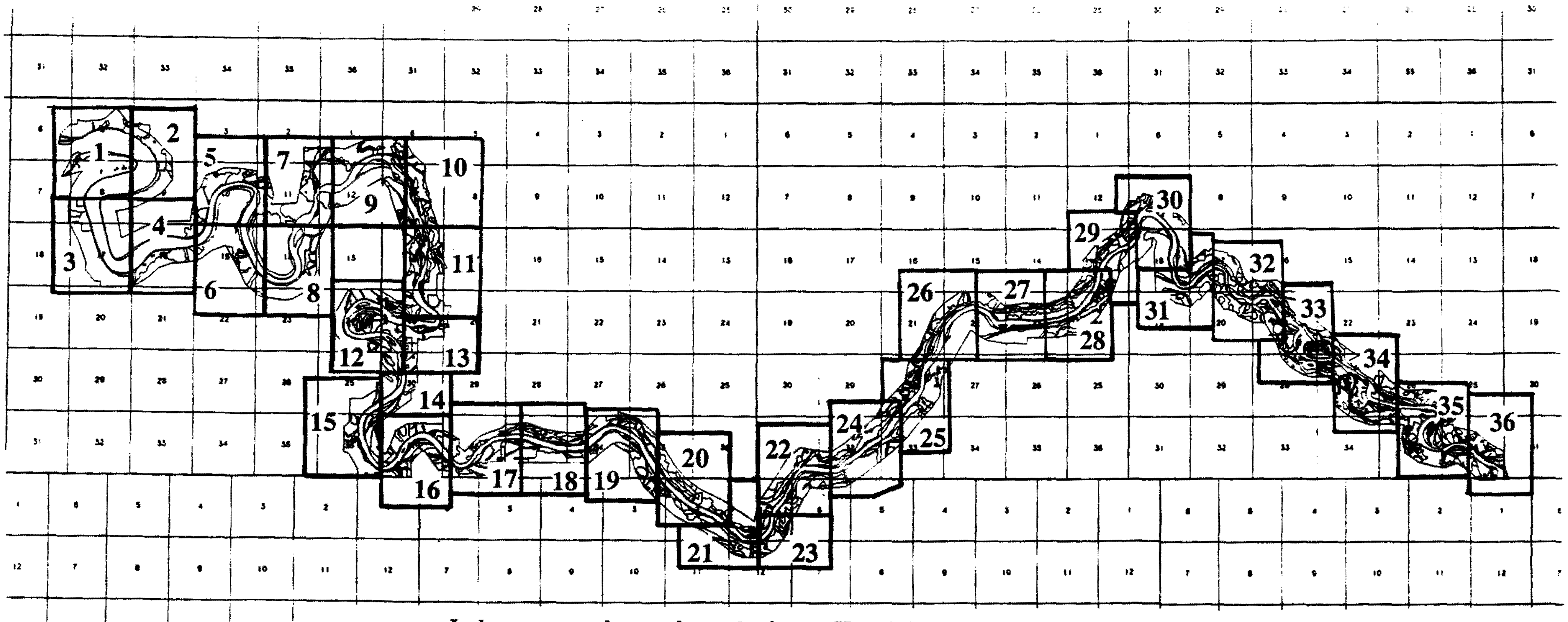
H = High abundance L = Low abundance
M = Moderate abundance ND = No Data

Plant Community	Wildberry Abundance	Willow Abundance	Cottonwood Abundance
d1 Feathermoss	L	L	L
d2 Feathermoss - lowbush cranberry	H	M	M
d3 Feathermoss - dwarf dogwood - lowbush cranberry	H	M	H
d5 Feathermoss - lichen - dwarf shrubs	H	L	L
d11 Feathermoss - variety of dwarf shrubs	H	M	M
d16 Willow	M	H	L
d21 Bluejoint - willow	M	H	M
d26 Bluejoint - dwarf shrub	M	M	L
d30 Alder - bluejoint	L	H	H
d42 Oak fern - grass - variety of forbs & shrubs	H	L	M
d45 Bluejoint	L	L	L
d47 Fireweed - bluejoint	M	L	L
d48 Horsetail	L	L	M
w1 Bluejoint	L	L	L

Plant Community	Wildberry Abundance	Willow Abundance	Cottonwood Abundance
w3 Alder - bluejoint	L	H	H
w4 Alder - bluejoint - forb	L	H	H
w6 Bluejoint - oak fern	ND	L	L
w7 Peat moss - feathermoss	M	H	L
w9 Bluejoint - horsetail	M	H	H
w10 Sedge - marsh five-finger	L	L	L
w11 Peat moss - shrub	H	M	L
w23 Horsetail	L	H	H
w27 Feathermoss - bluejoint	L	M	L
w29 Bluejoint - willow	L	H	M
w30 Sedge - Willow	L	M	L
w31 Sedge - shrub	M	M	L
w33 Peat moss - sedge	ND	L	L
w35 Cottongrass - willow - peat moss	L	M	L

Plant Community	Wildberry Abundance	Willow Abundance	Cottonwood Abundance
w38 Crowberry - sedge	H	M	L
w39 Buckbean - cottongrass	ND	L	L
w40 Peat moss - cottongrass	ND	L	L
w41 Horsetail - peat moss	L	L	L
w45 Sedge	L	L	L
w46 Sphagnum - marsh five-finger	L	L	L
w47 Feathermoss	M	L	L

C. MAPS OF SOILS ALONG THE LOWER KENAI RIVER, MAPS OF PLANT COMMUNITIES ALONG THE LOWER KENAI RIVER



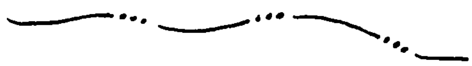
Index to map sheets along the lower Kenai River (index for both soil maps and plant community maps).

SYMBOLS USED ON SOIL MAPS

WATER FEATURES

Perennial stream, double line 

Perennial stream, single line 

Intermittent stream, single line 

Drainage ditch 

LAKES AND PONDS

Perennial 

MISCELLANEOUS WATER FEATURES

Spring 

Wet spot 

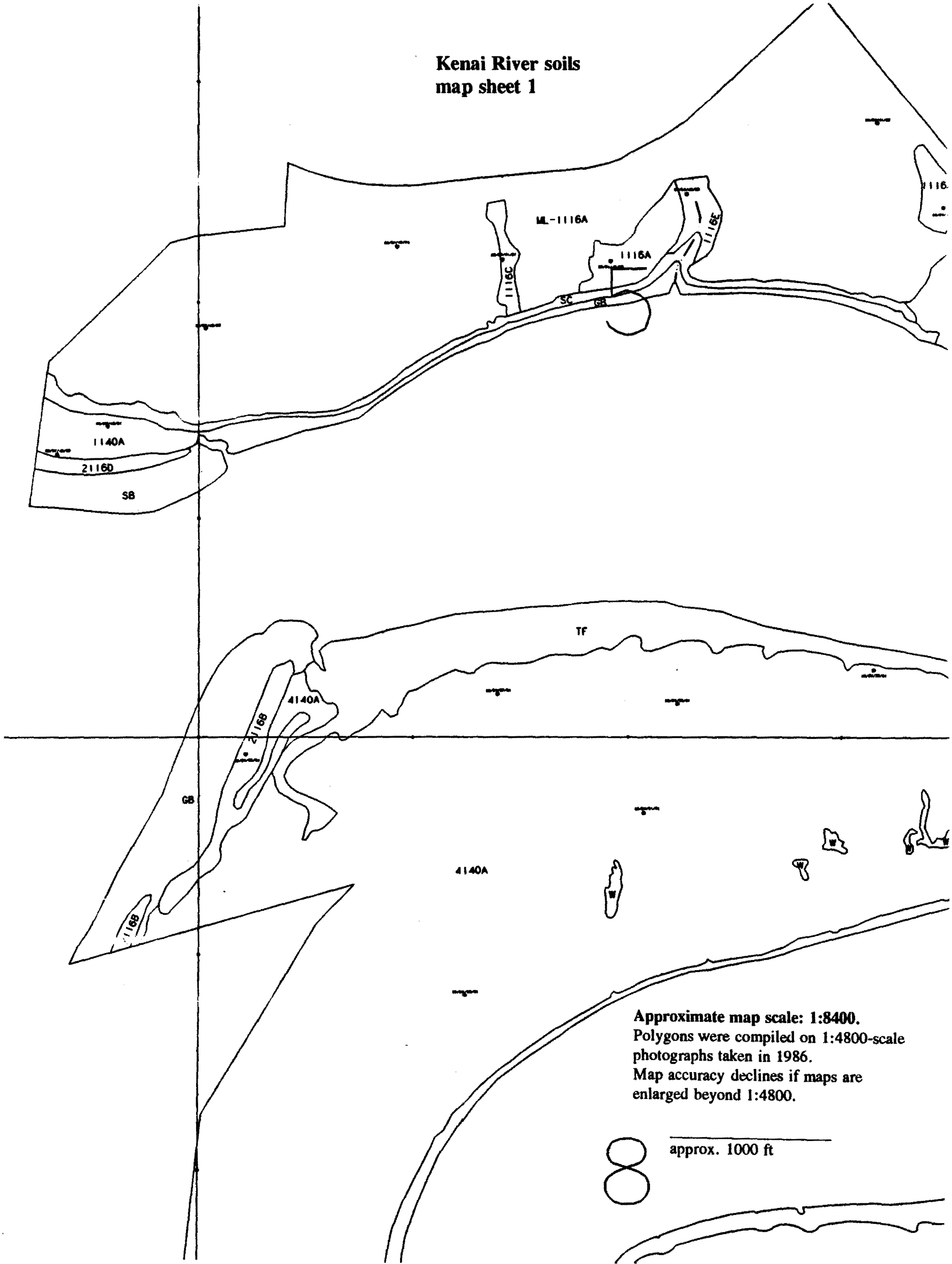
SPECIAL SYMBOLS FOR SOIL INVESTIGATION

Short steep slope	....
Depression	◇
Clay spot	※
Sandy spot	
Gravelly spot	∴
Madeland	≋ (ML)
Boulder	

ABBREVIATIONS

Escarpment	ES	Gravel beach	GB	Gravel pit	GP
Riverwash	RW	Sand pit	SP	Sandy Beach	SB
Sea cliff	SC	Tidal flat	TF		

Kenai River soils
map sheet 1



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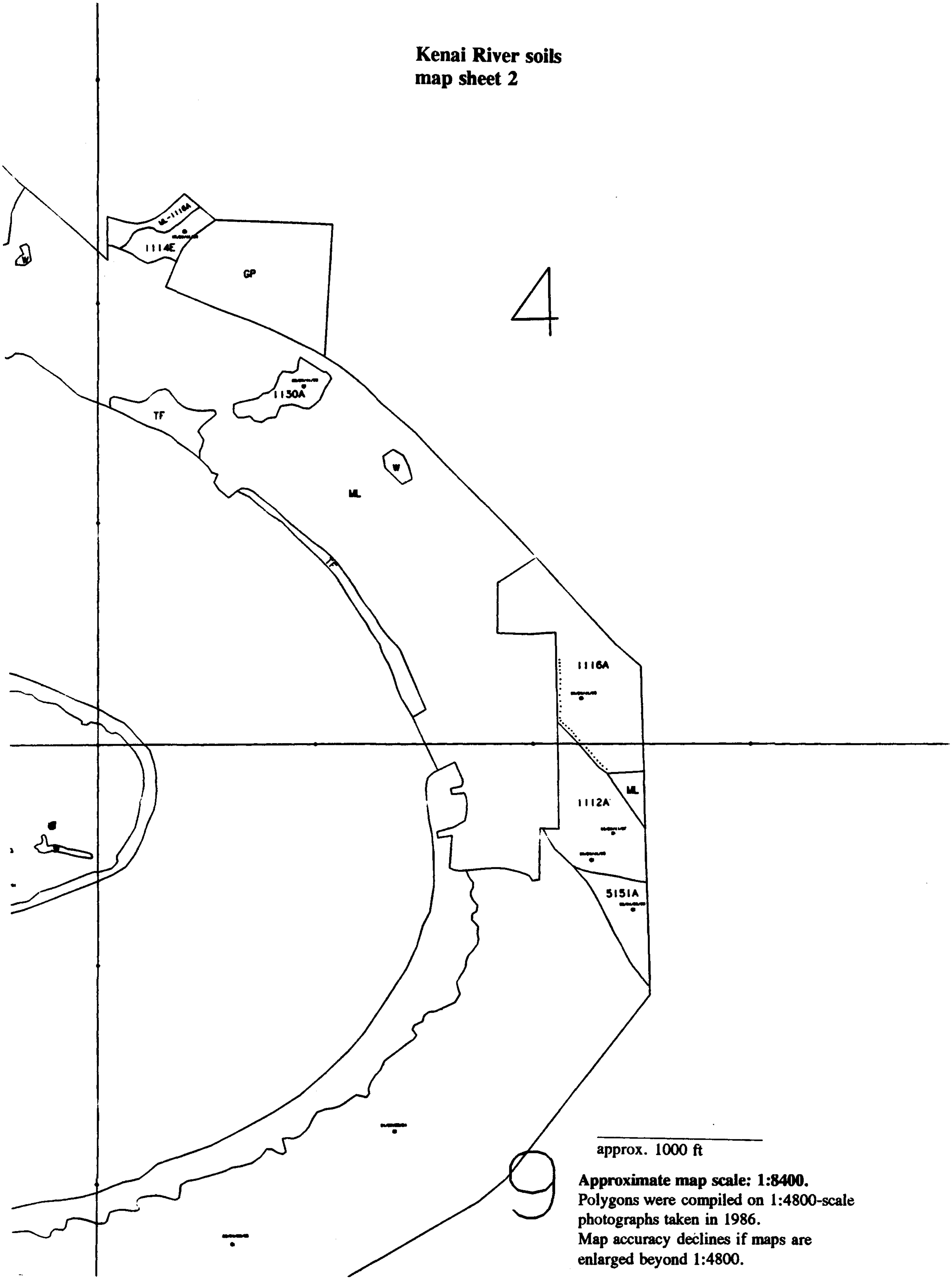
Polygons were compiled on 1:4800-scale photographs taken in 1986.
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

8

Kenai River soils map sheet 2



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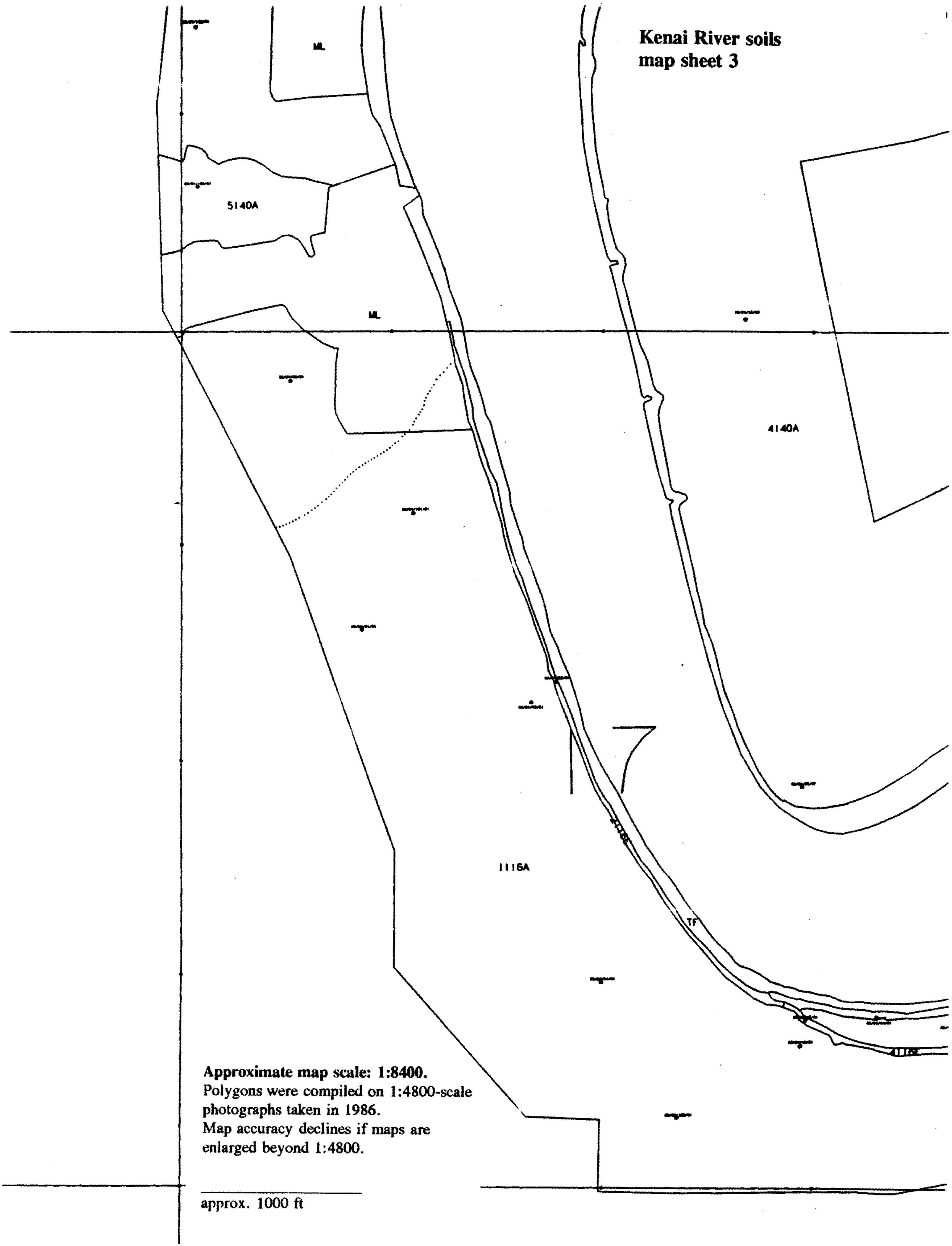
Kenai River soils map sheet 3



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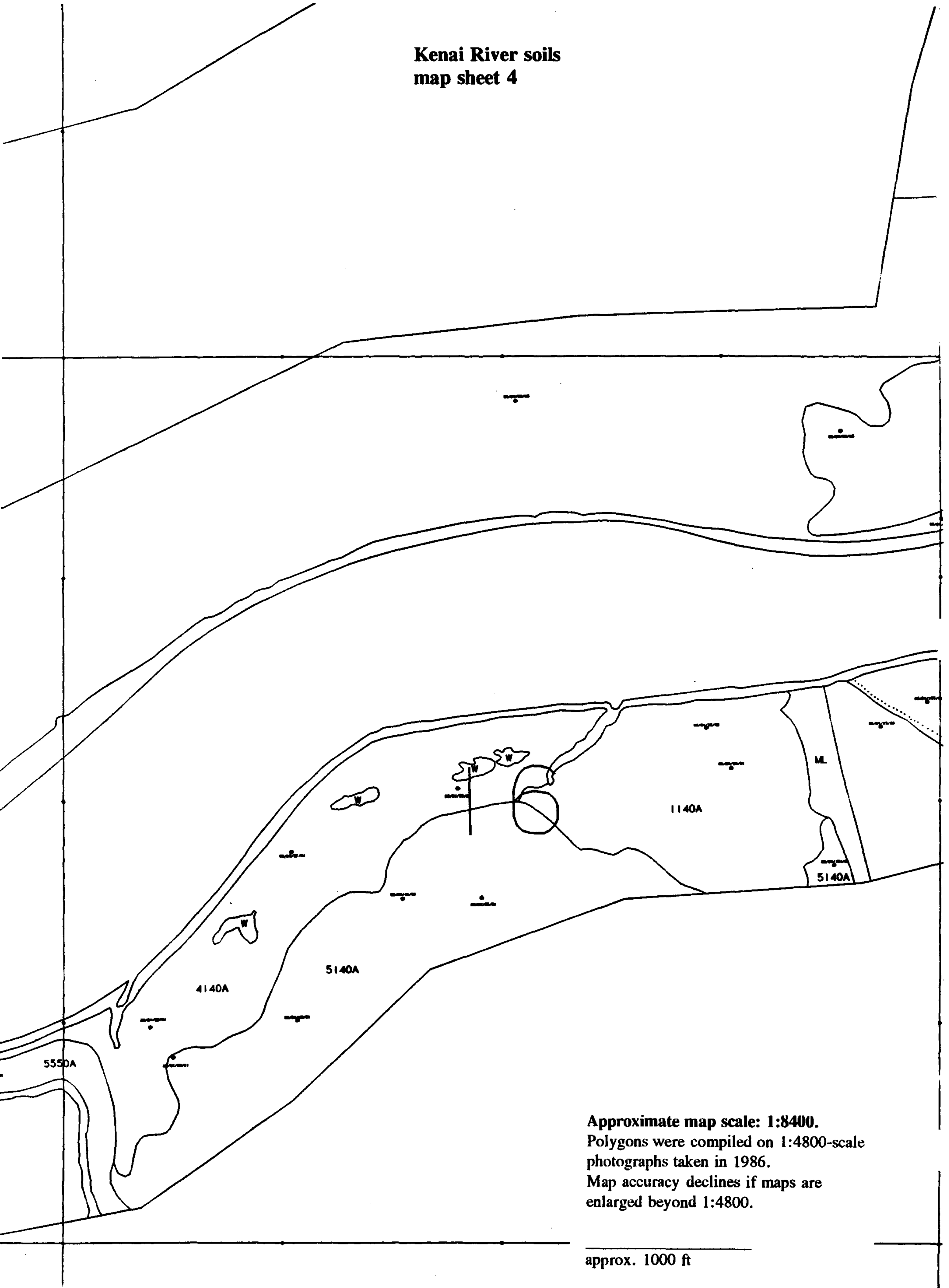
approx. 1000 ft

Kenai River soils
map sheet 4



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approx. 1000 ft

Kenai River soils
map sheet 5

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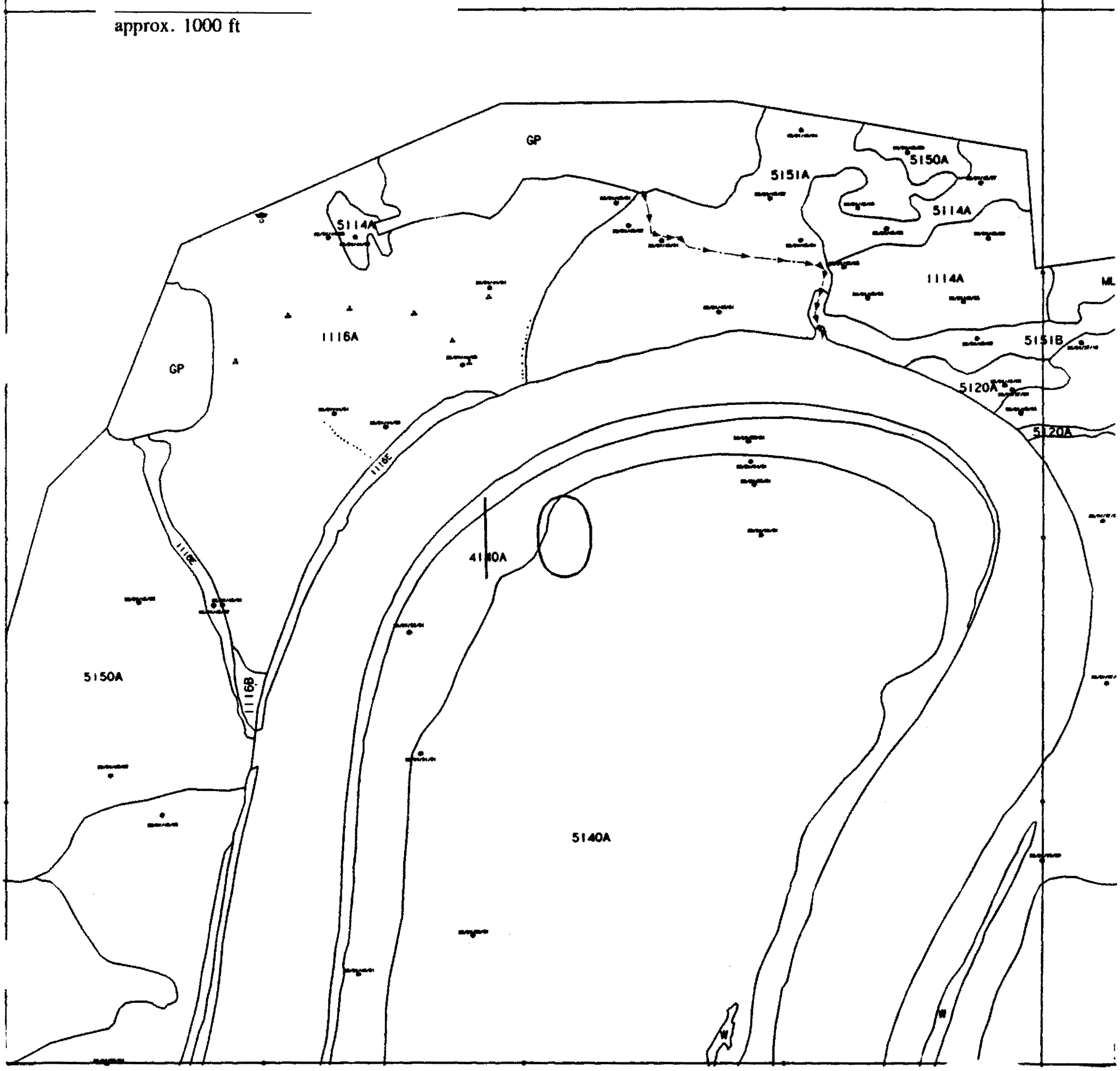
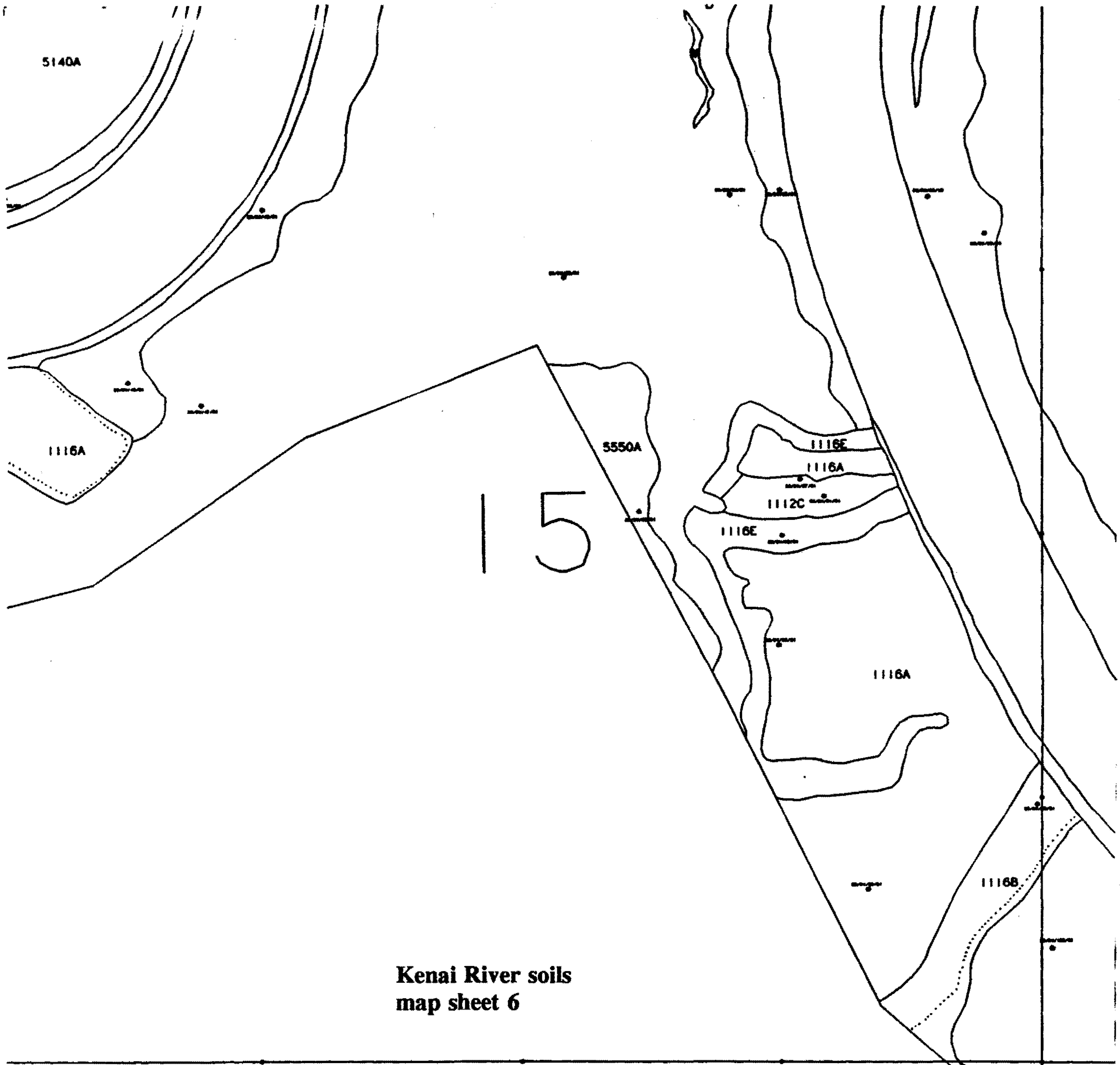
approx. 1000 ft





Kenai River soils
map sheet 6

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Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

**Kenai River soils
map sheet 7**

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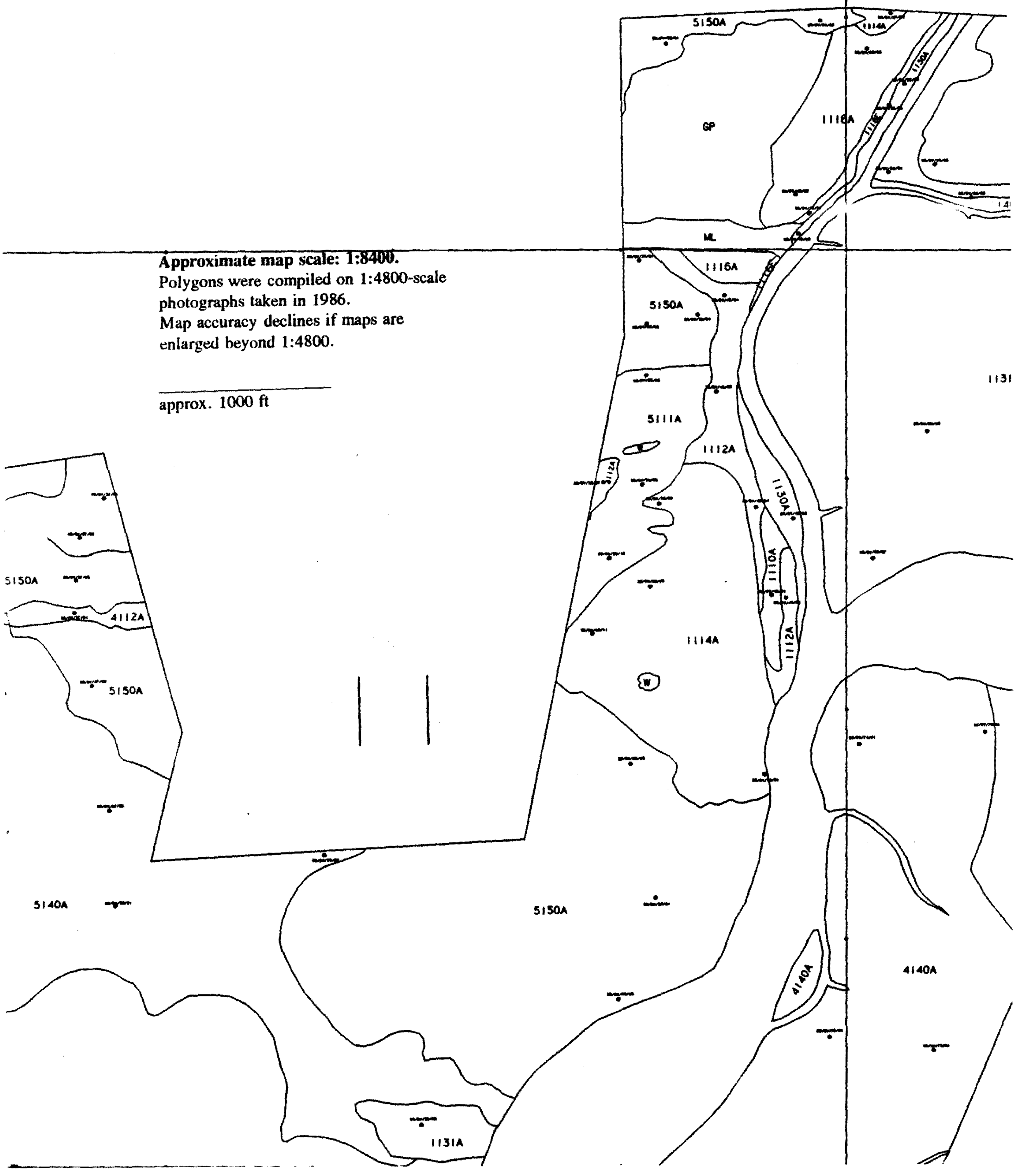
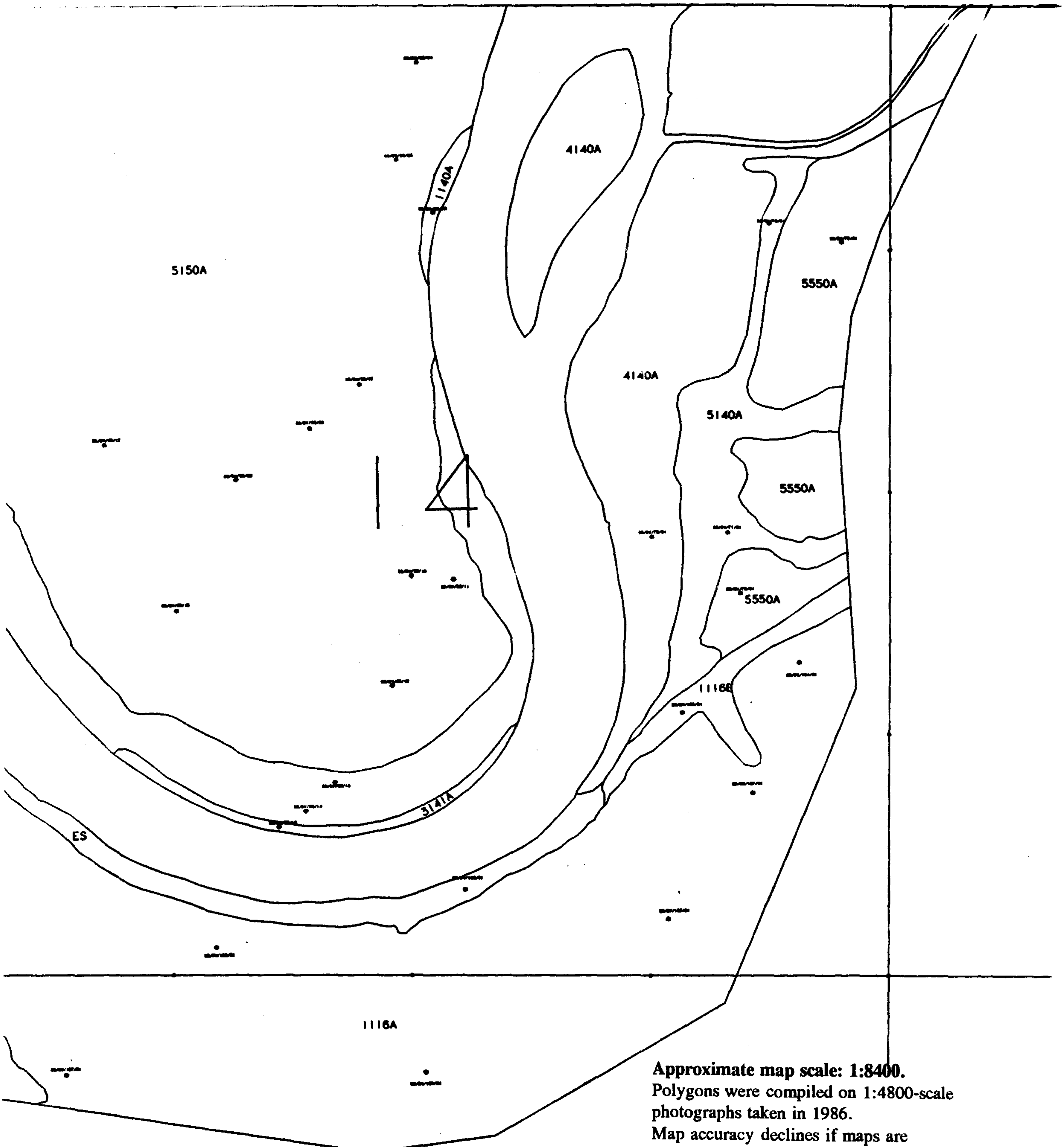
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft





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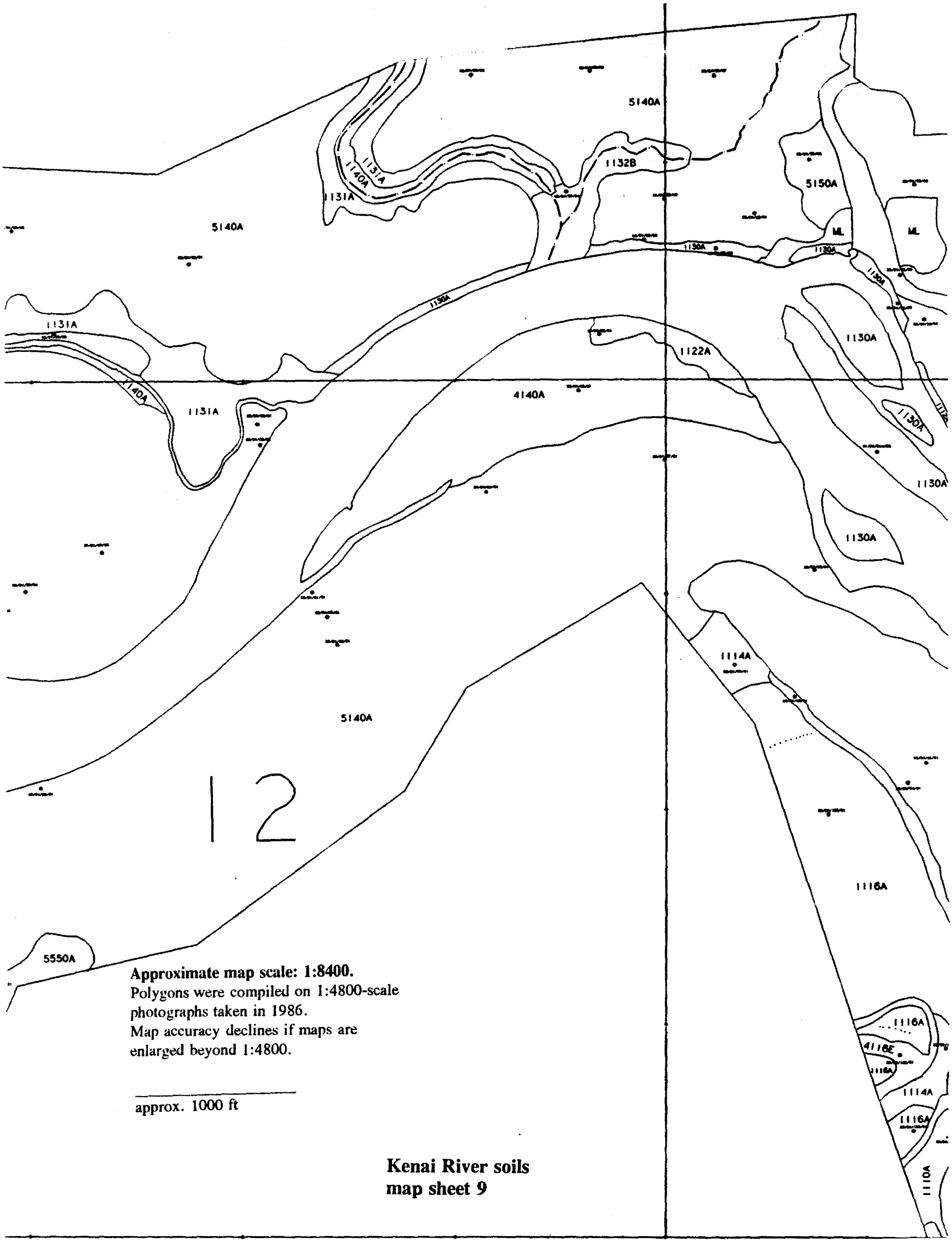
approx. 1000 ft

Kenai River soils
map sheet 8



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approx. 1000 ft

Kenai River soils map sheet 9

Kenai River soils map sheet 10

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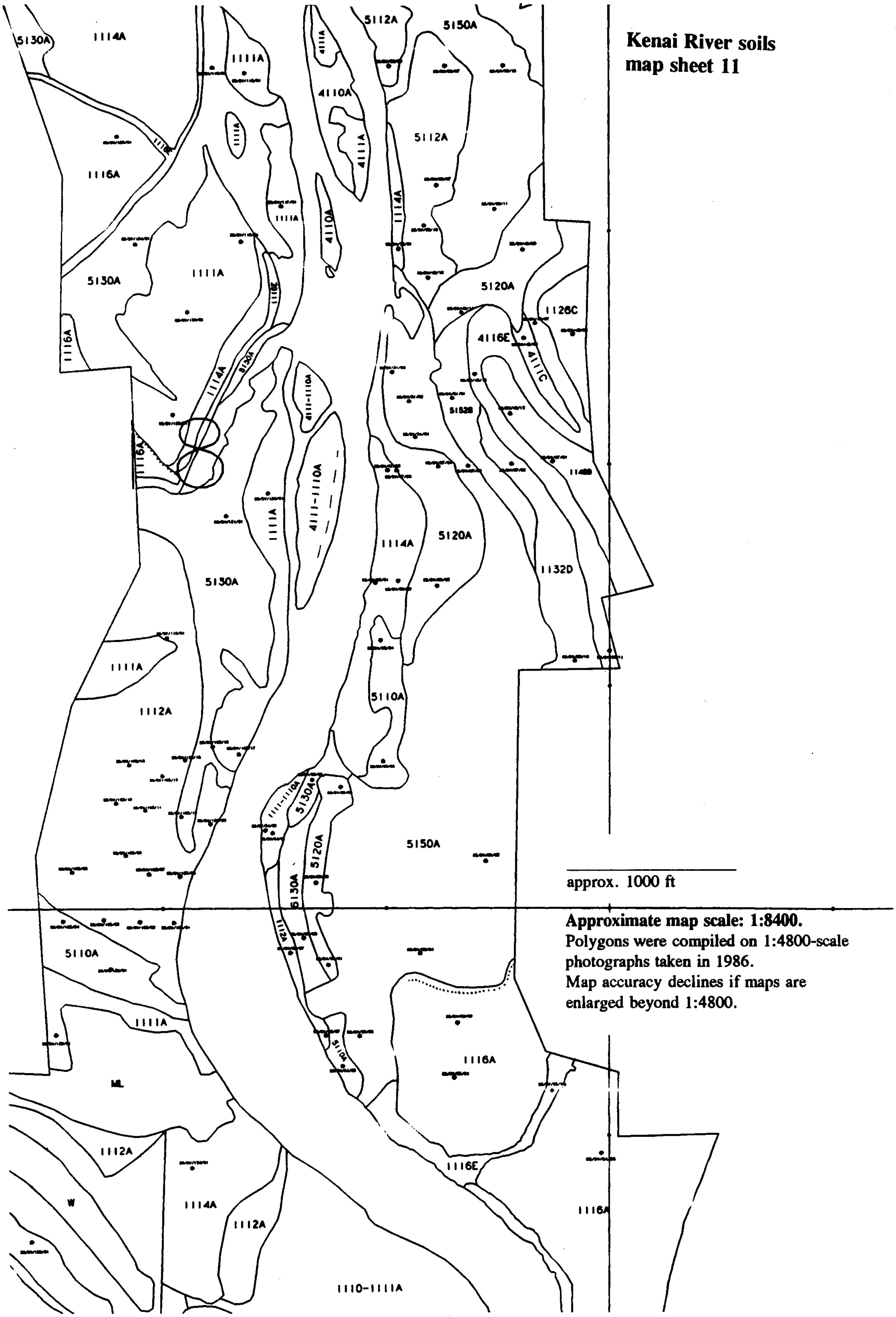
approx. 1000 ft

Kenai River soils map sheet 11



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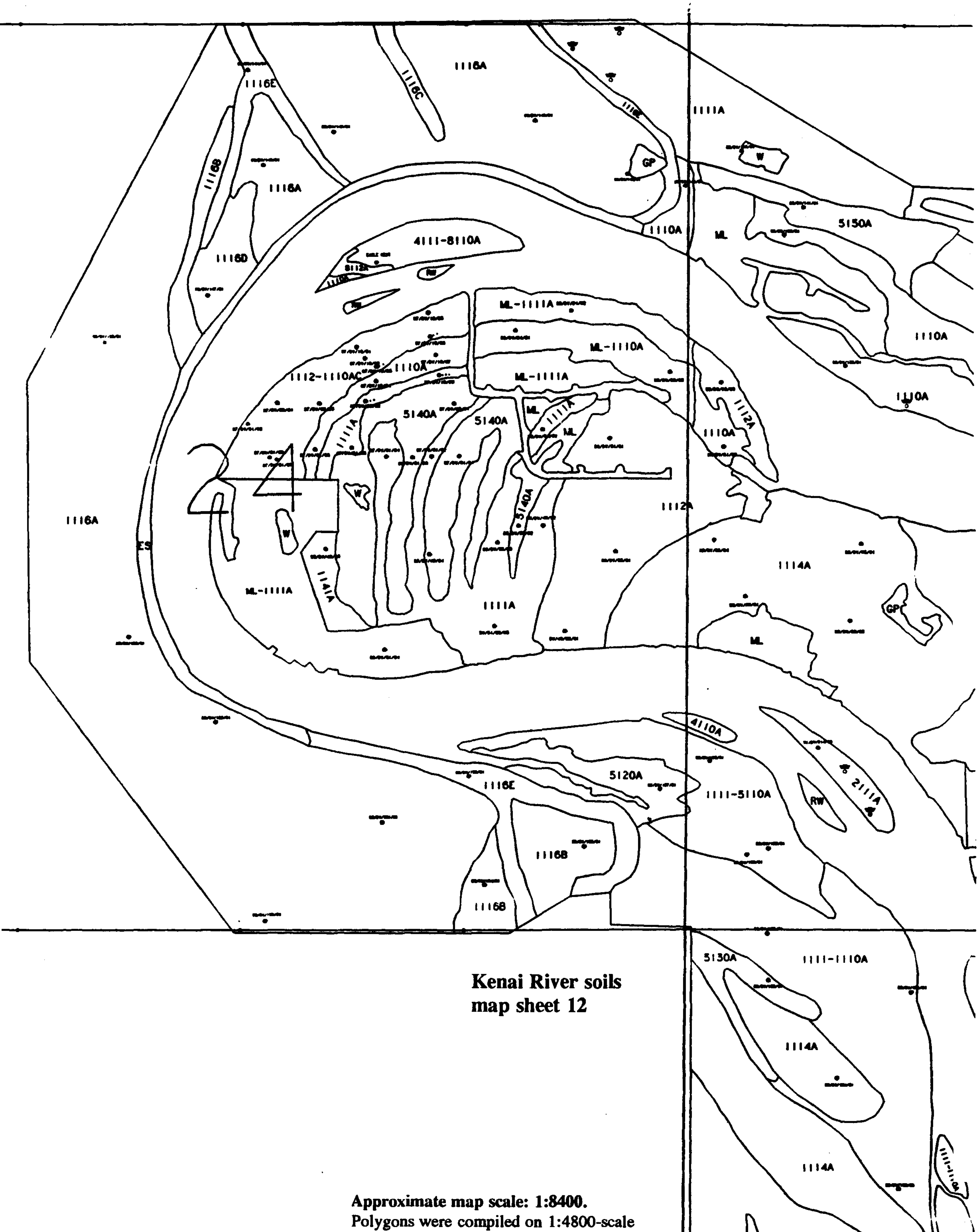

Kenai River soils map sheet 12

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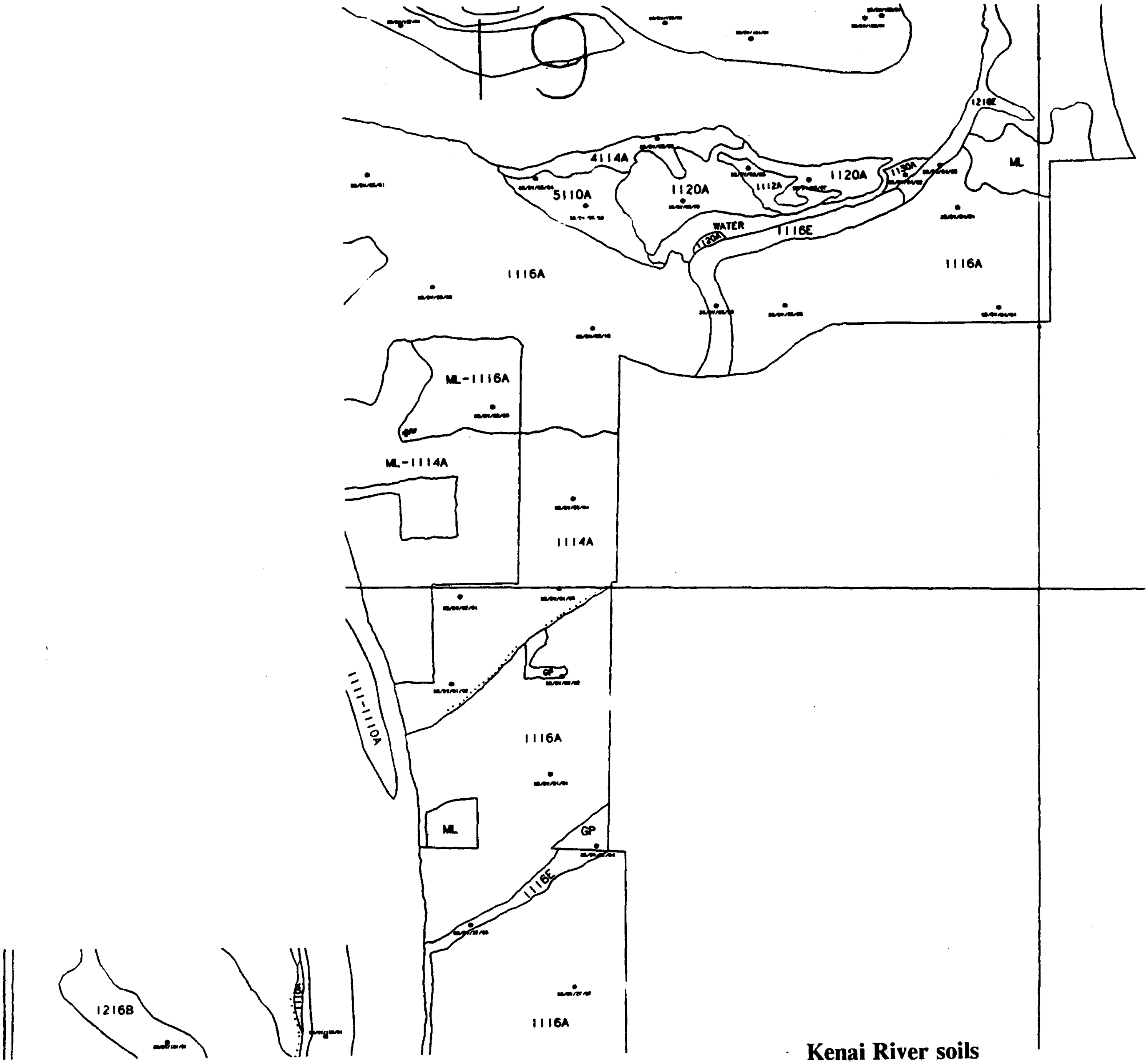
approx. 1000 ft



Kenai River soils map sheet 13

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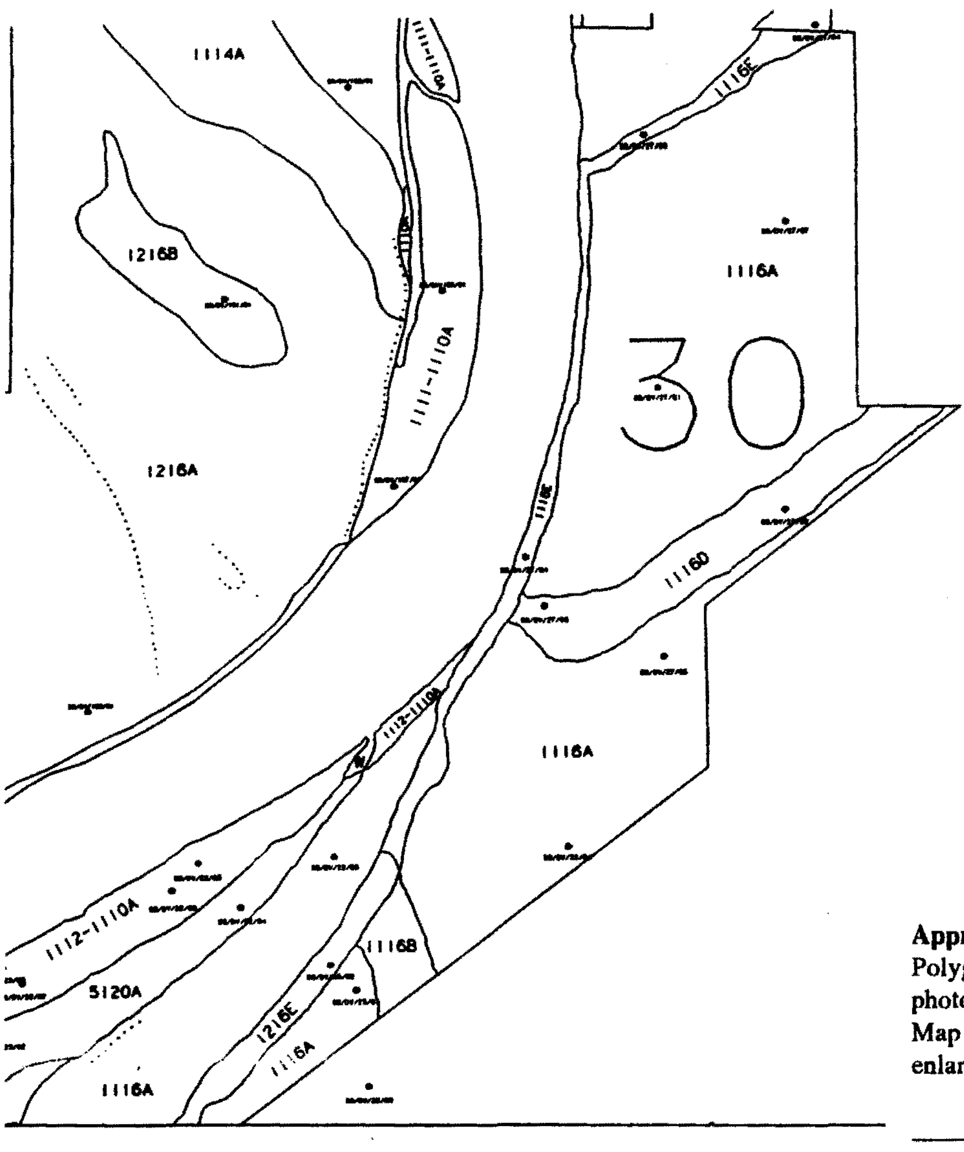
approx. 1000 ft

Kenai River soils
map sheet 14



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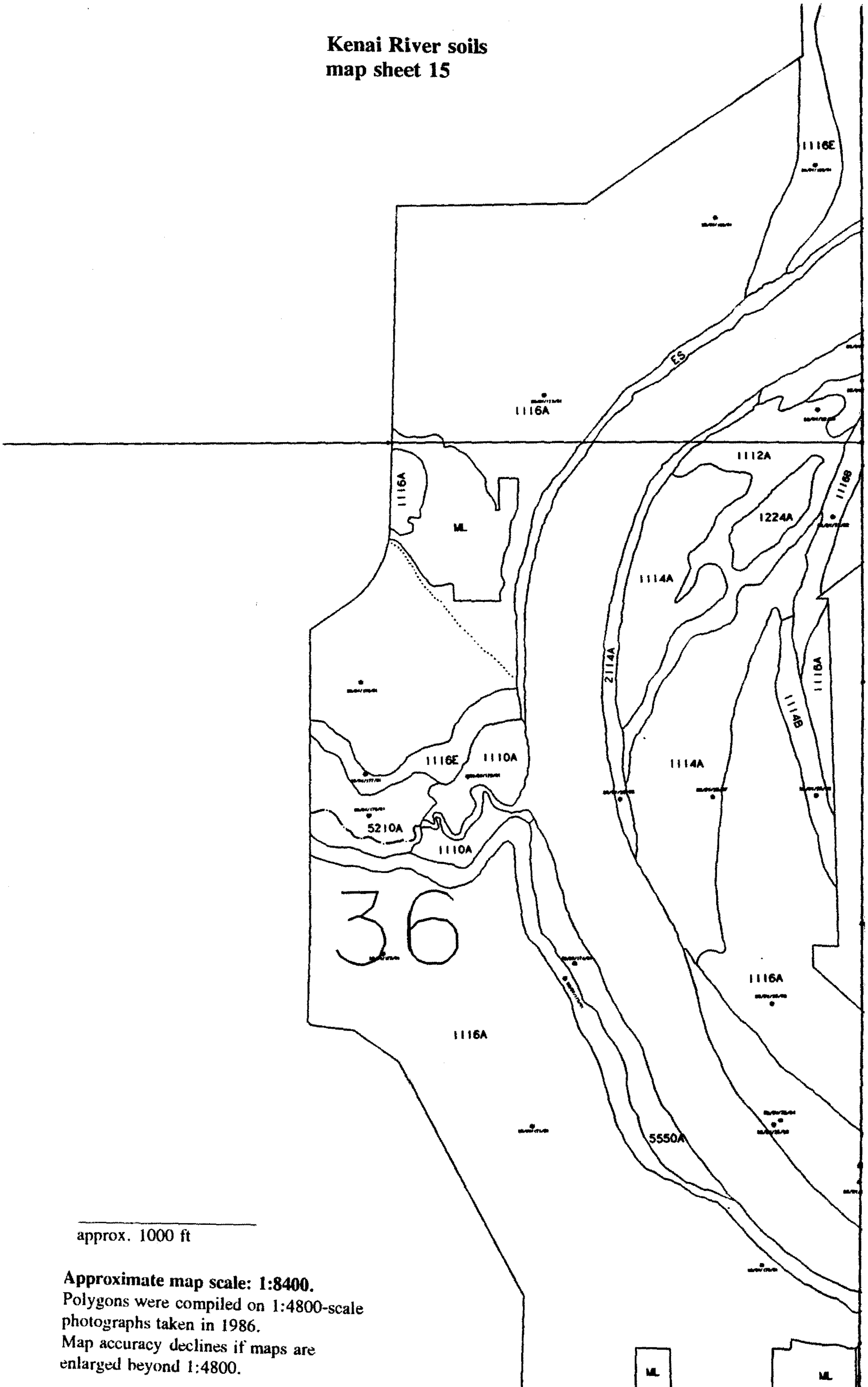
approx. 1000 ft

Kenai River soils
map sheet 15



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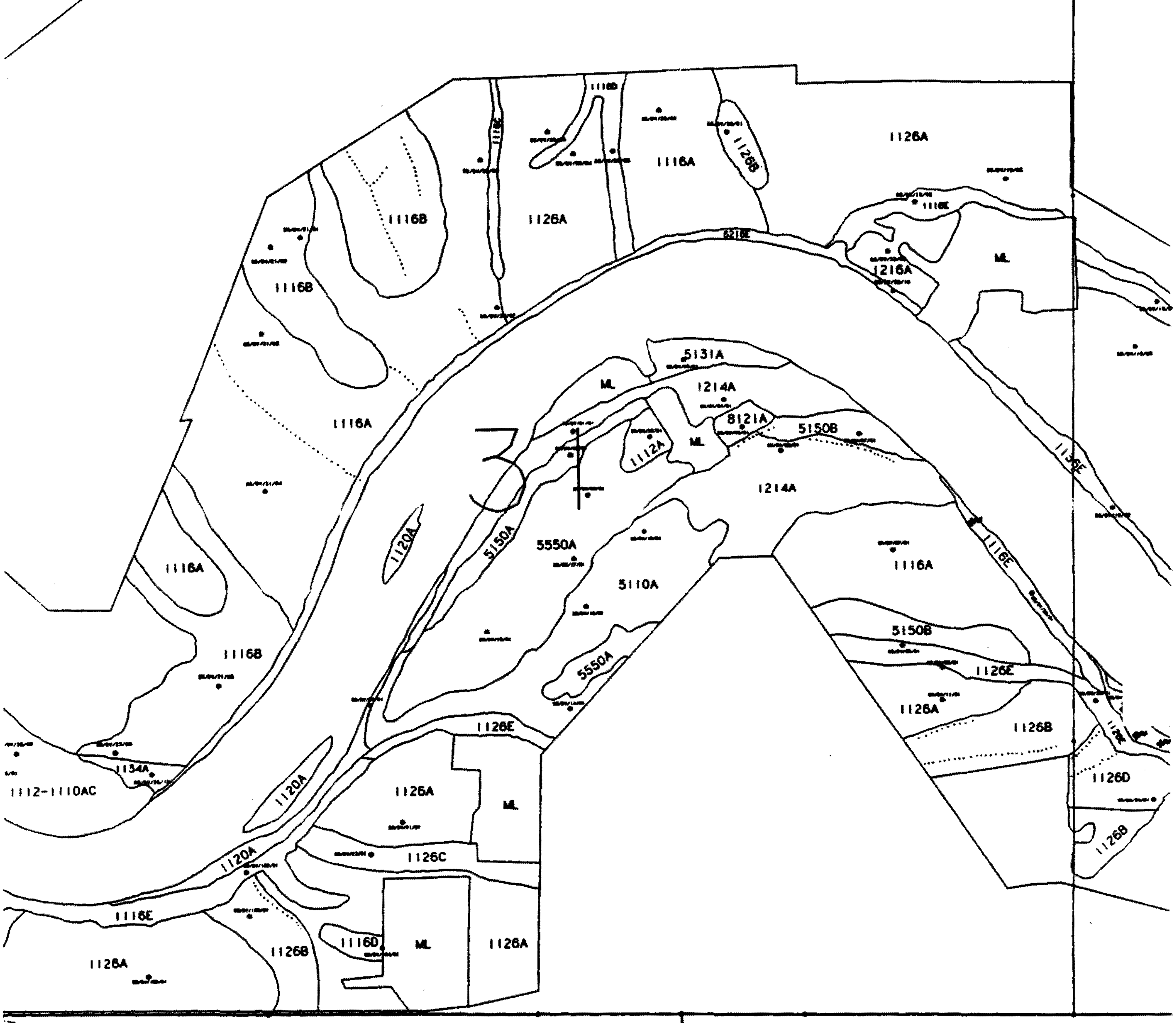
Kenai River soils
map sheet 16



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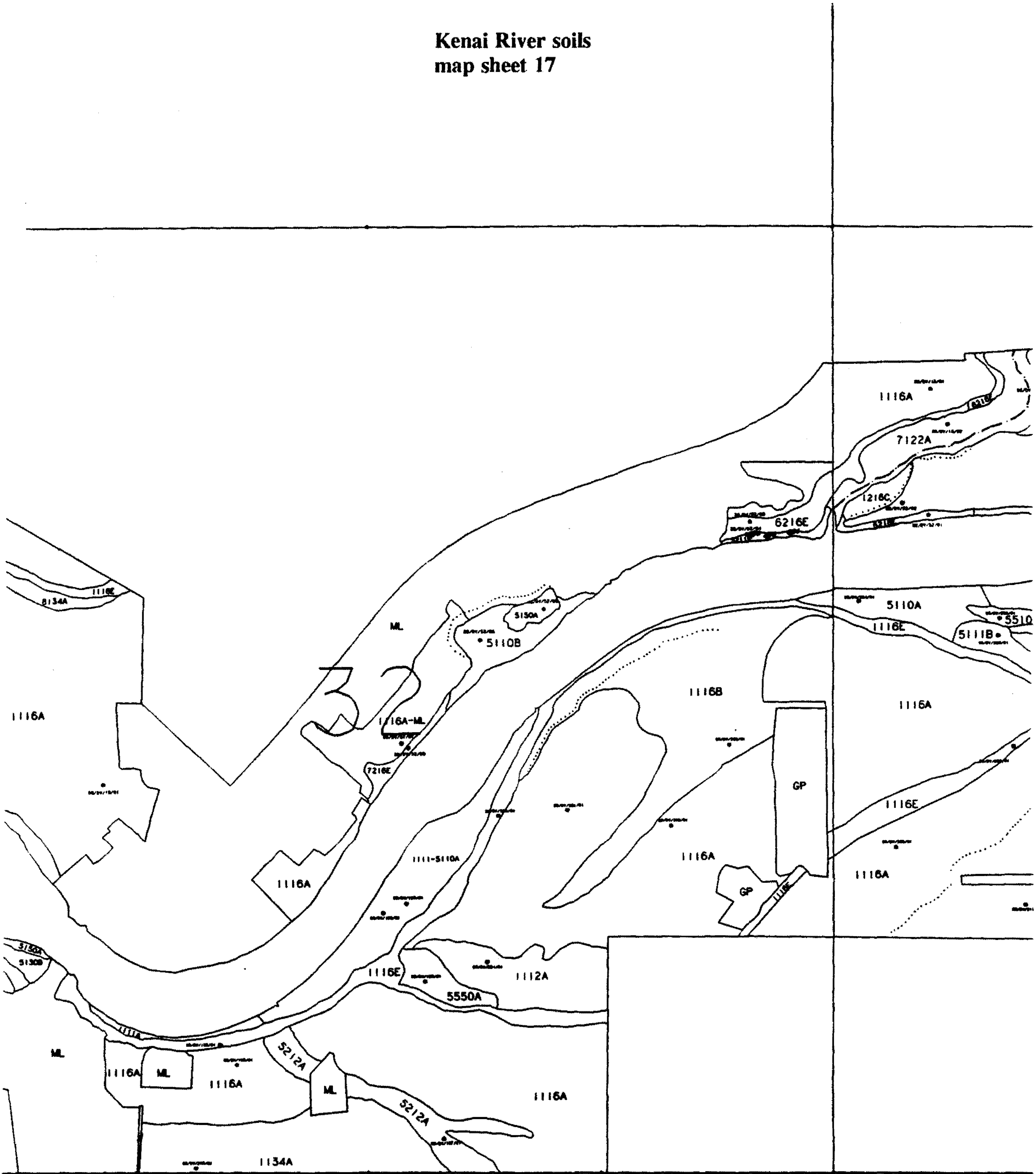
Kenai River soils
map sheet 17



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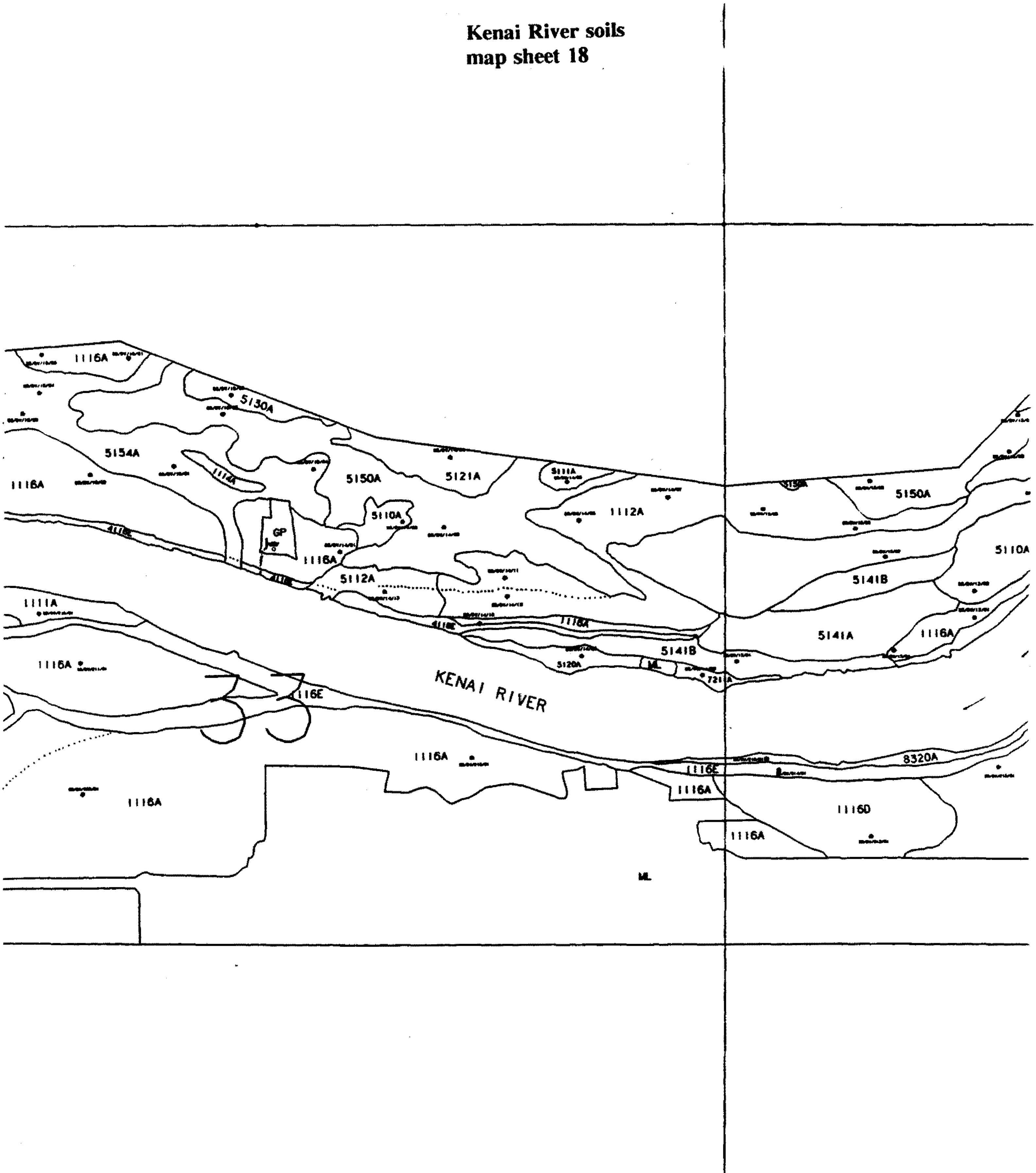
approx. 1000 ft

Kenai River soils map sheet 18



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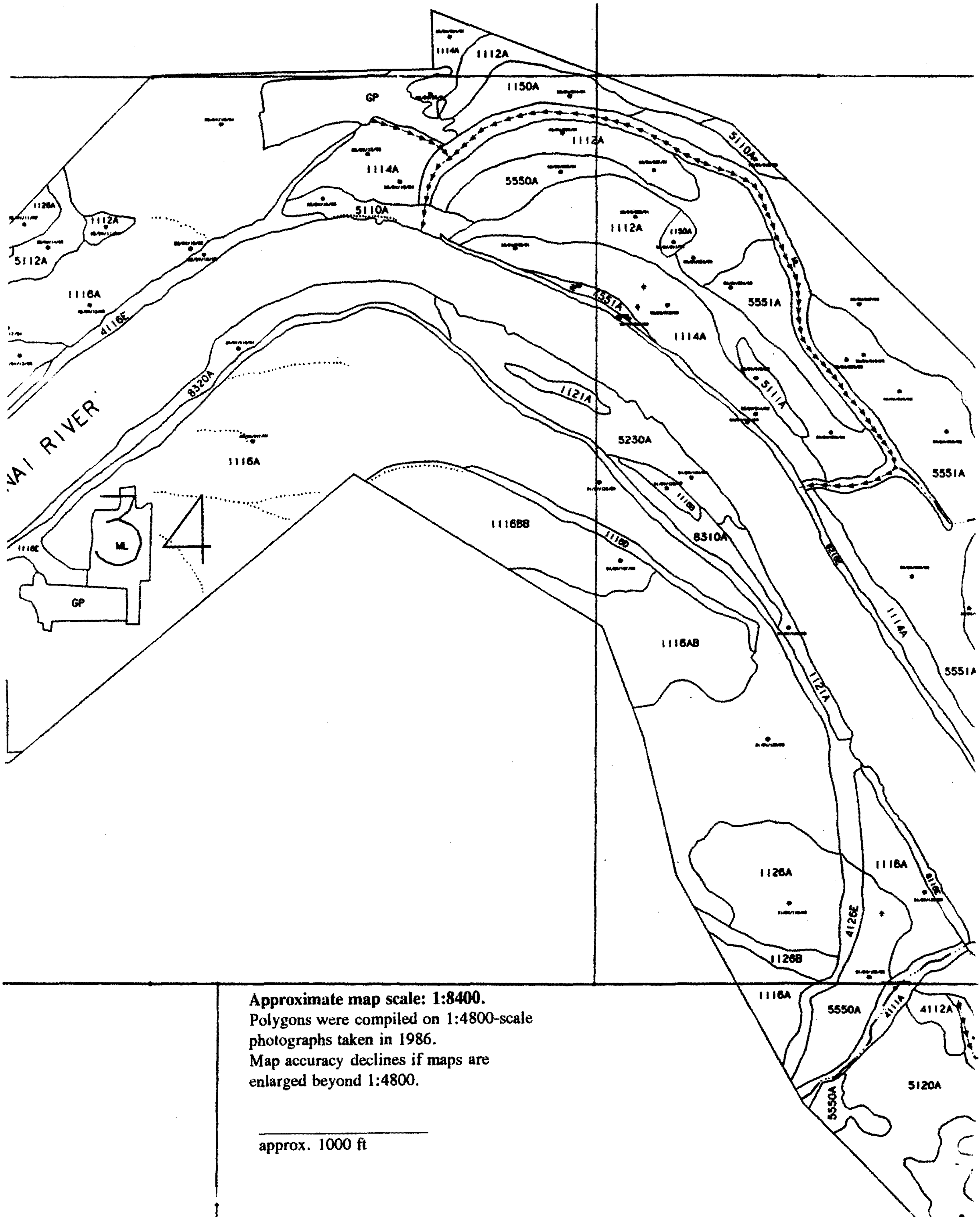

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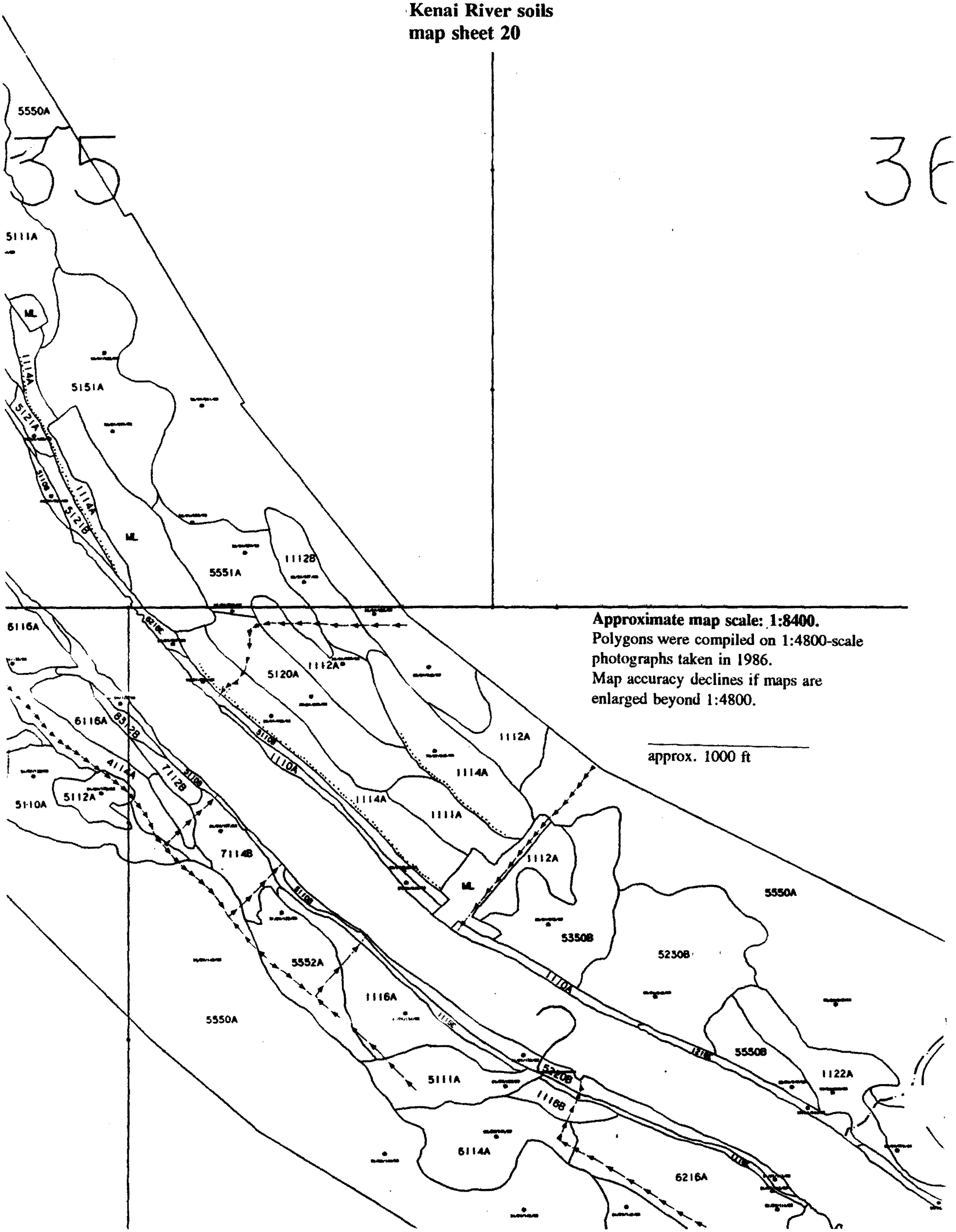
approx. 1000 ft

Kenai River soils
map sheet 19

Kenai River soils
map sheet 20



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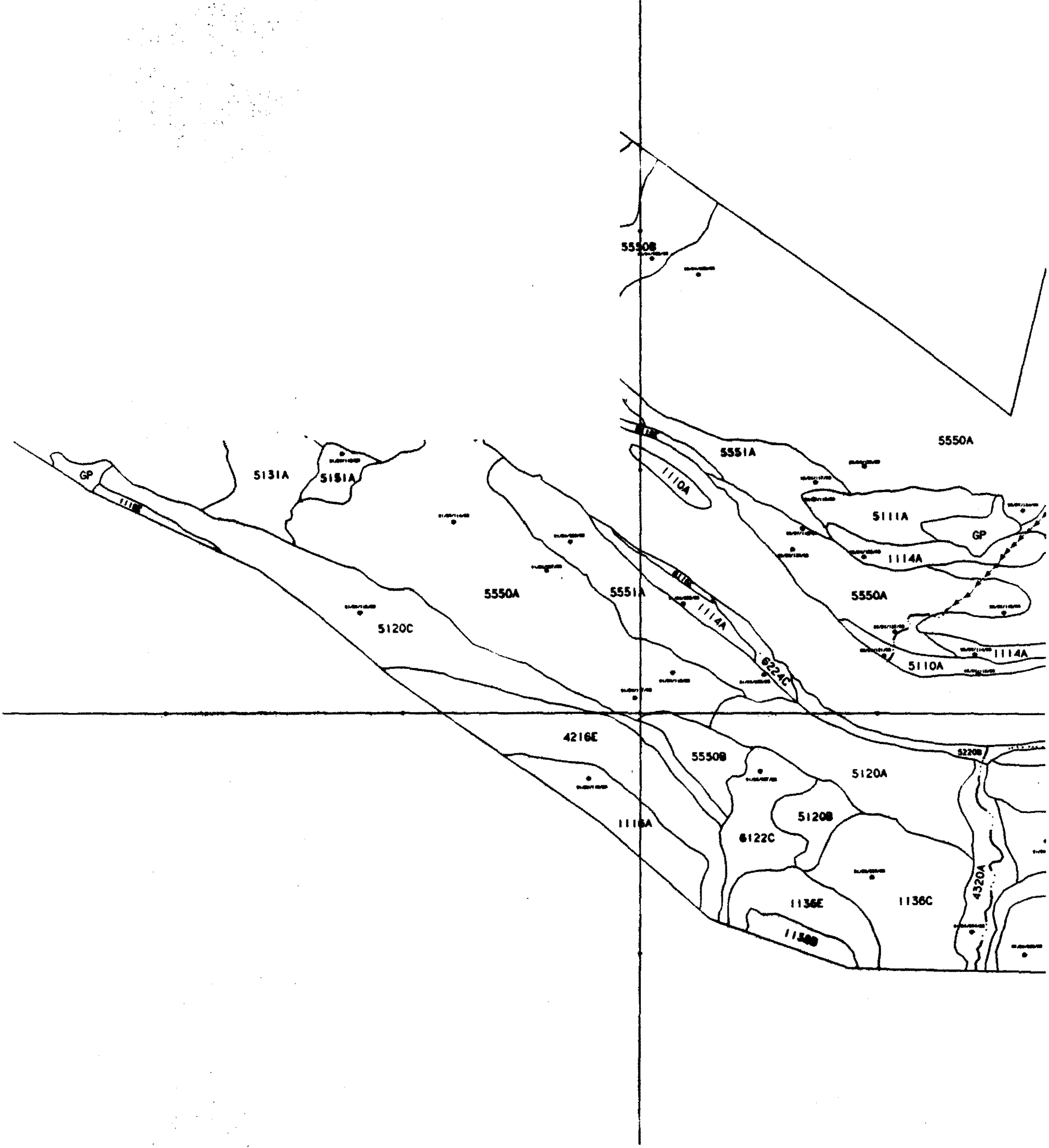
approx. 1000 ft

Kenai River soils
map sheet 21



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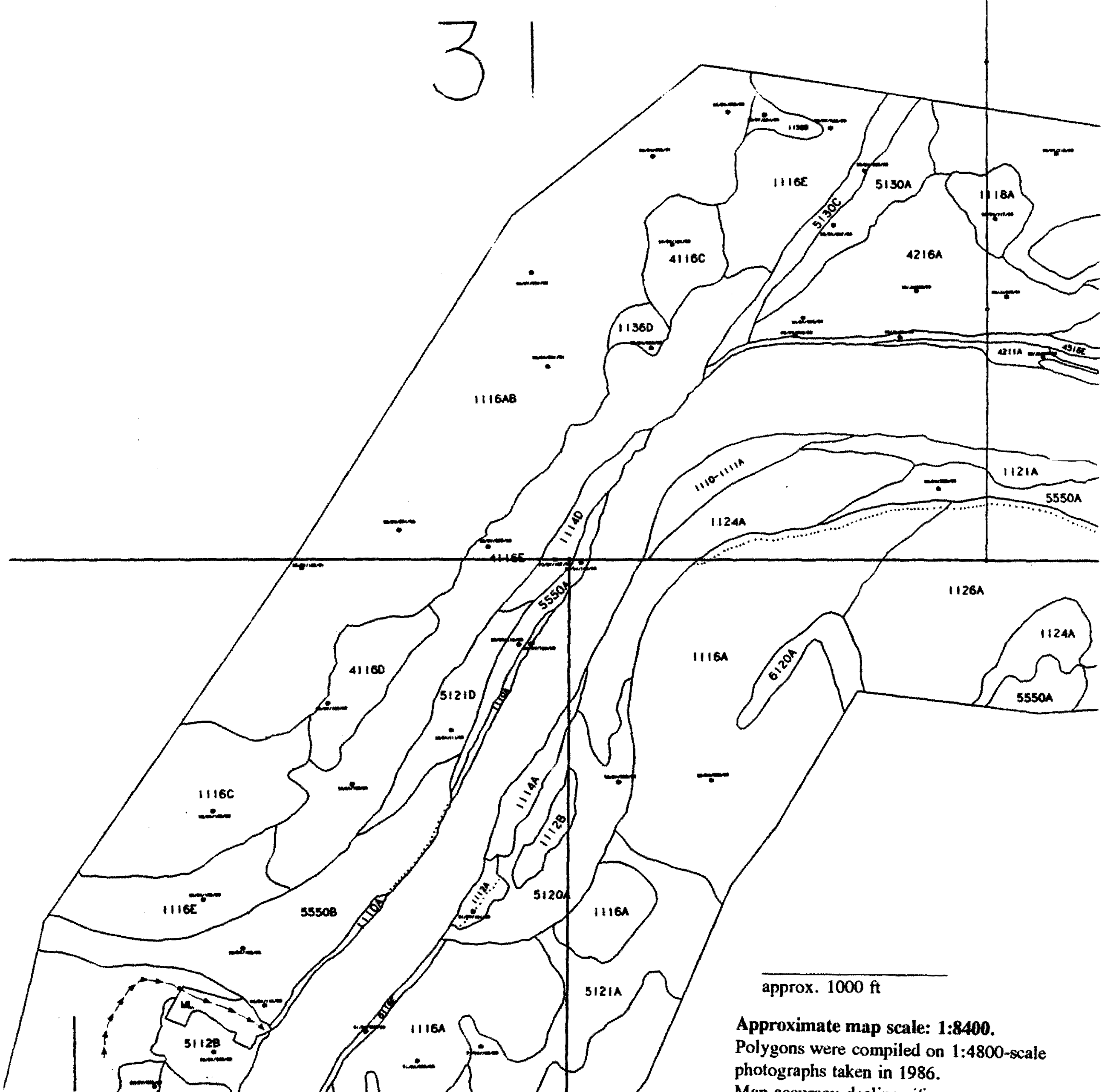
Kenai River soils
map sheet 22



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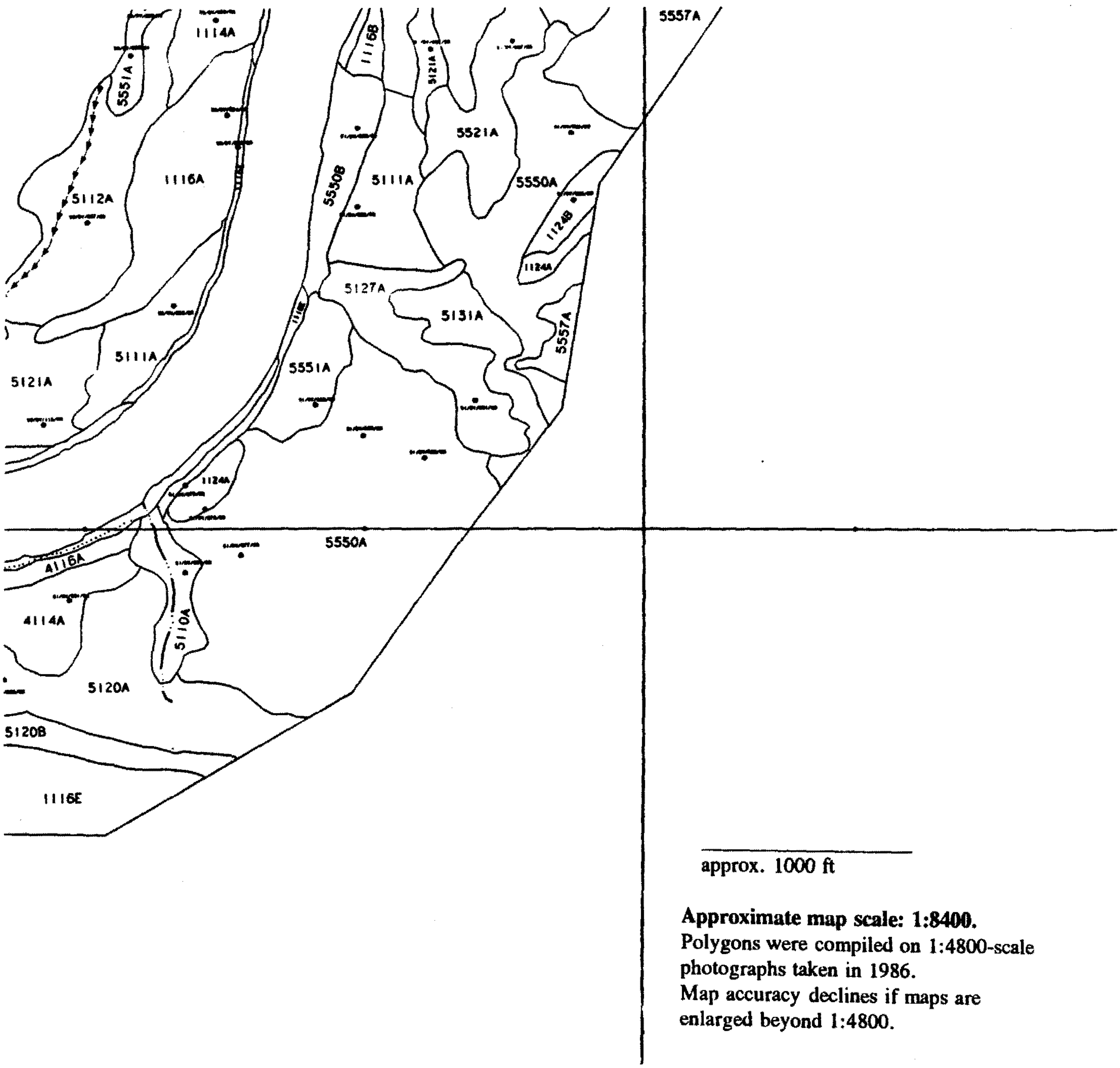
Kenai River soils
map sheet 23



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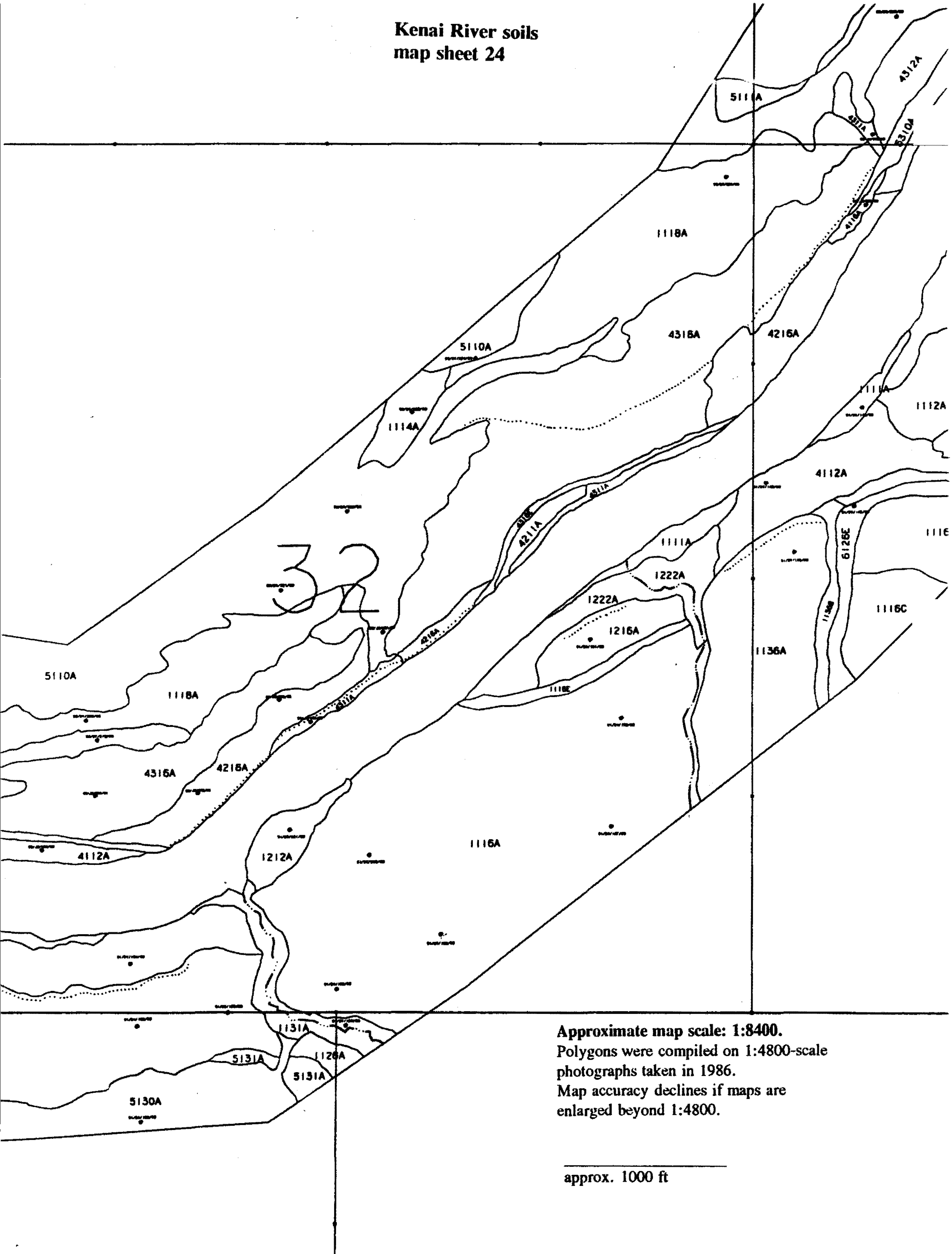
Kenai River soils
map sheet 24



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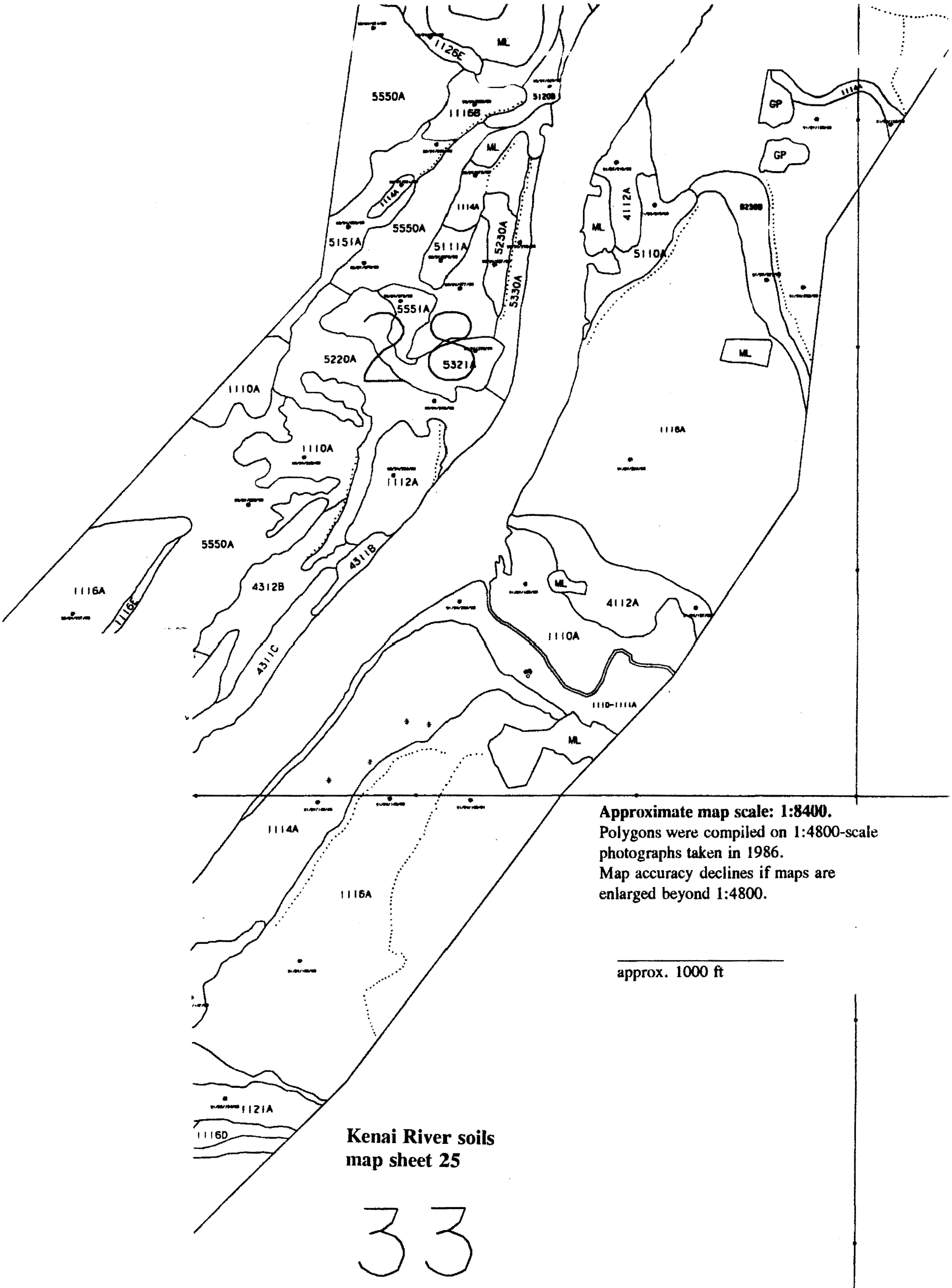

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approx. 1000 ft

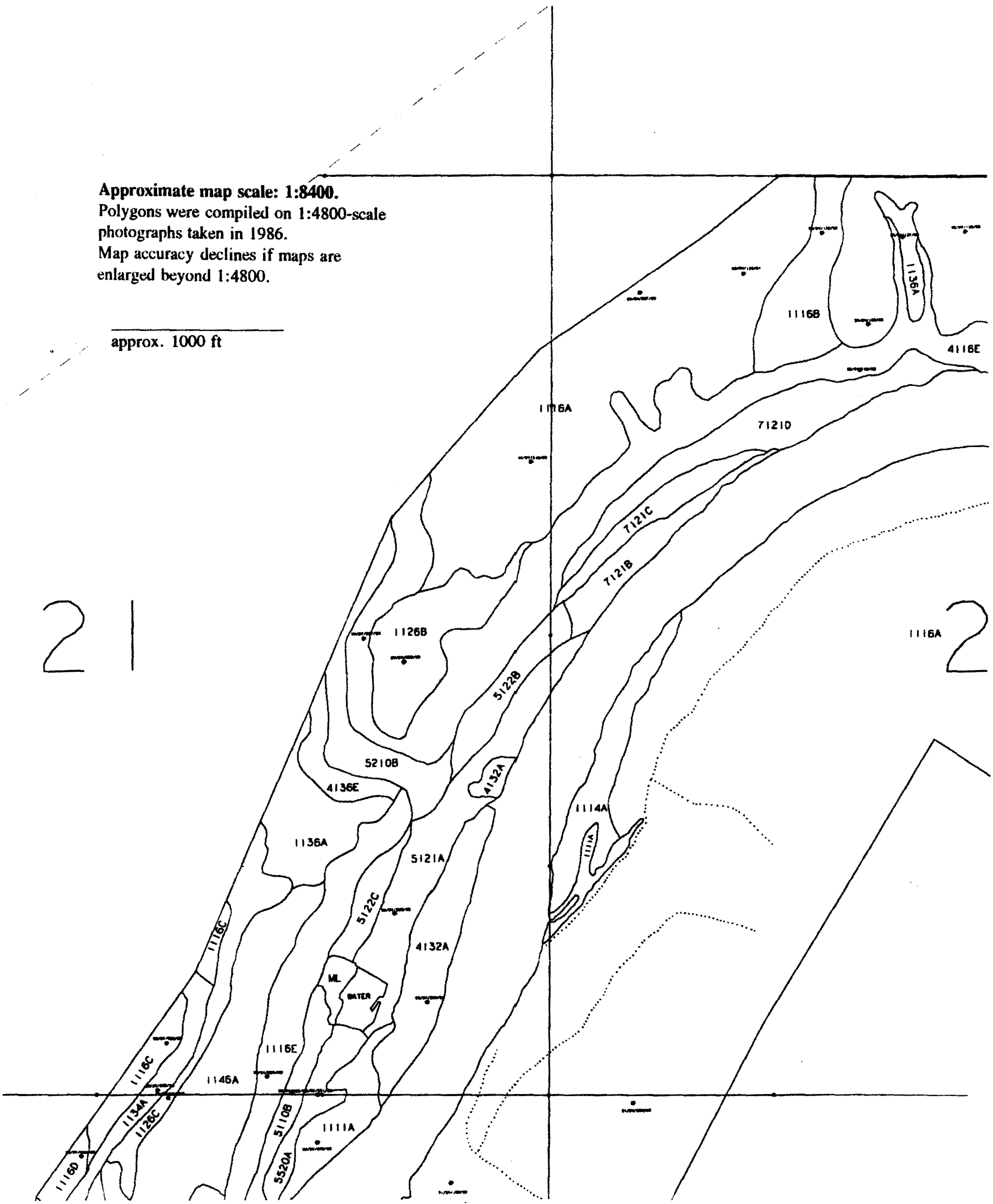
Kenai River soils map sheet 25

33

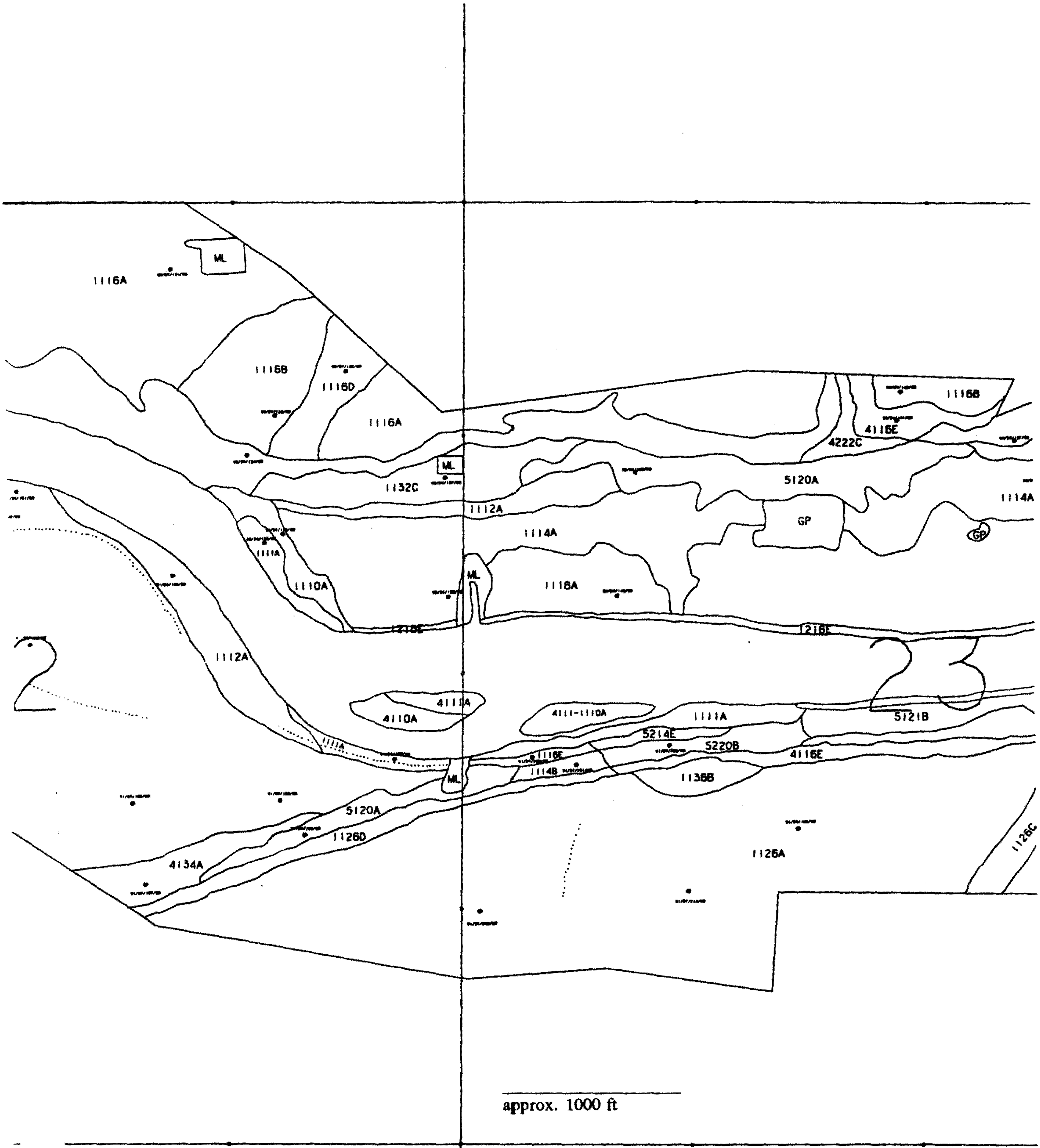
Kenai River soils
map sheet 26

Approximate map scale: 1:8400.
Polygons were compiled on 1:4800-scale photographs taken in 1986.
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft



Kenai River soils
map sheet 27



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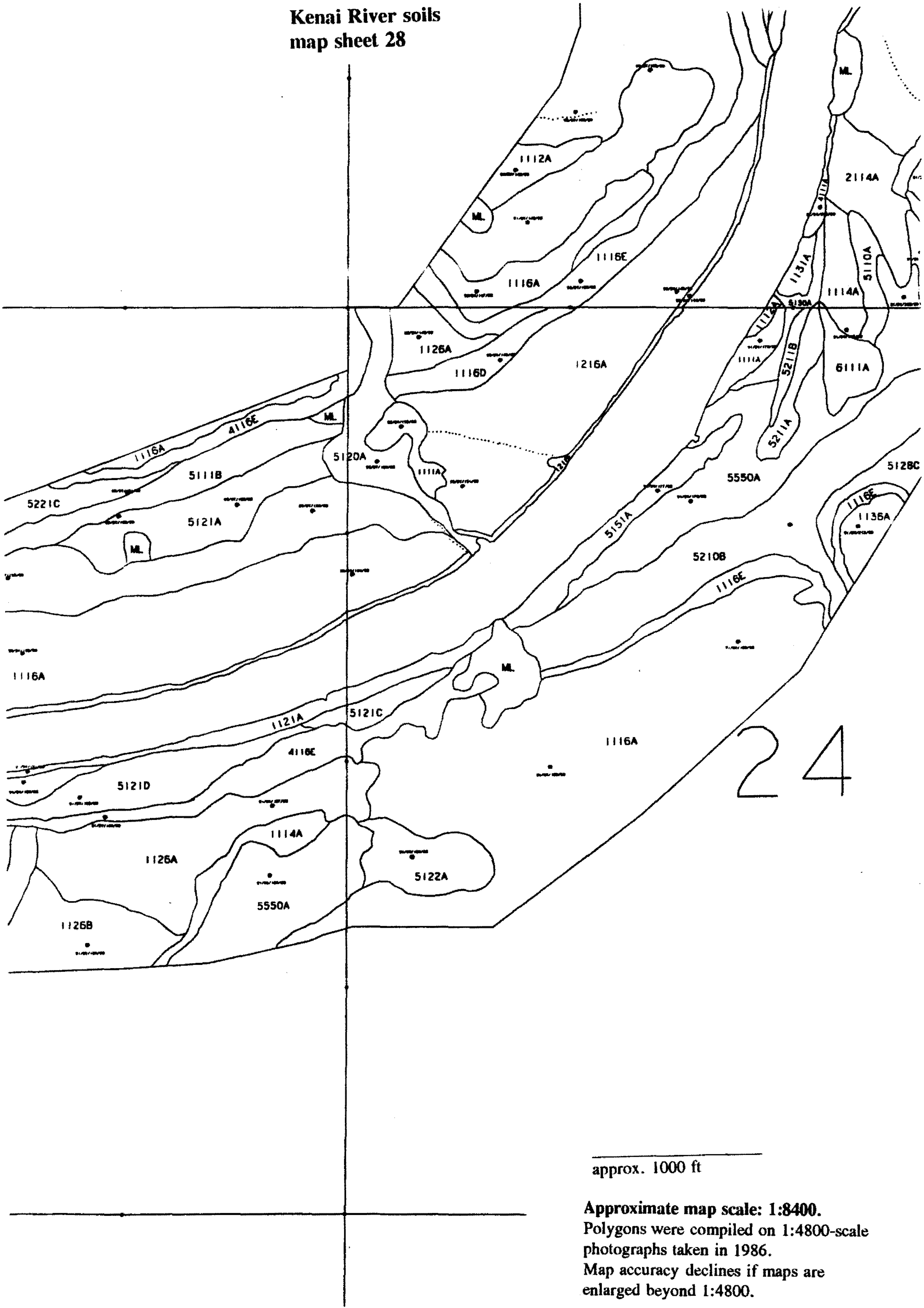
Kenai River soils map sheet 28



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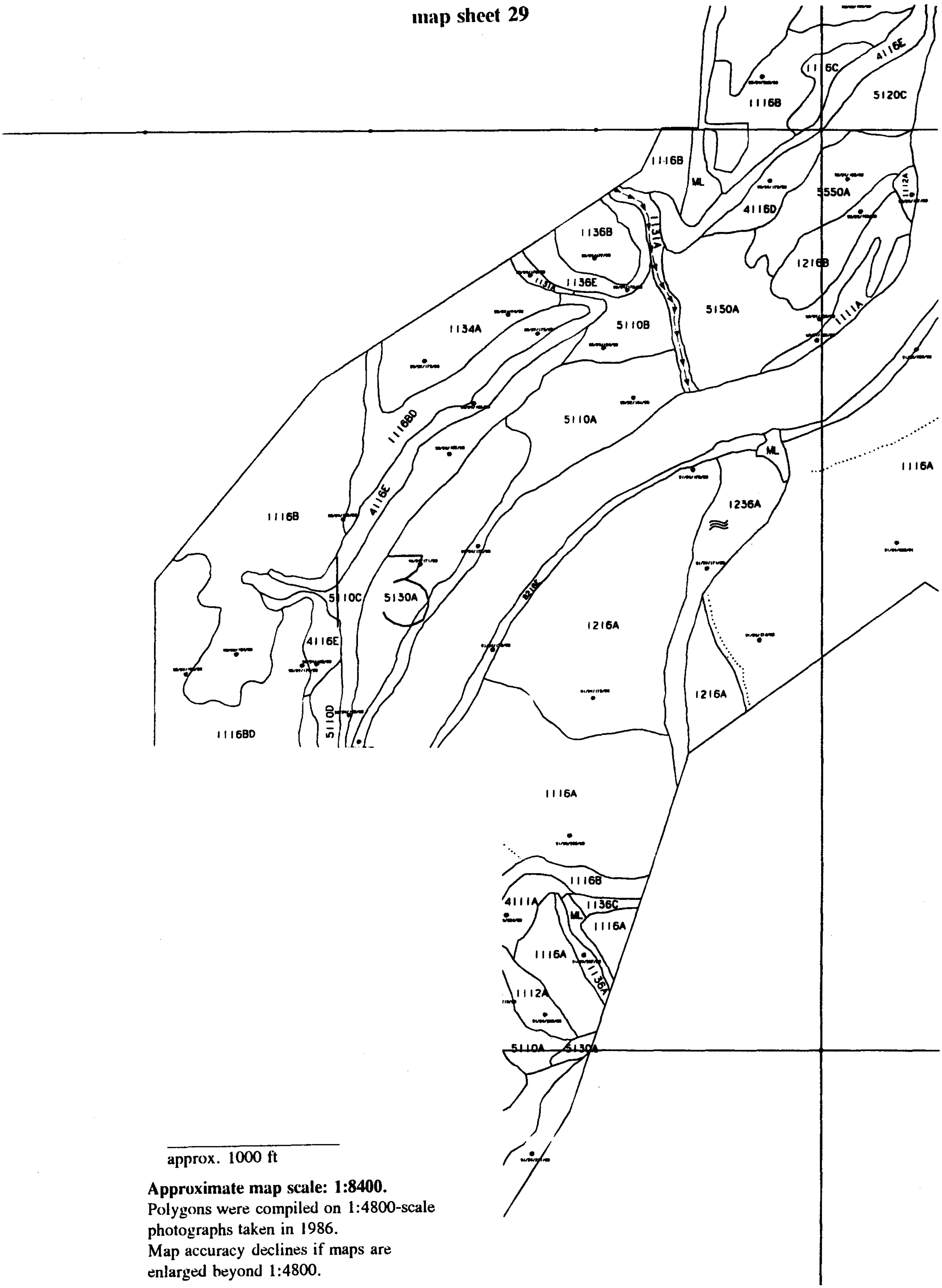
Kenai River soils
map sheet 29



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Map accuracy declines if maps are enlarged beyond 1:4800.

Kenai River soils
map sheet 30

approx. 1000 ft

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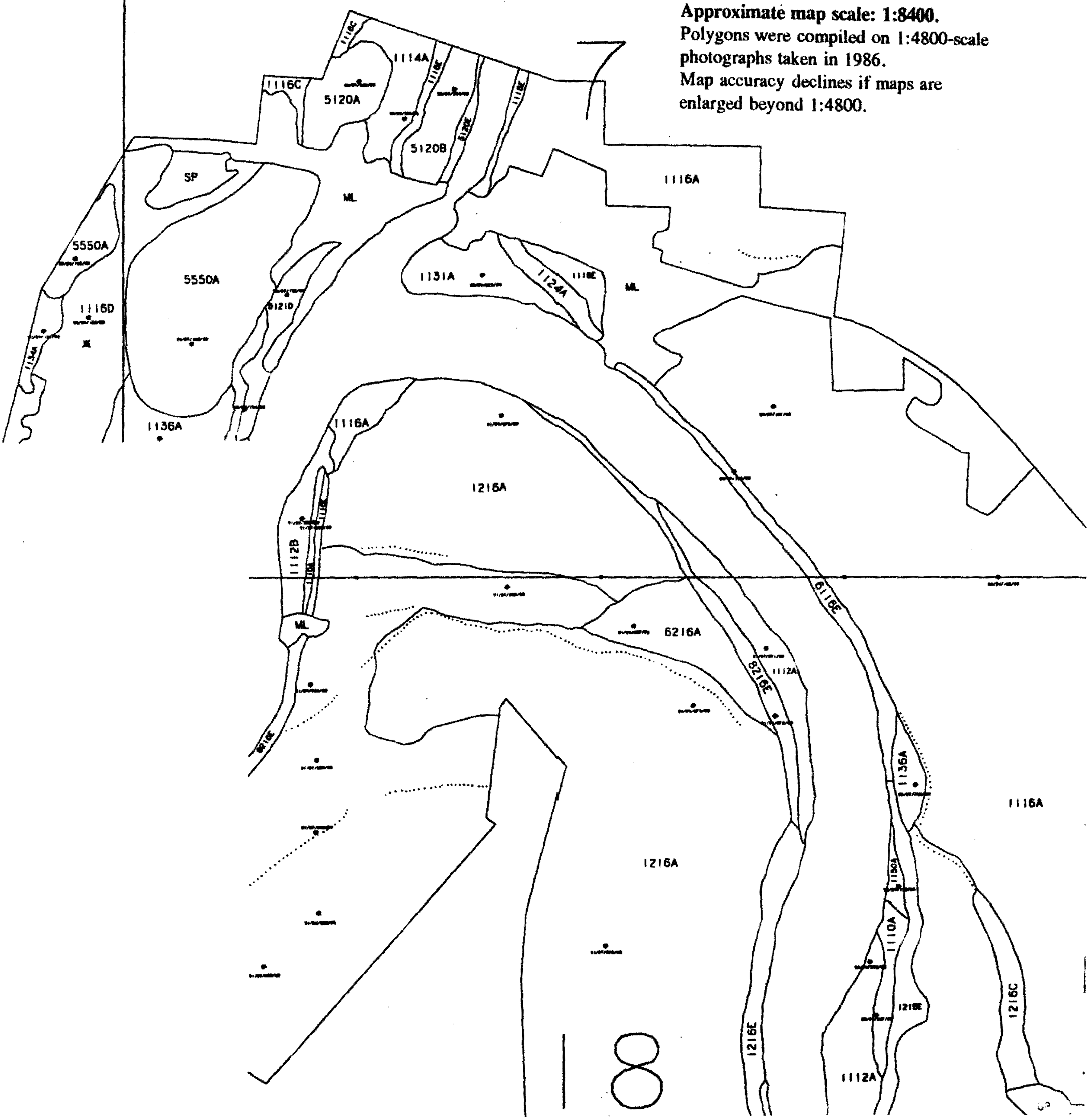
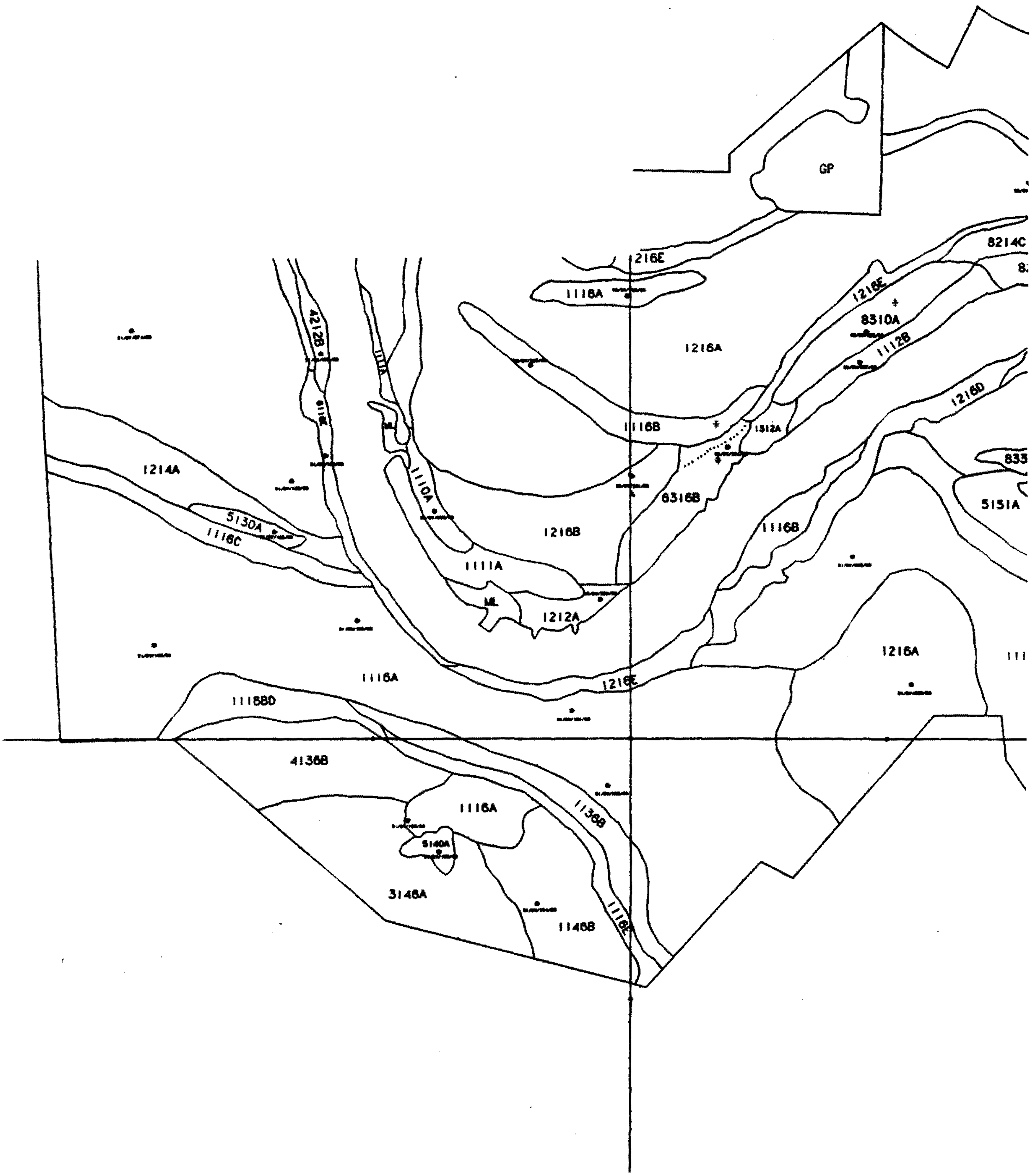


Kenai River soils
map sheet 31



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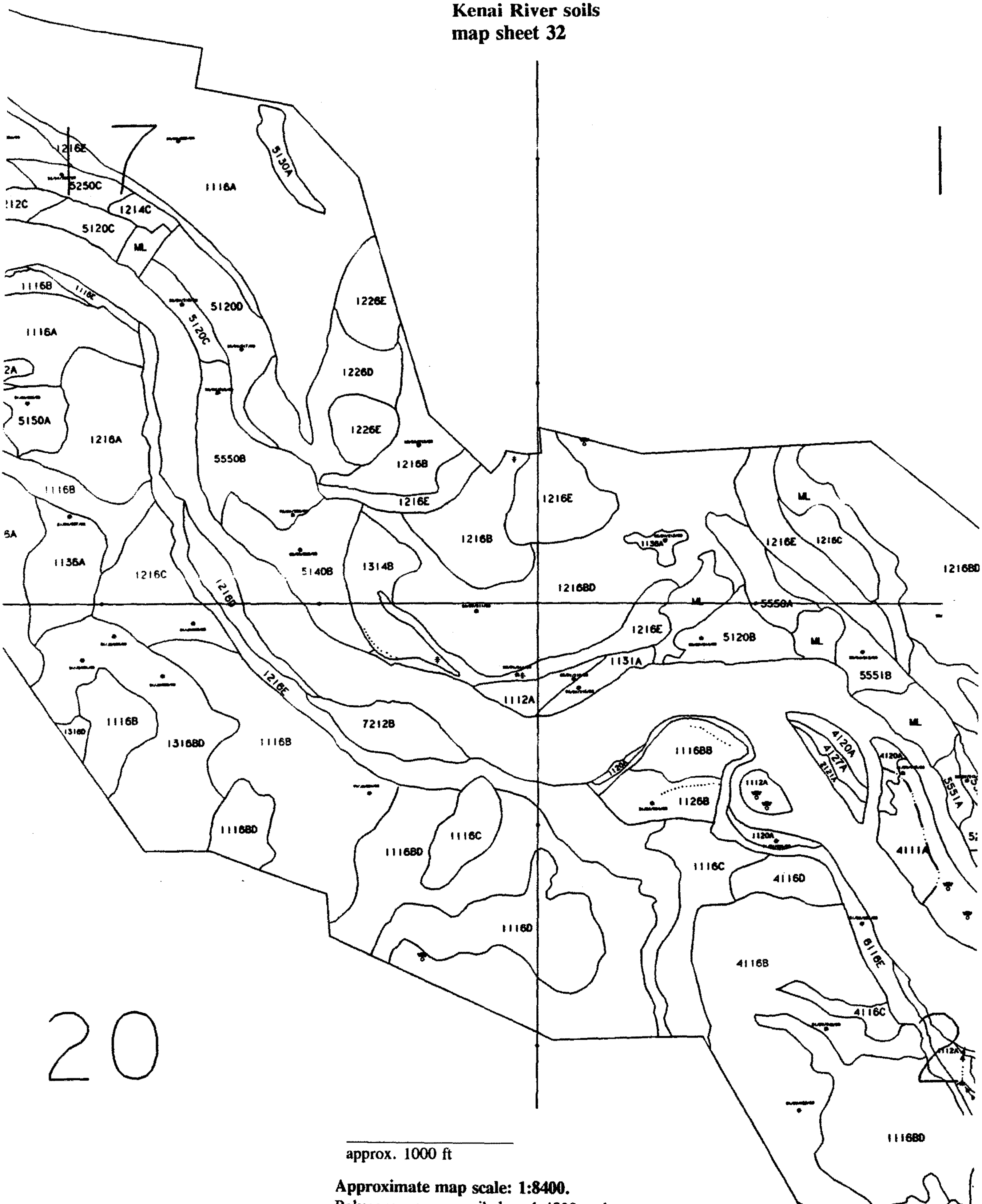
Kenai River soils
map sheet 32



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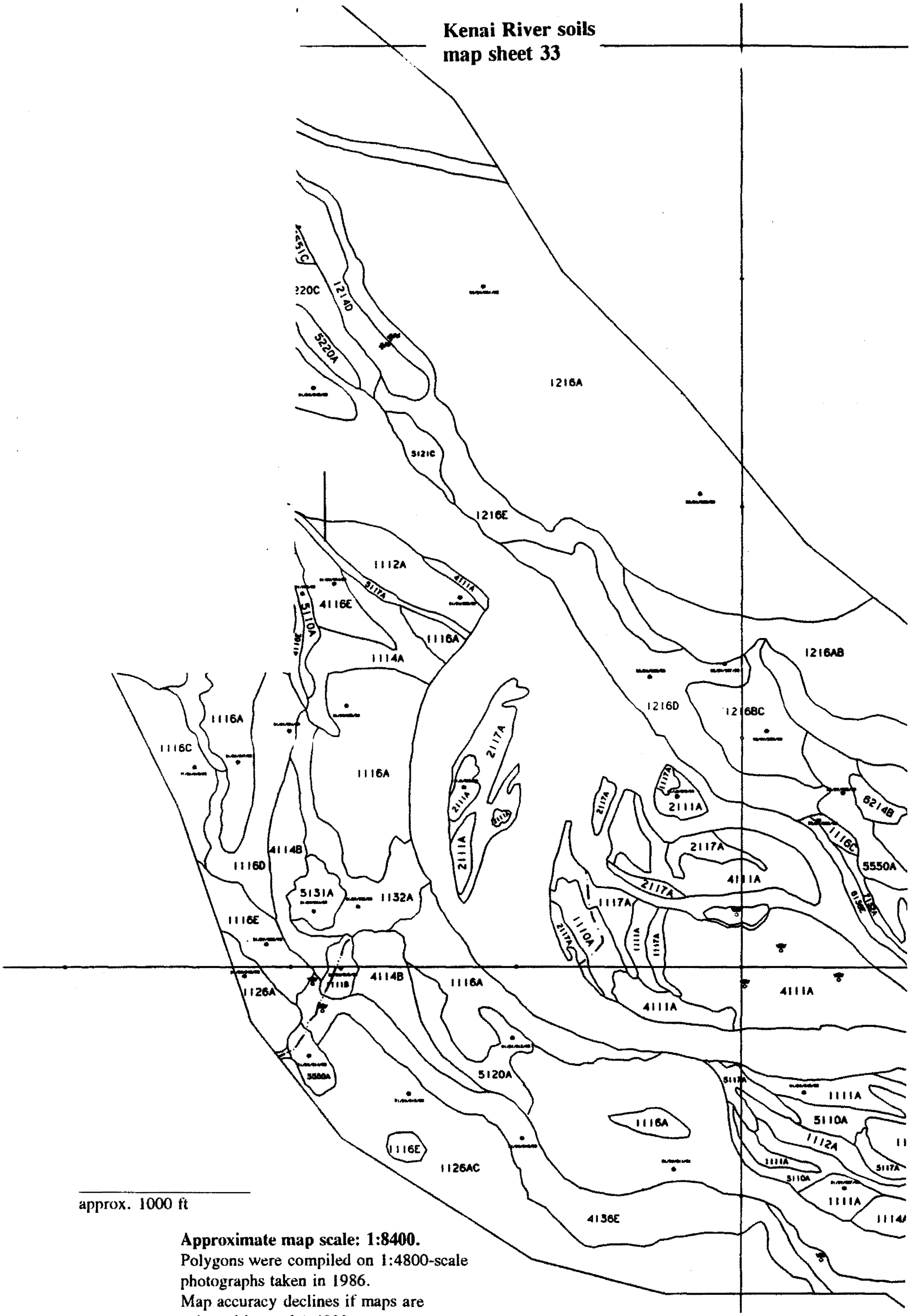
Kenai River soils map sheet 33



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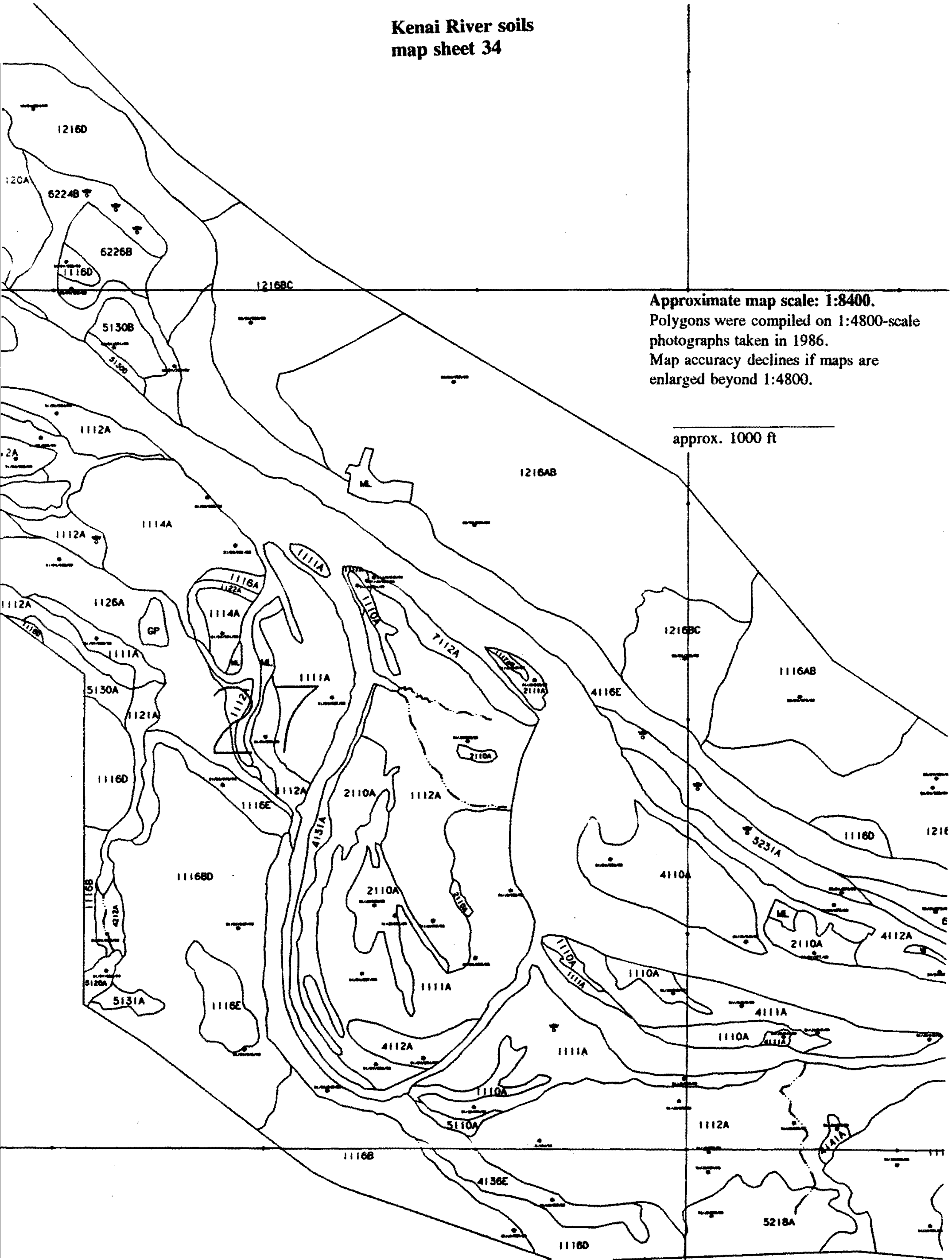
Kenai River soils
map sheet 34



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approx. 1000 ft

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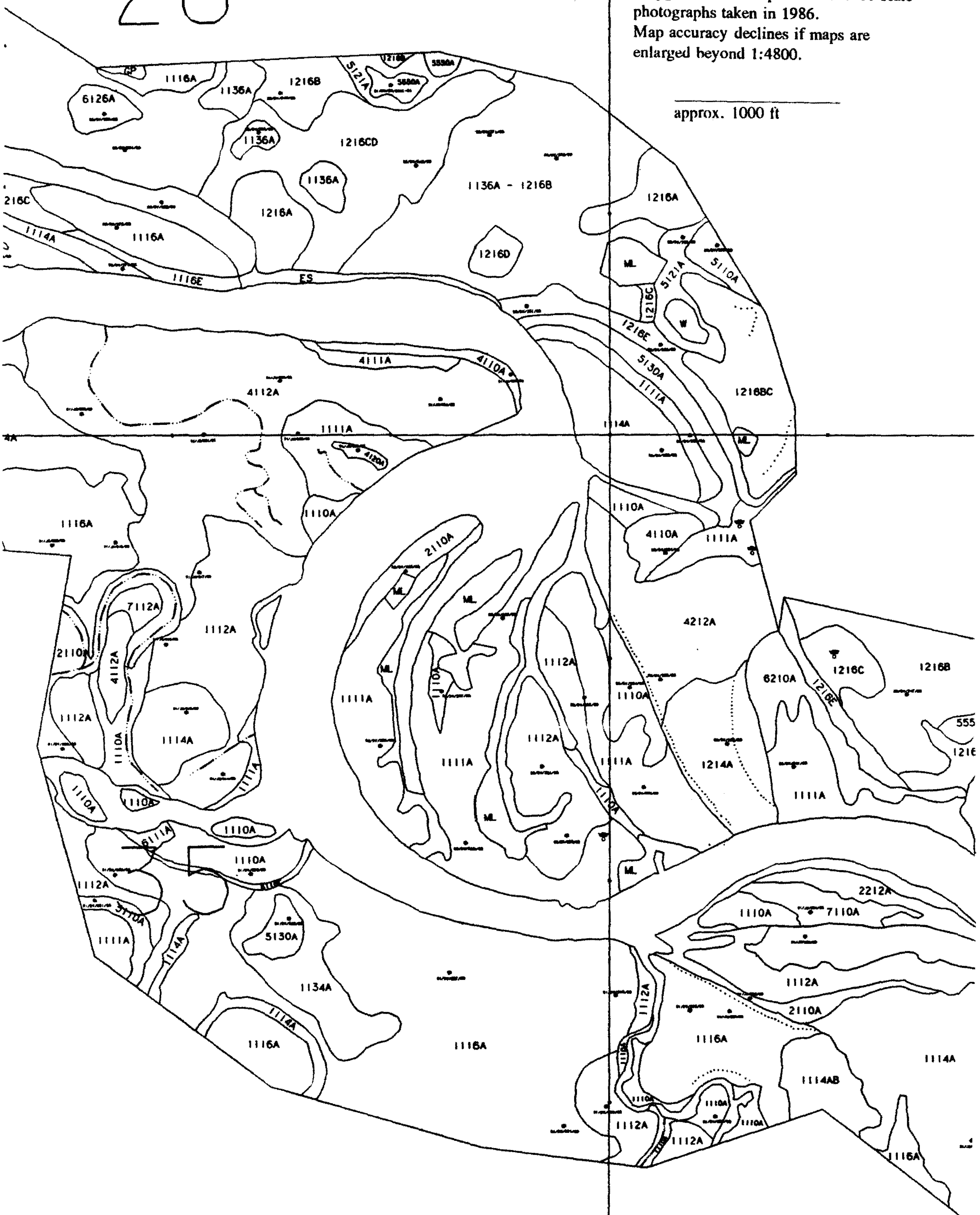
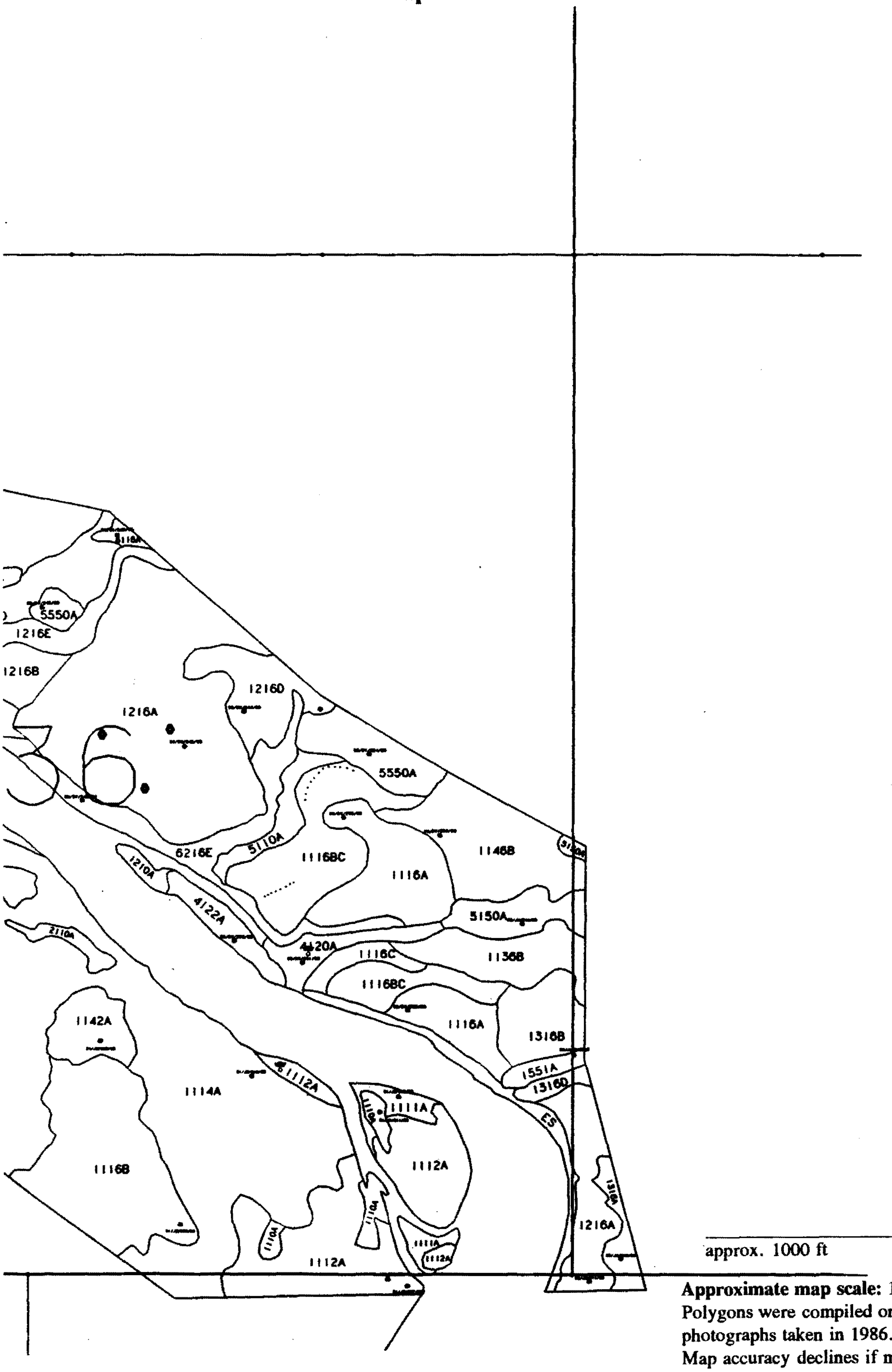


Kenai River soils
map sheet 35

Kenai River soils
map sheet 36



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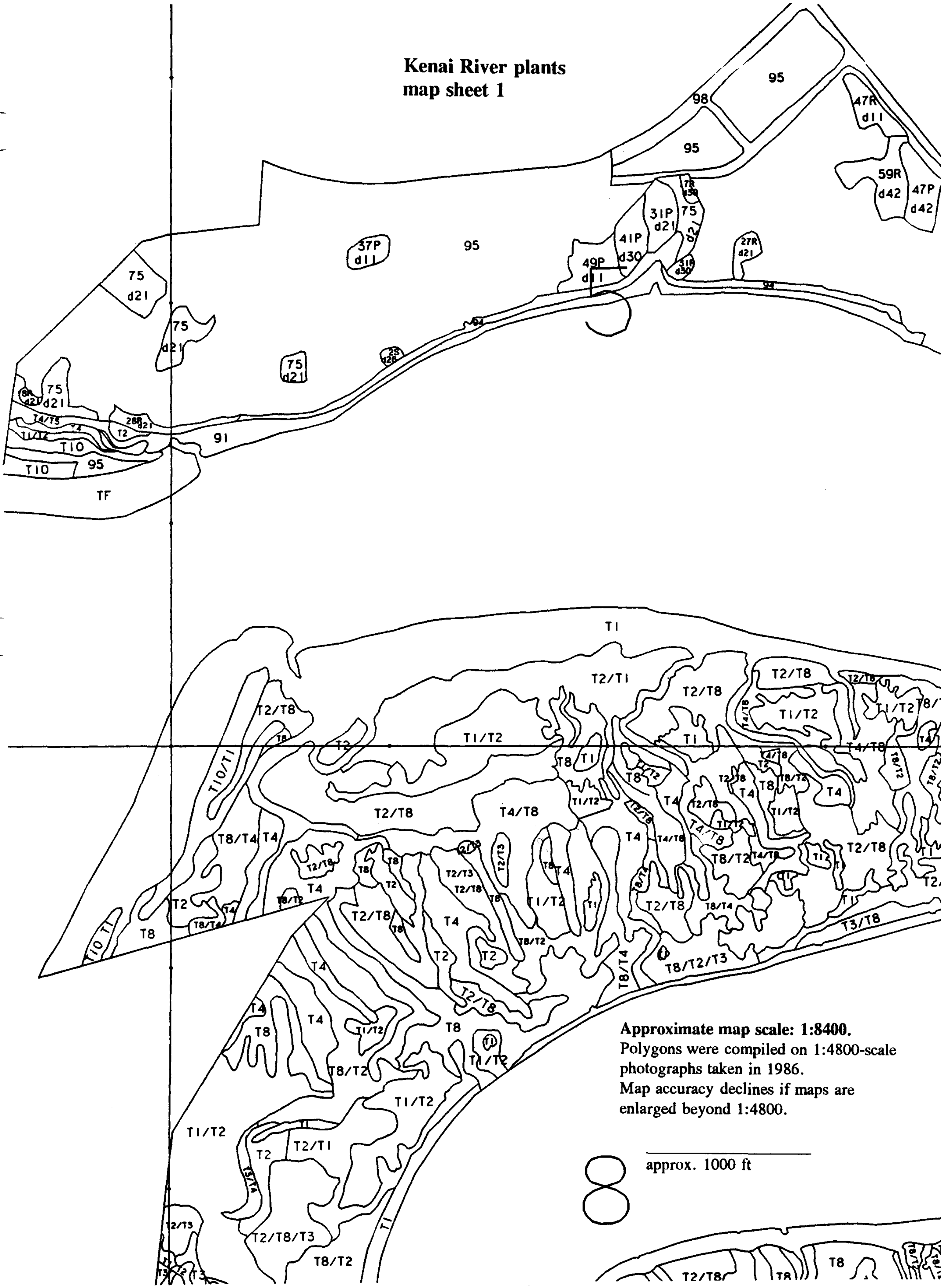

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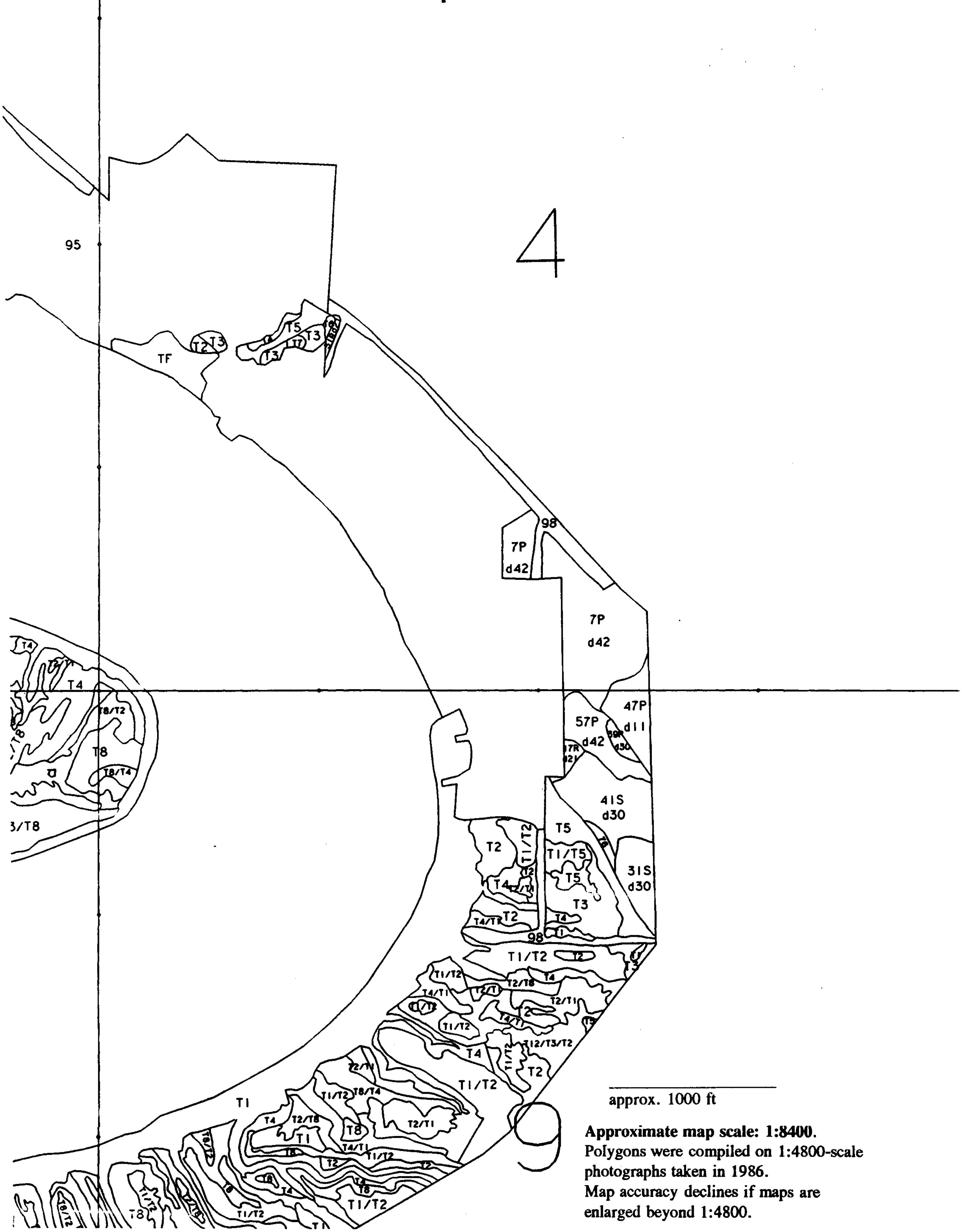
Kenai River plants
map sheet 2



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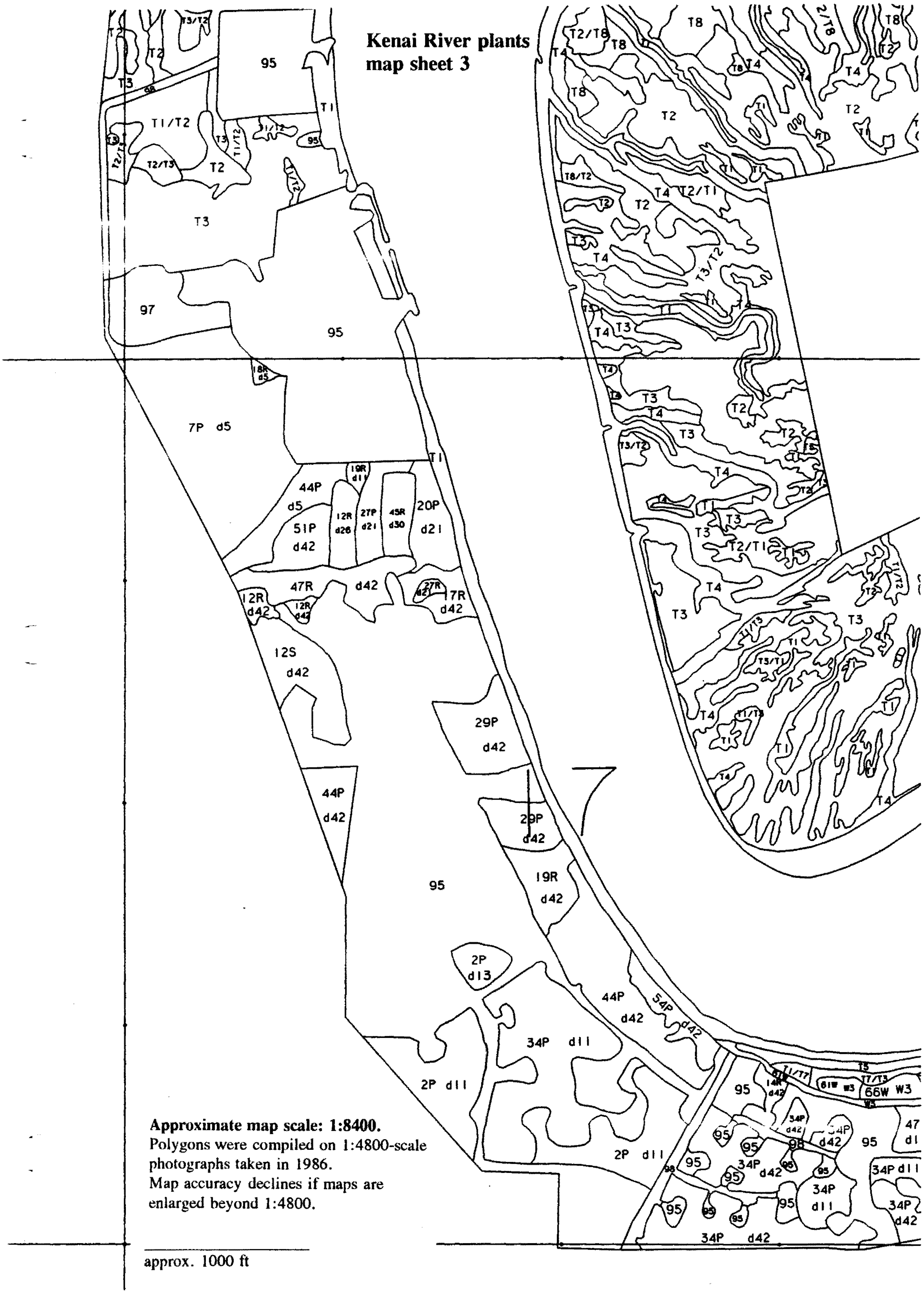
Map accuracy declines if maps are enlarged beyond 1:4800.

Kenai River plants map sheet 3



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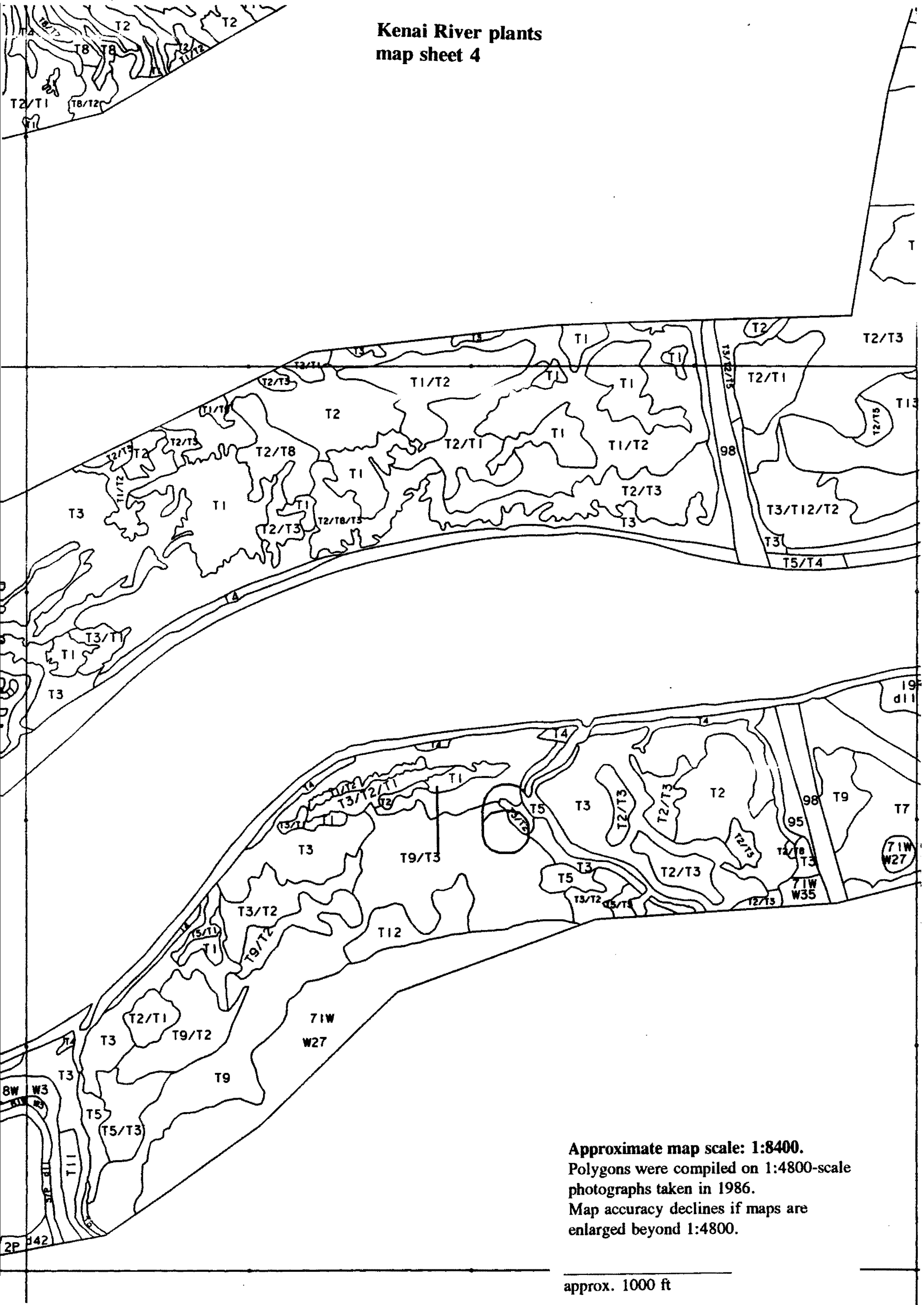
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

Kenai River plants
map sheet 4



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Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

Kenai River plants
map sheet 5

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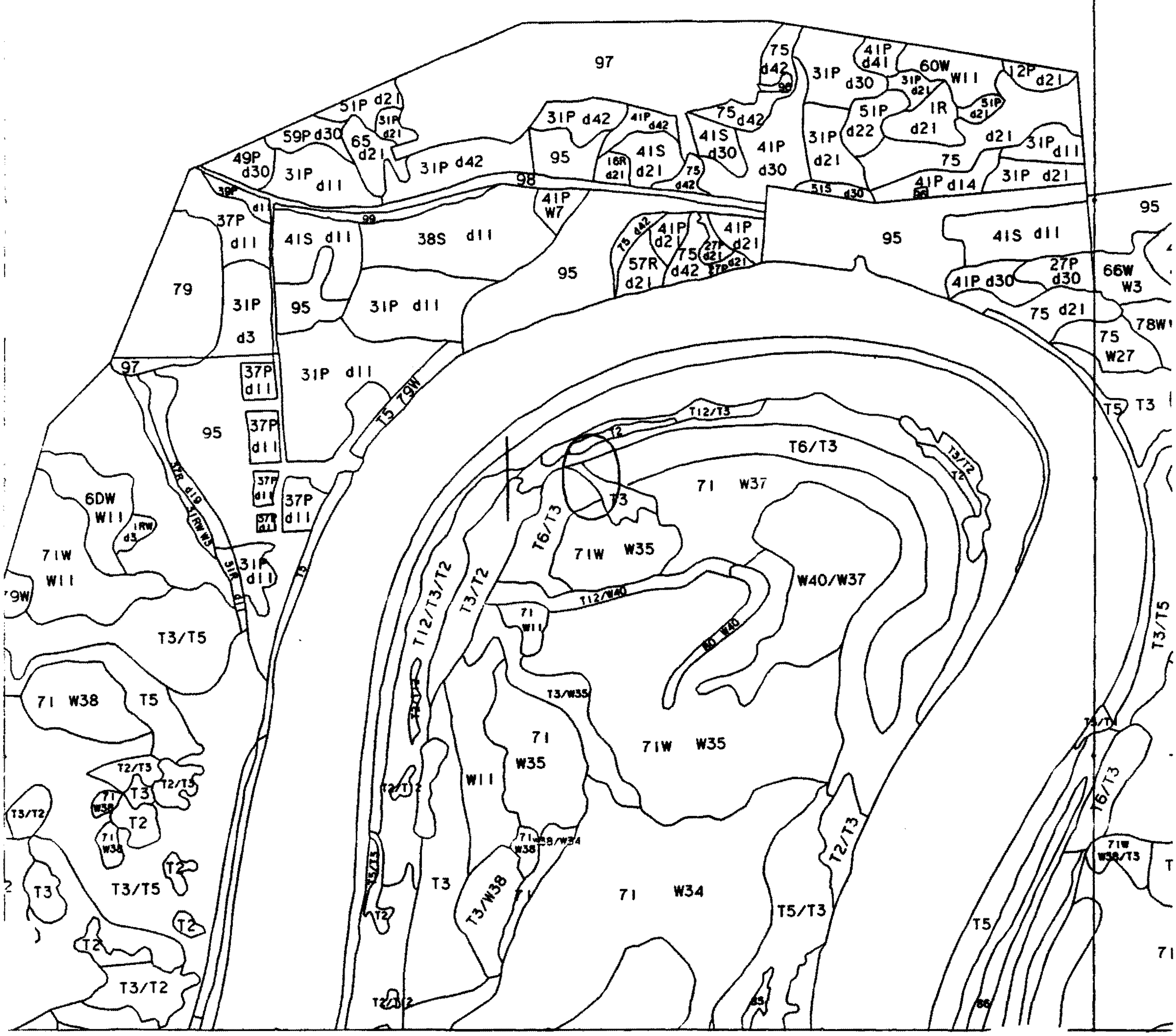
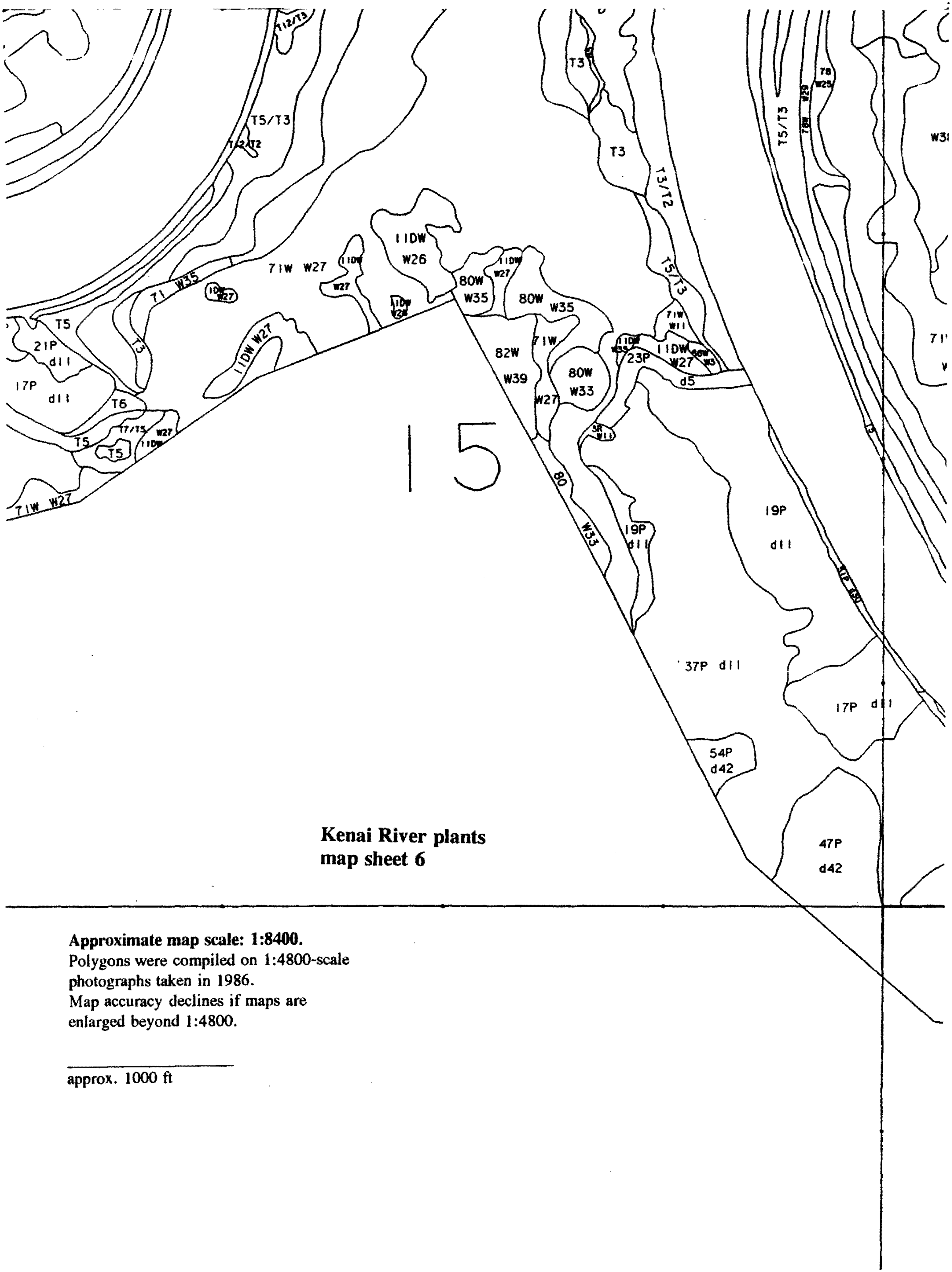
approx. 1000 ft





Kenai River plants
map sheet 6

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Polygons were compiled on 1:4800-scale photographs taken in 1986.
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

Kenai River plants
map sheet 7

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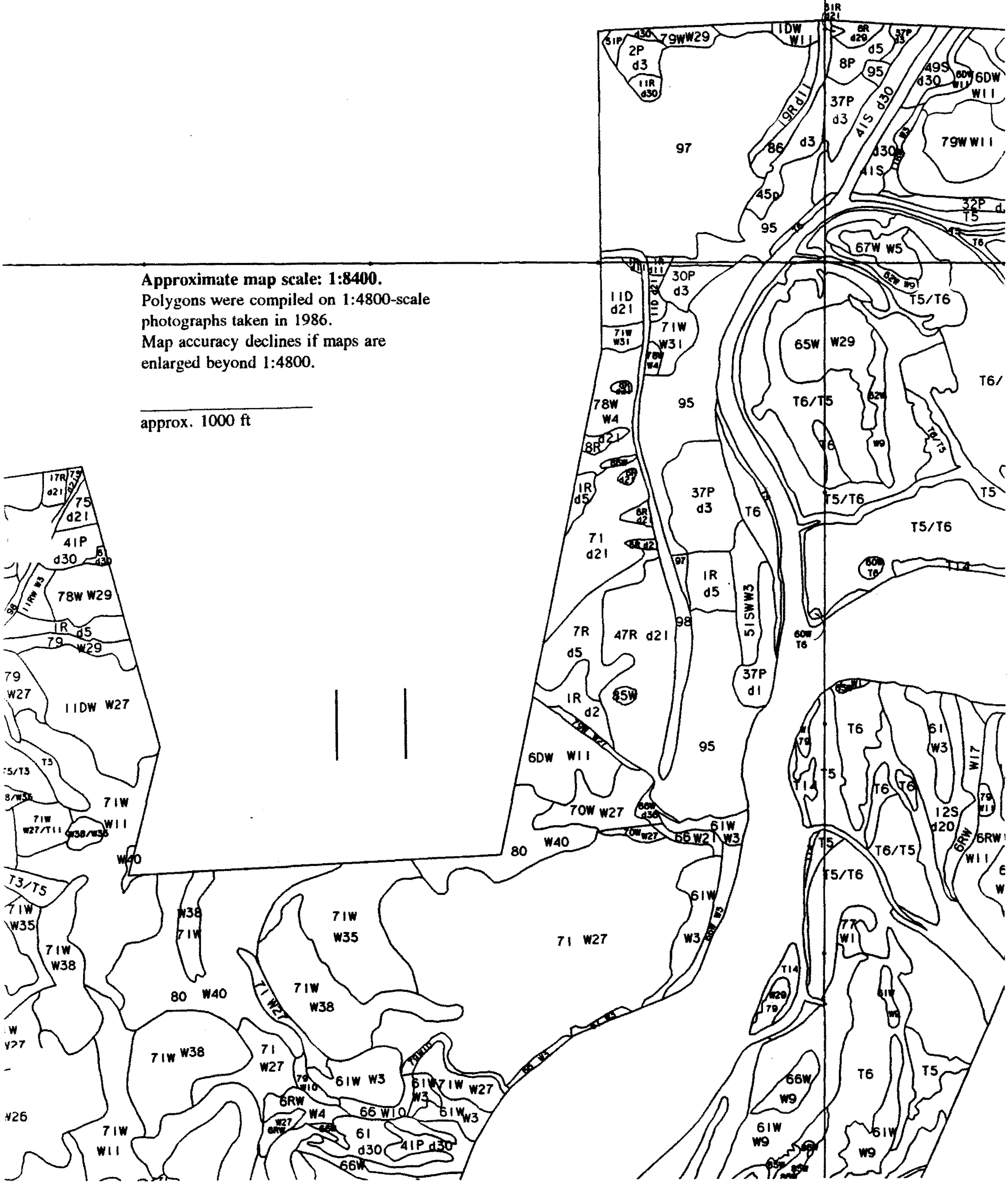
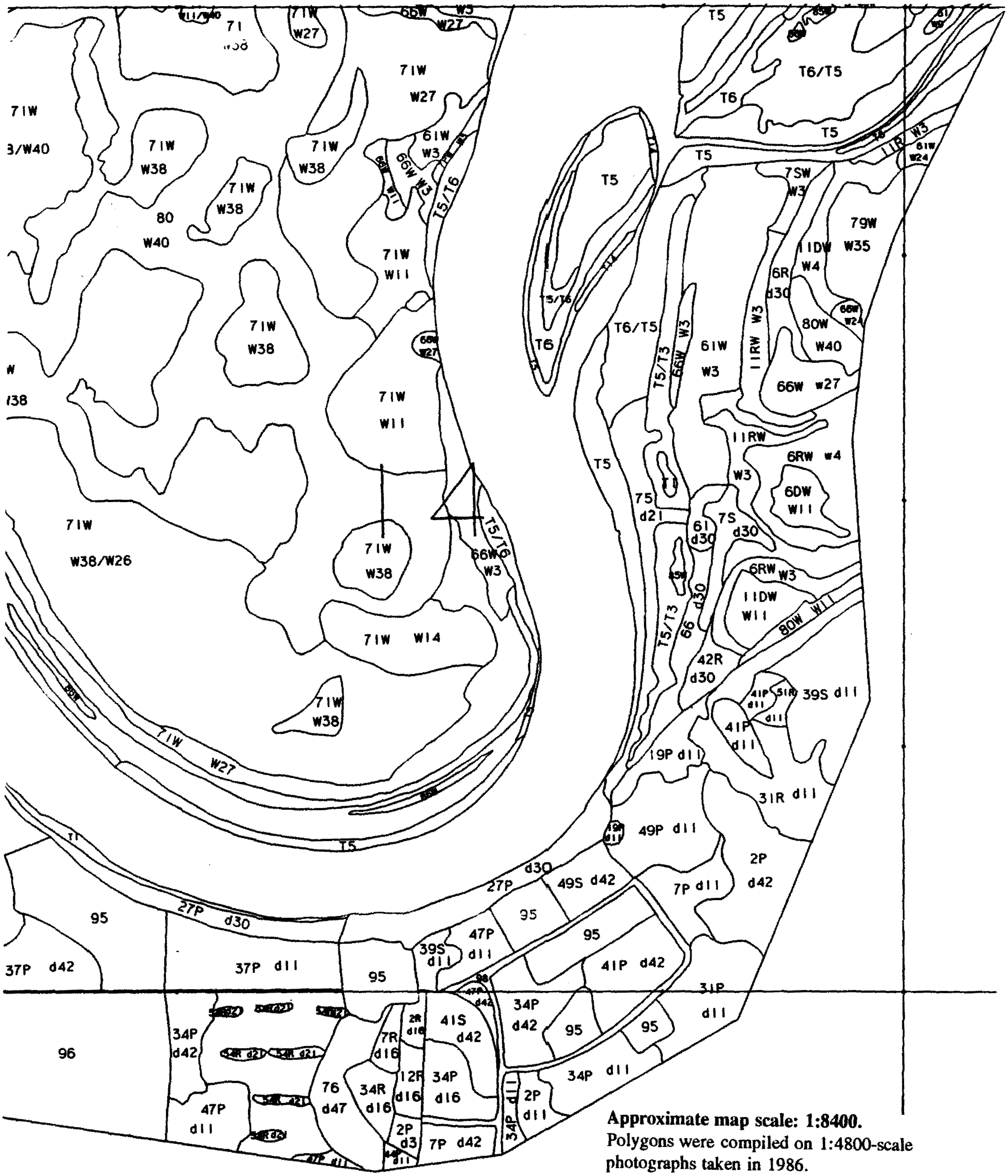
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft





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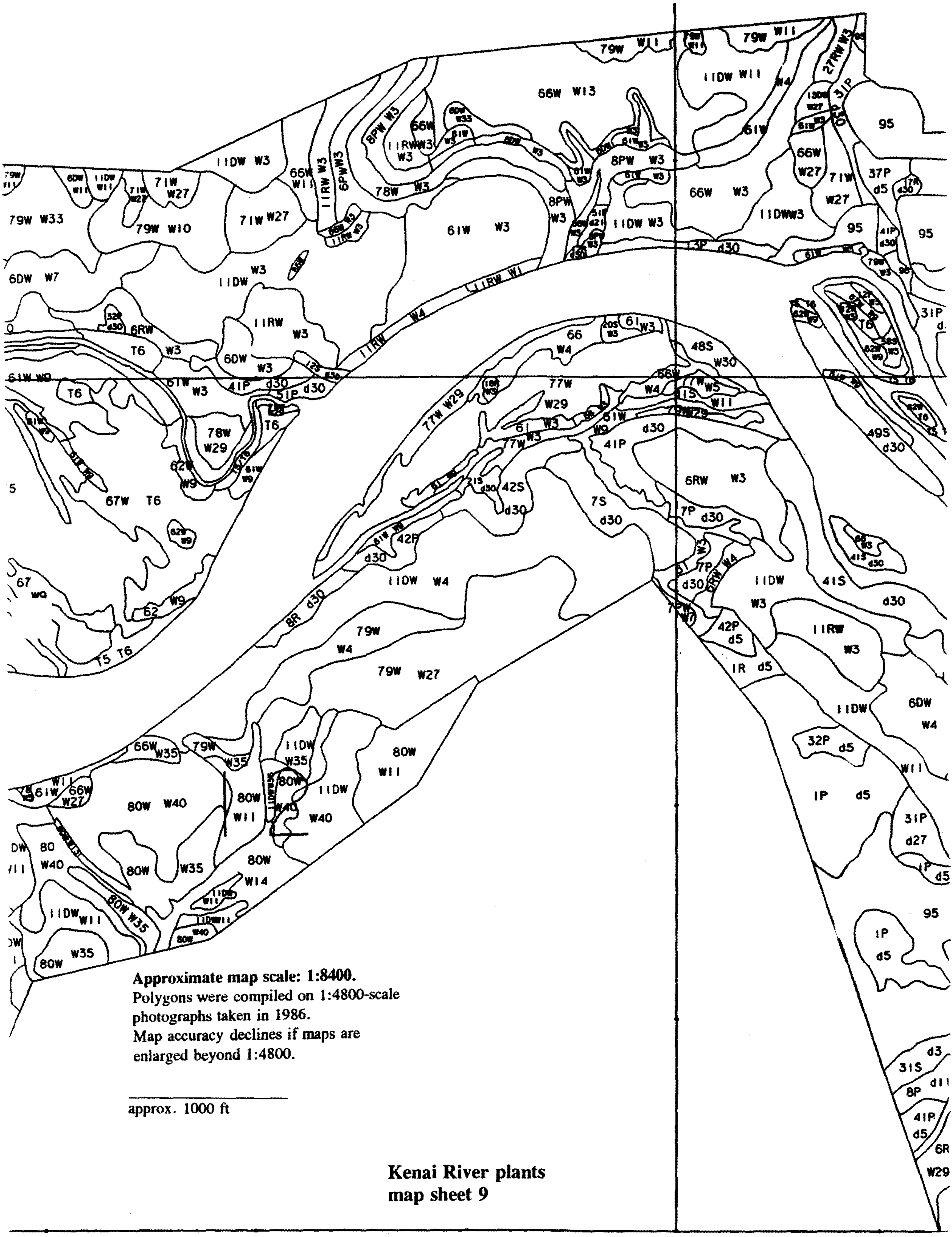
Kenai River plants map sheet 8

approx. 1000 ft



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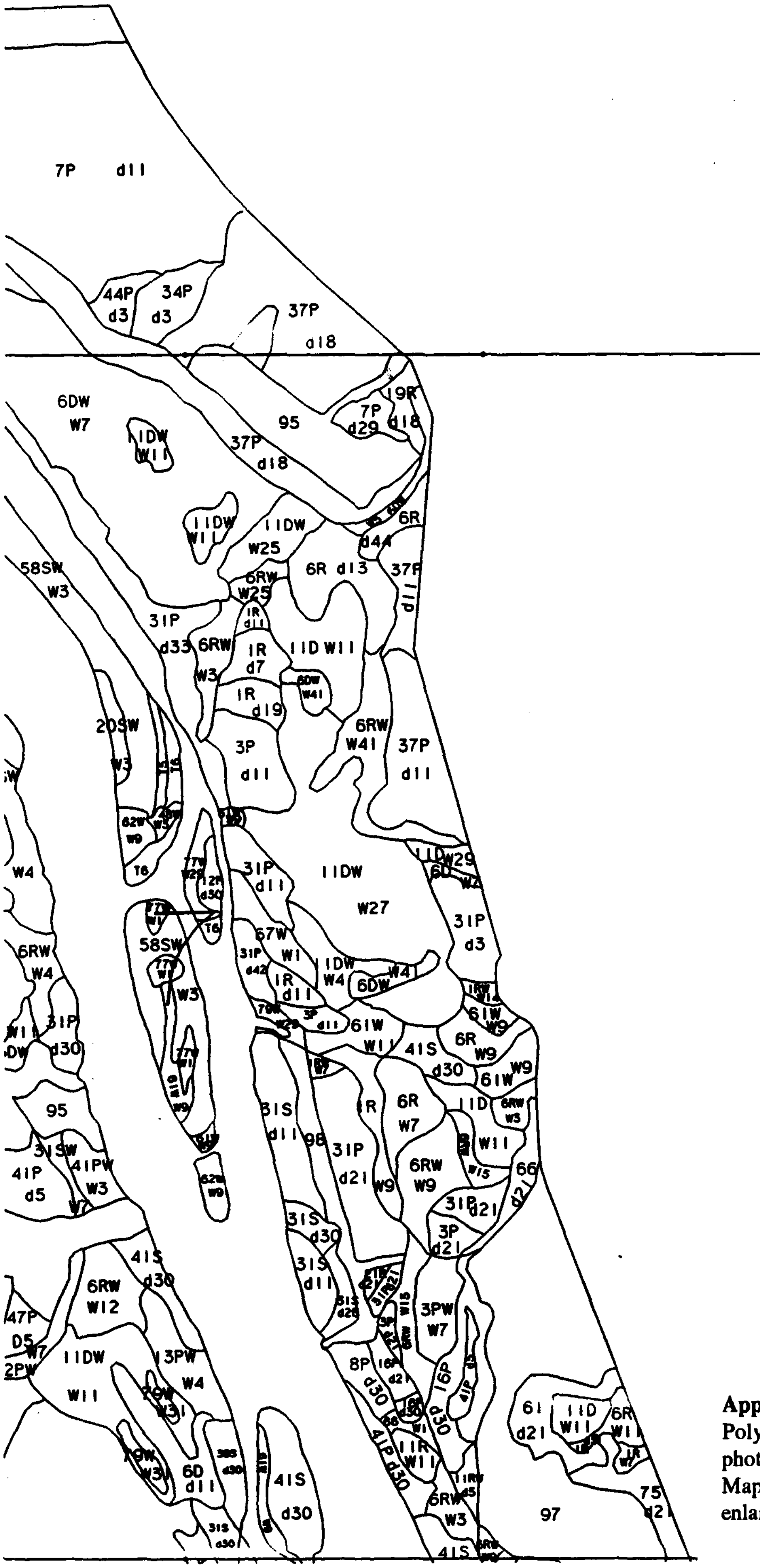
approx. 1000 ft

Kenai River plants
map sheet 9

**Kenai River plants
map sheet 10**



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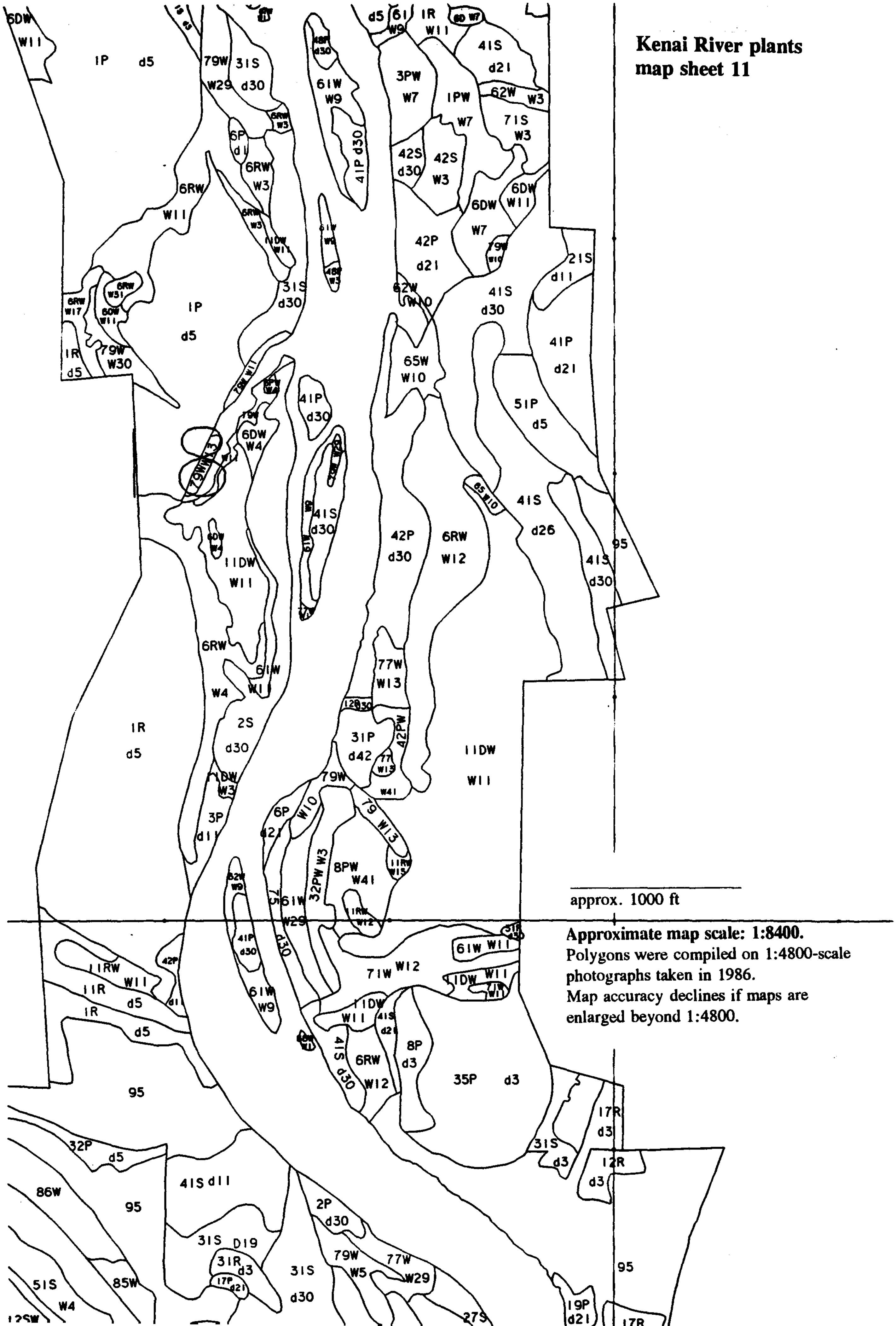
approx. 1000 ft

Kenai River plants map sheet 11



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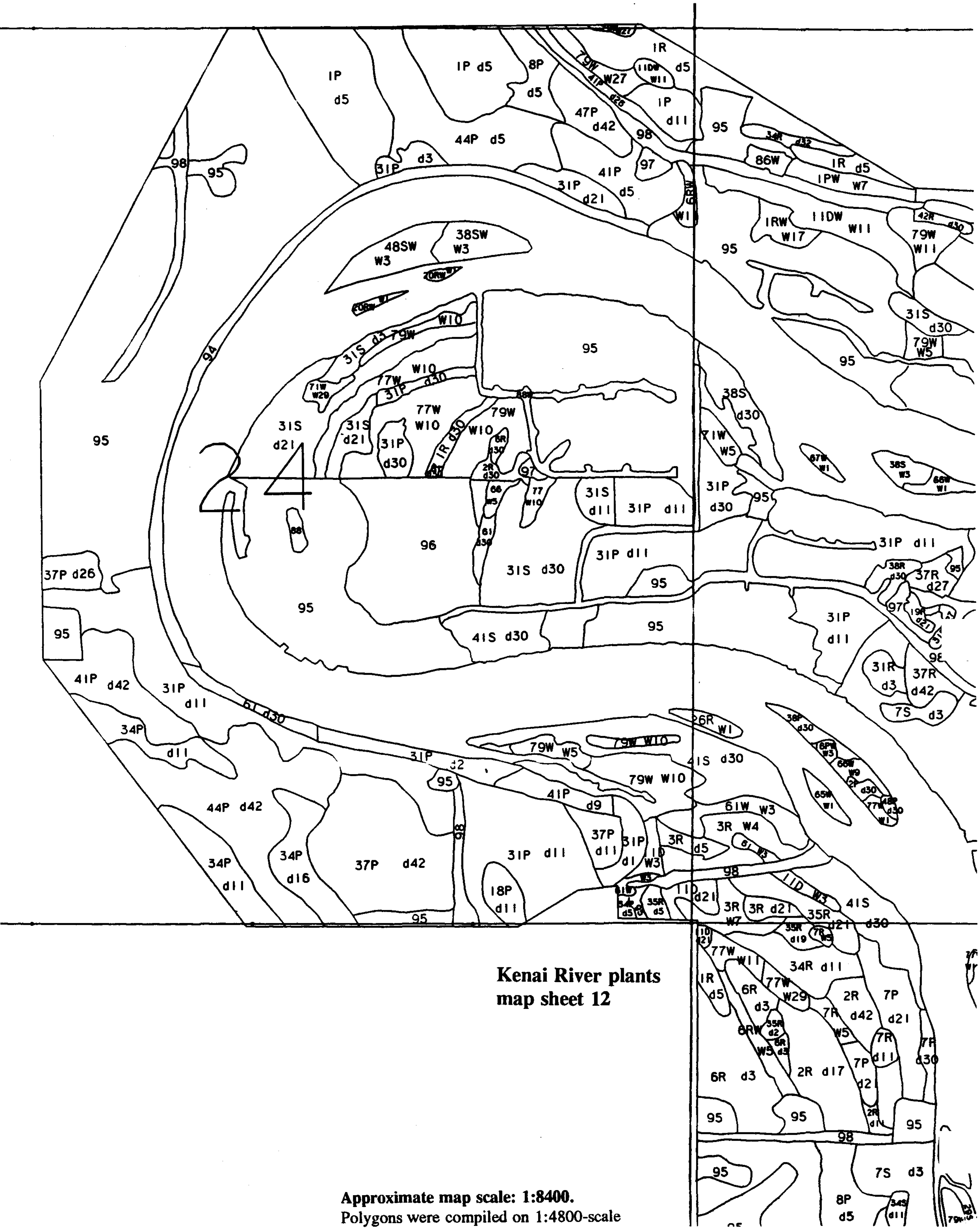

Kenai River plants map sheet 12

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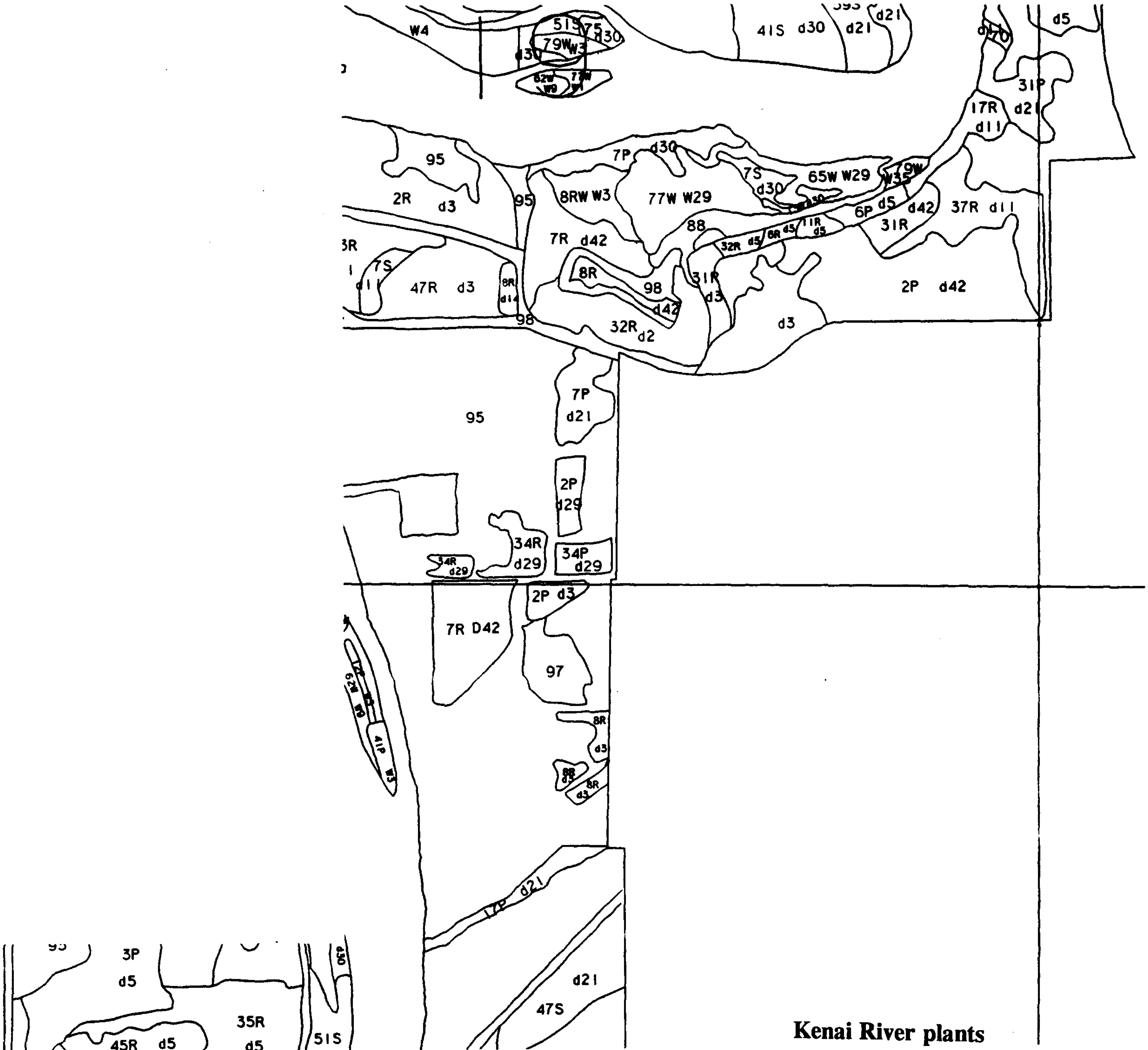
approx. 1000 ft



Kenai River plants map sheet 13

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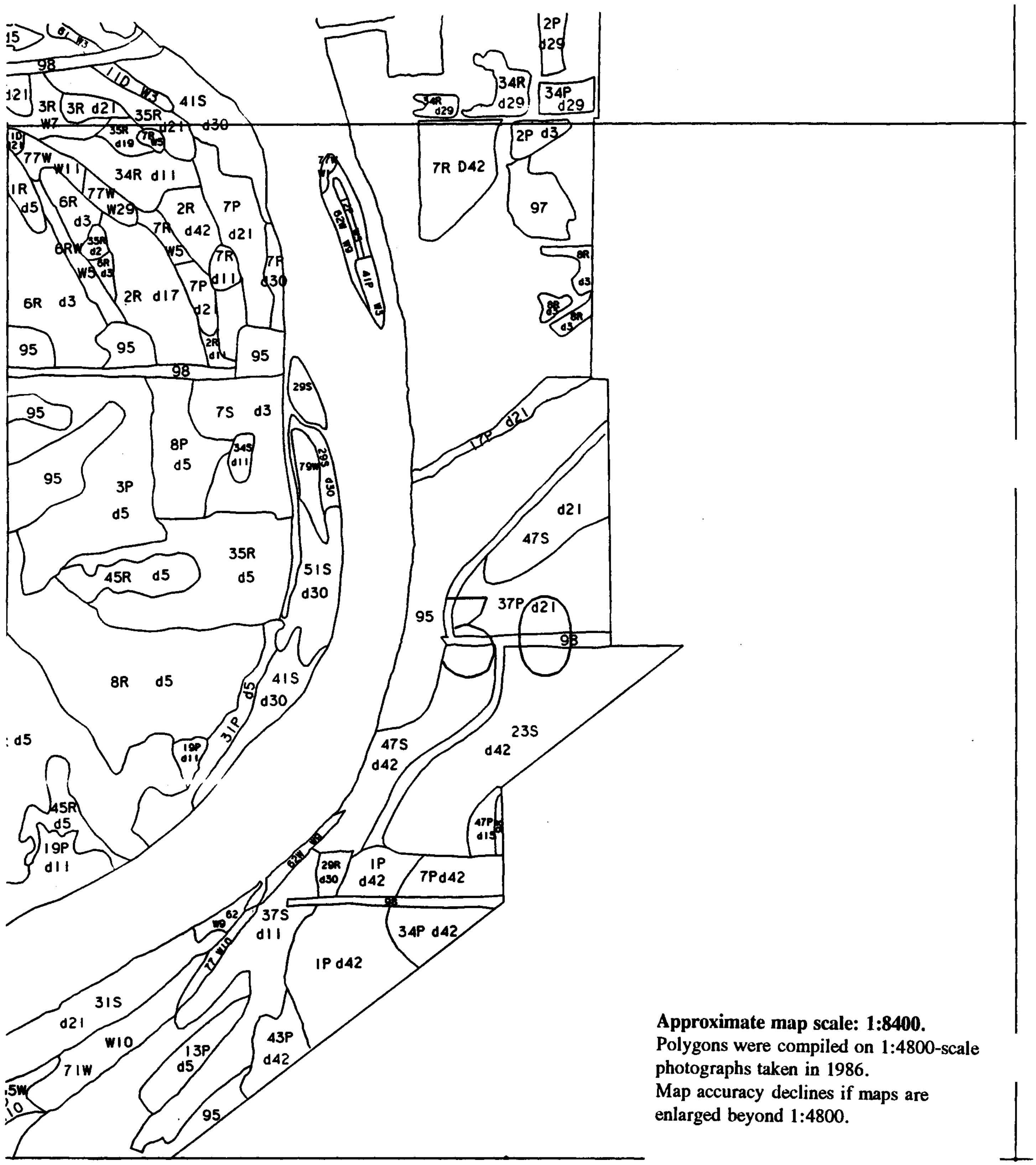
Map accuracy declines if maps are enlarged beyond 1:4800.

approx. 1000 ft

Kenai River plants
map sheet 14



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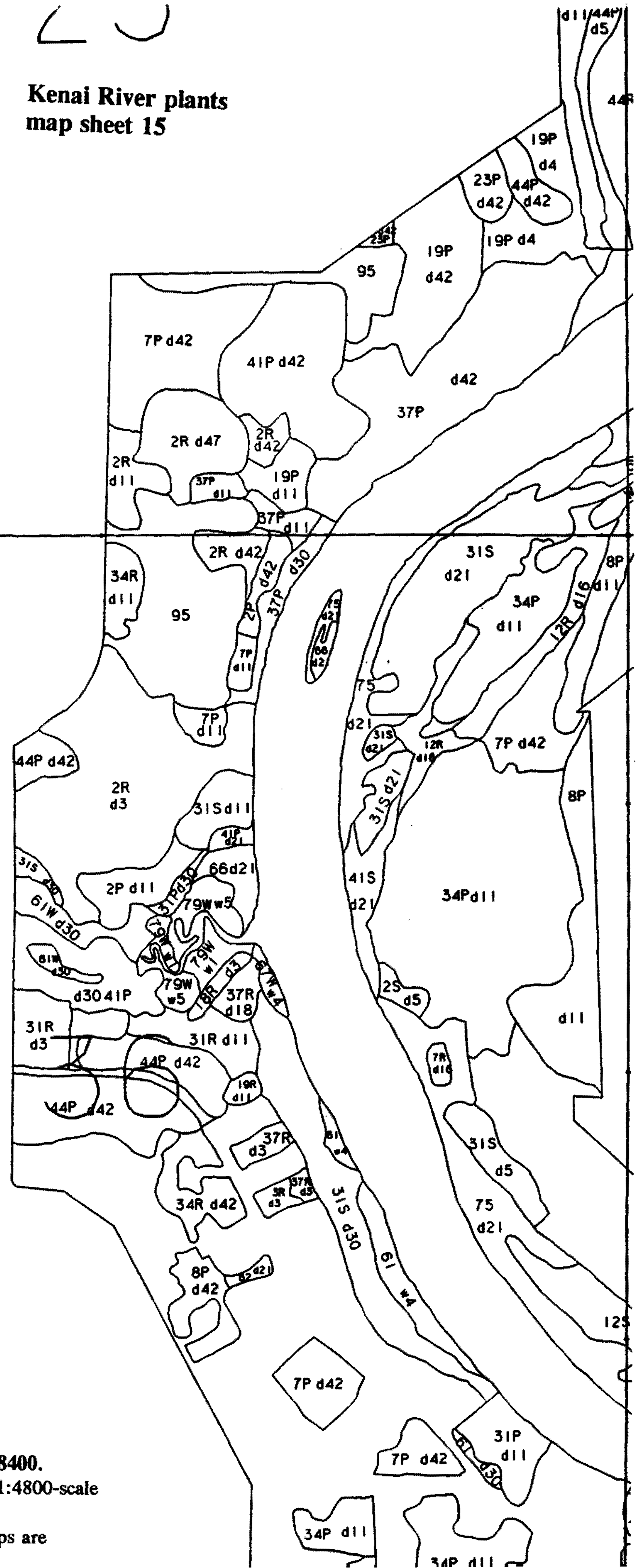
approx. 1000 ft

Kenai River plants map sheet 15



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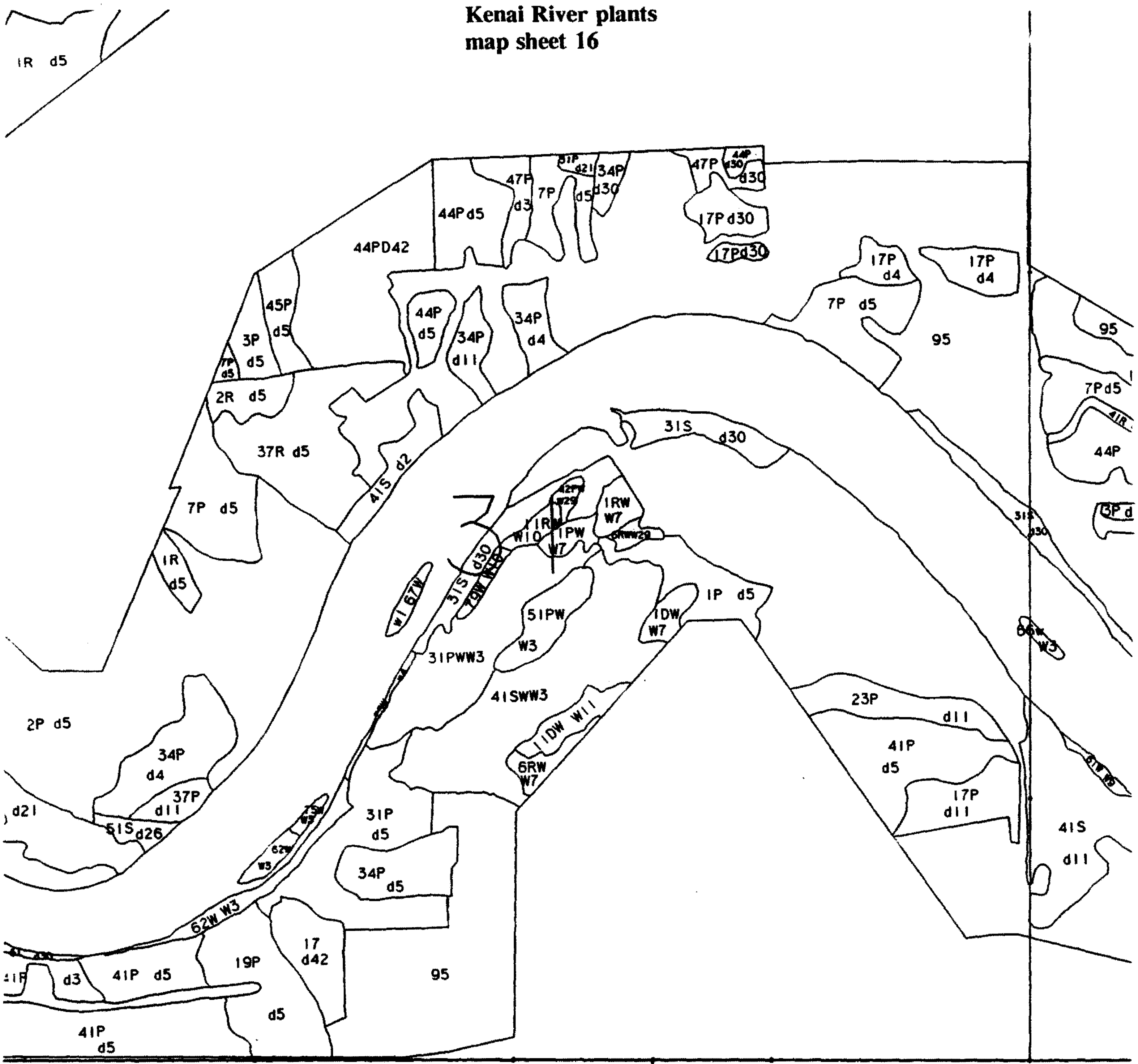
Kenai River plants
map sheet 16



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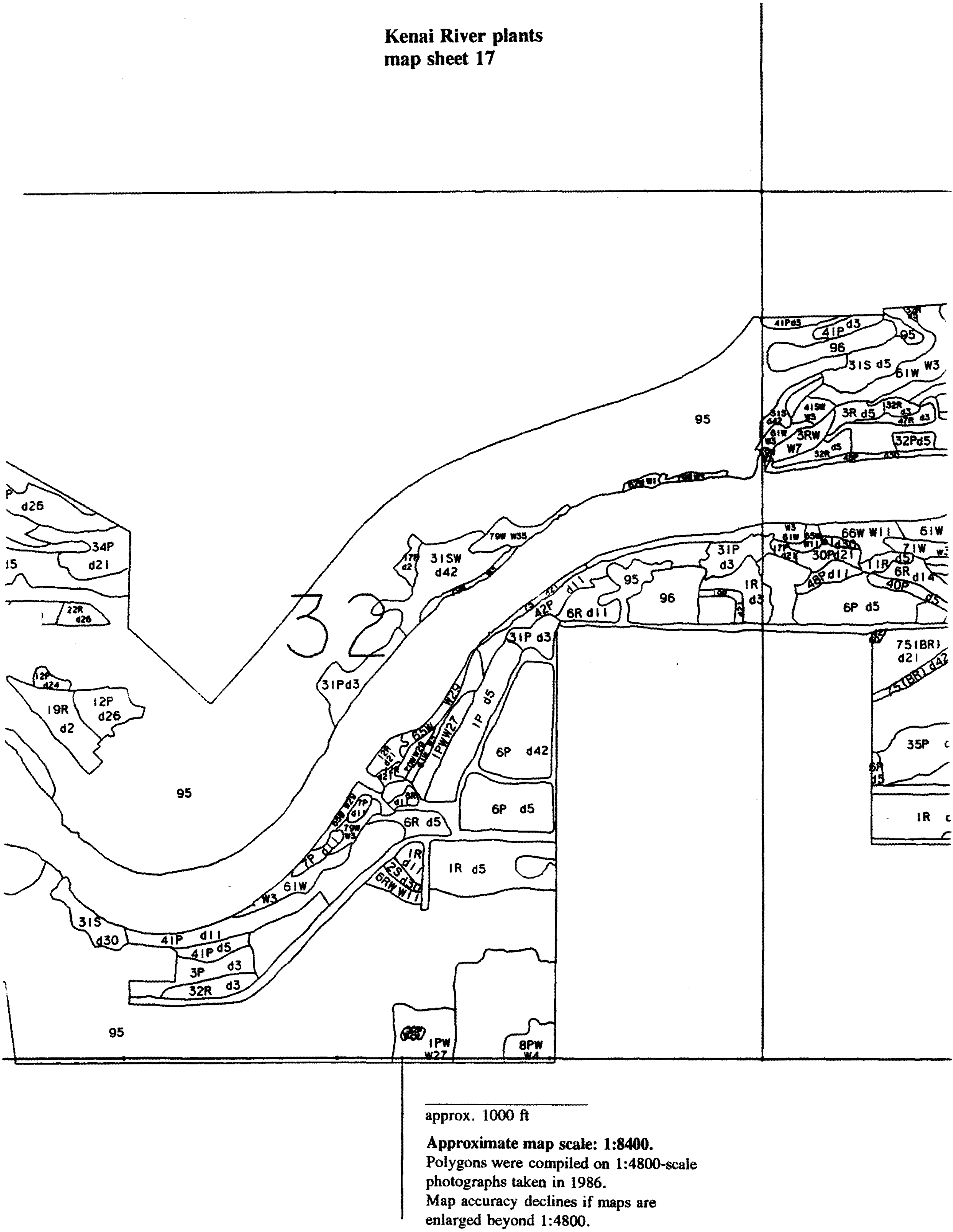
Kenai River plants
map sheet 17



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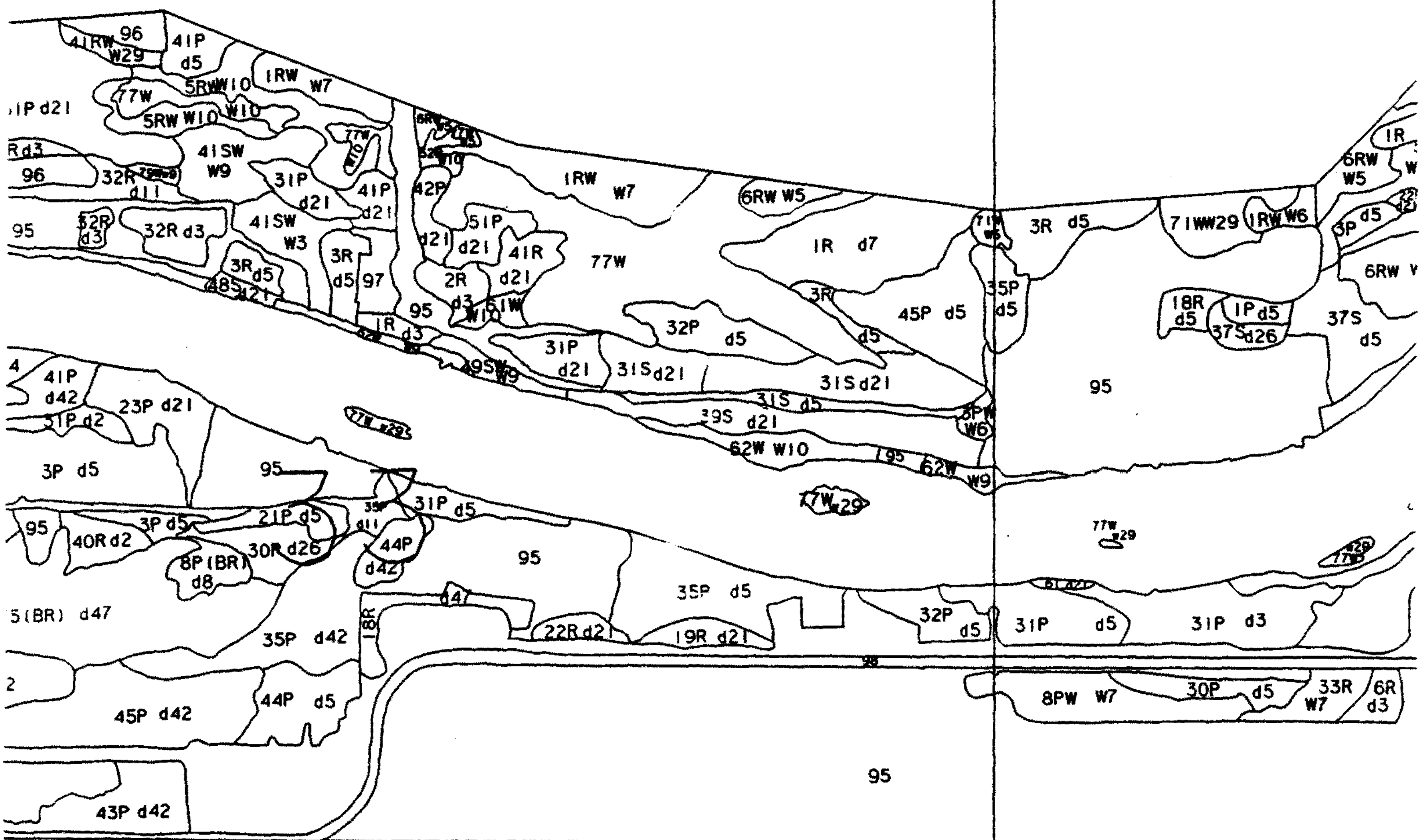
Kenai River plants
map sheet 18



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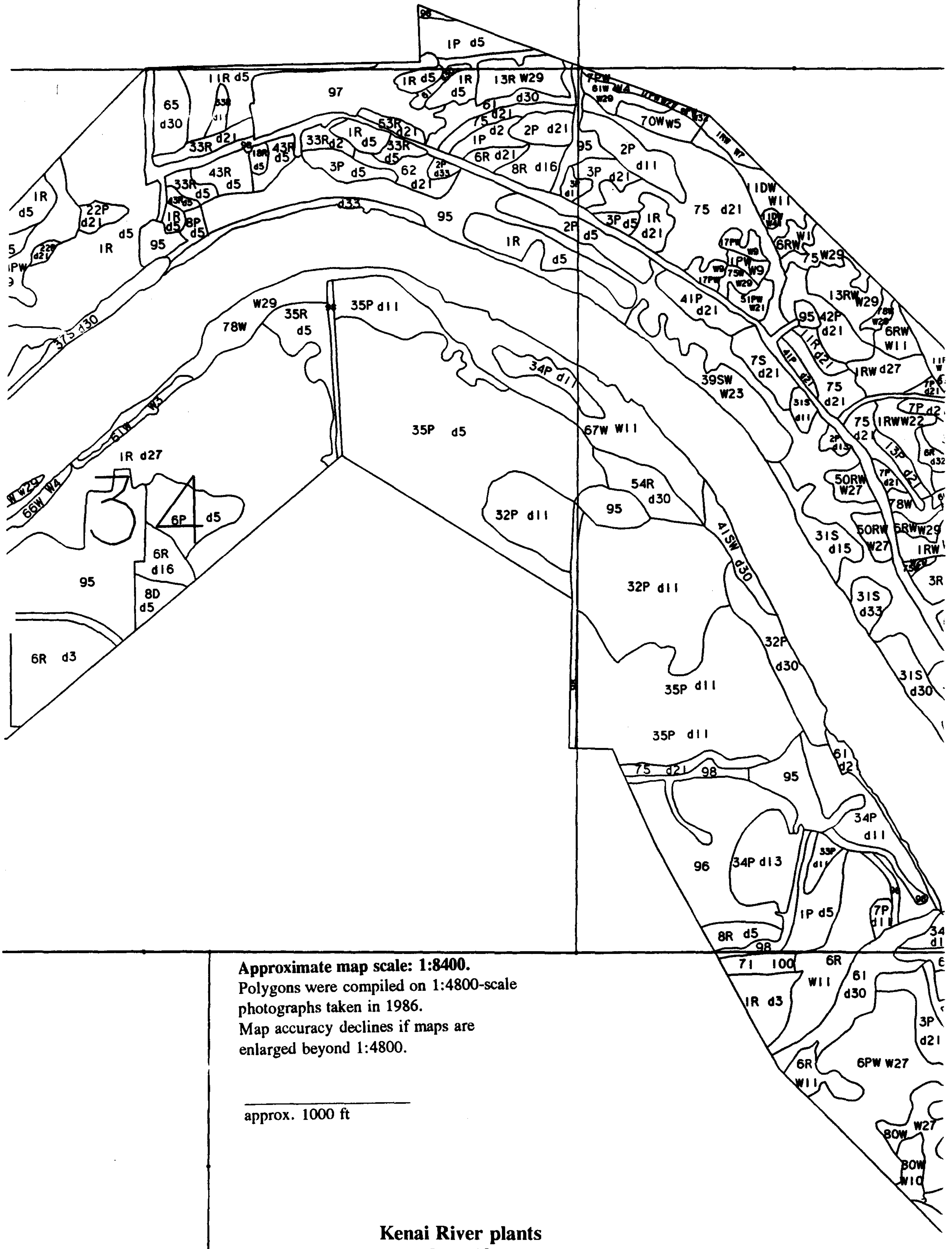

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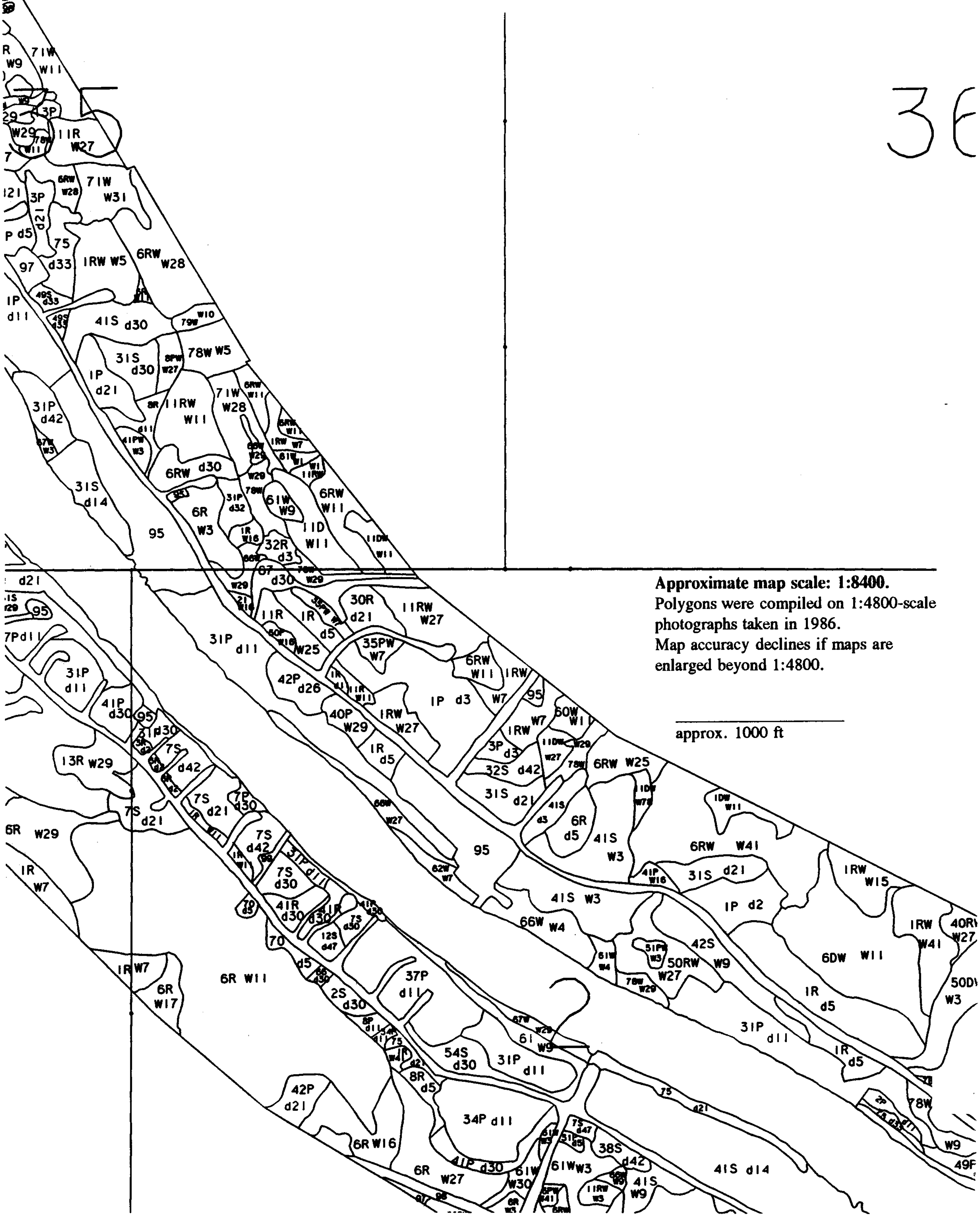
approx. 1000 ft

Kenai River plants
map sheet 19

Kenai River plants
map sheet 20



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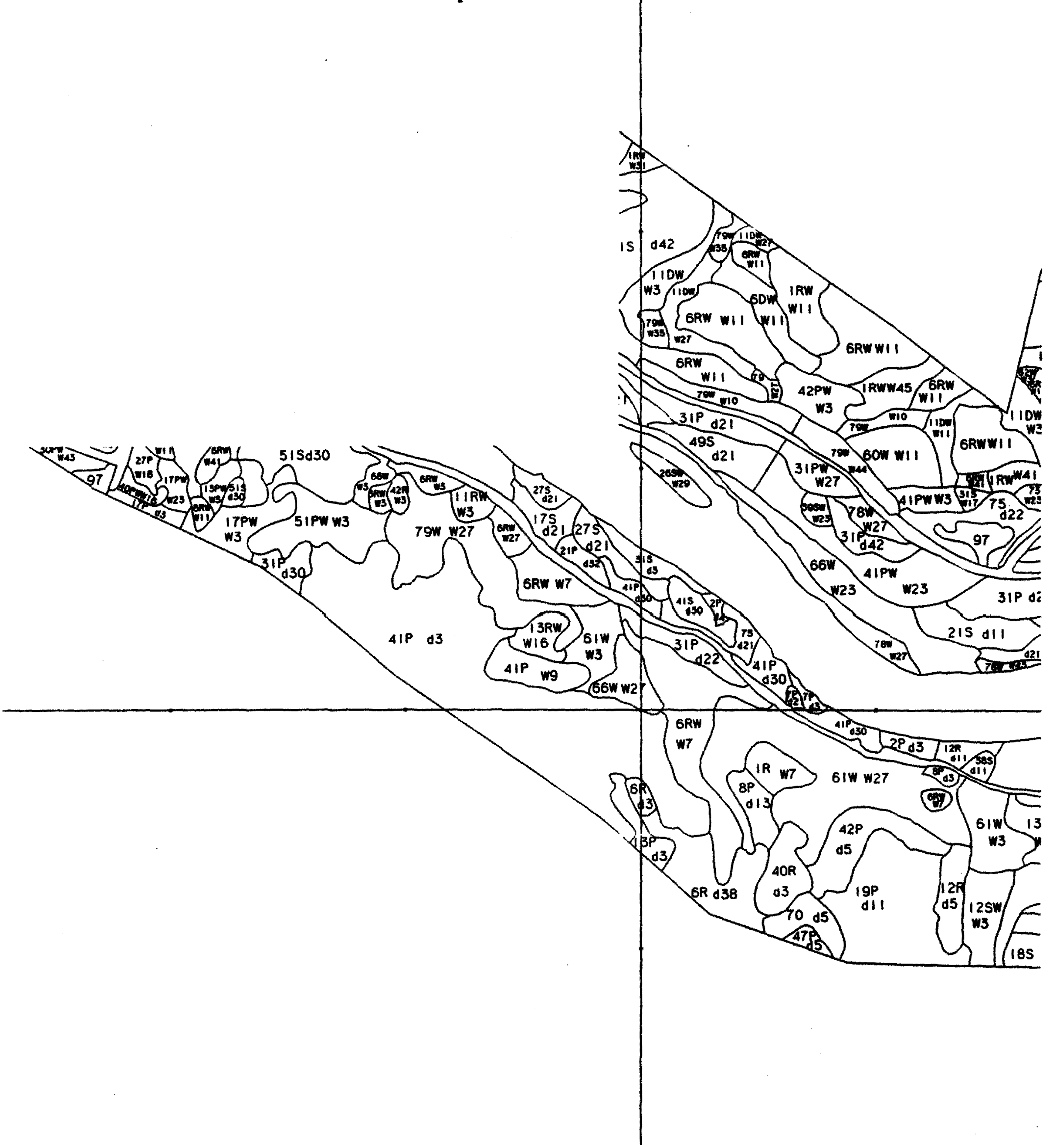
Kenai River plants
map sheet 21



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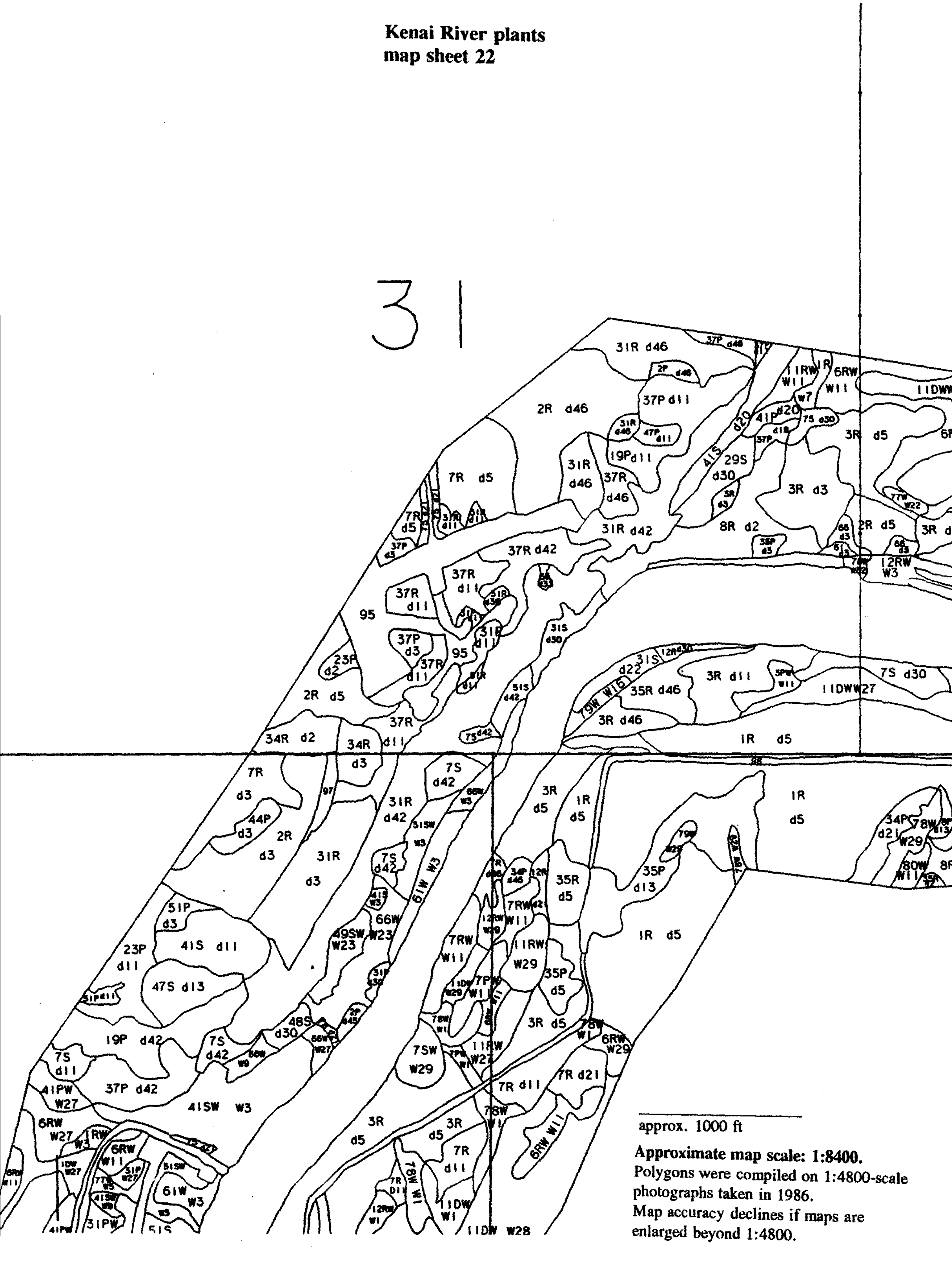
Kenai River plants
map sheet 22



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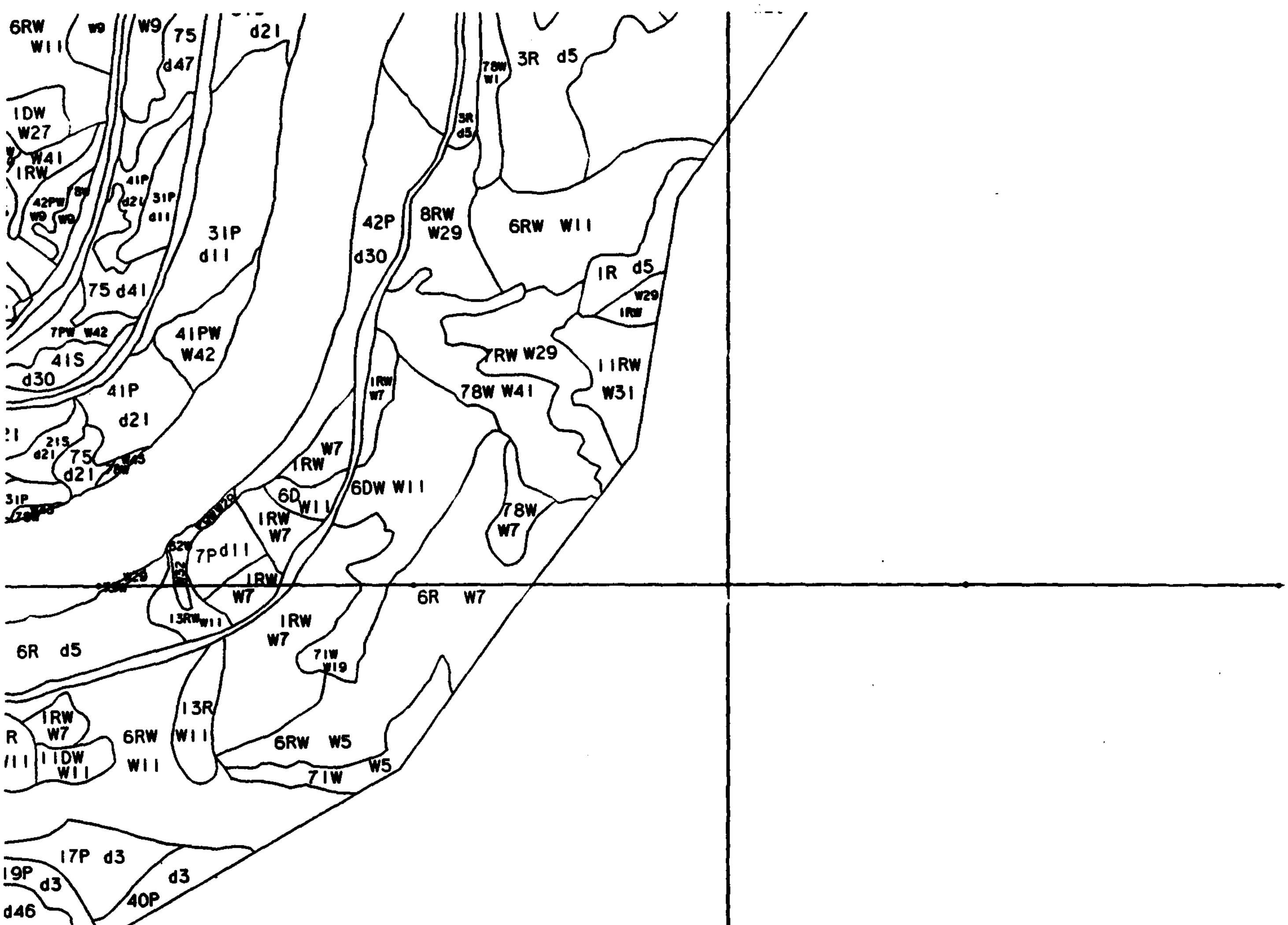
Map accuracy declines if maps are enlarged beyond 1:4800.

Kenai River plants
map sheet 23



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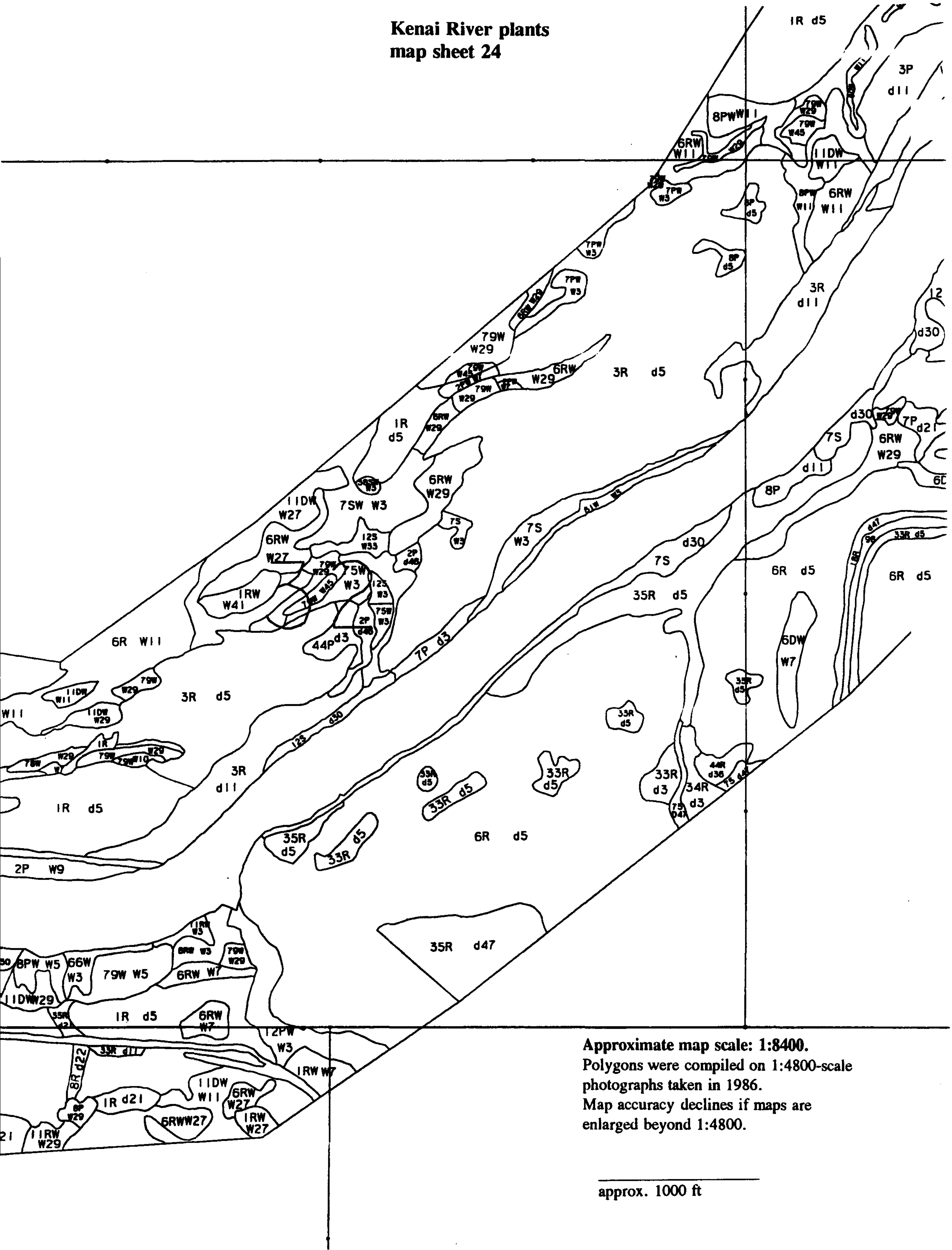
Kenai River plants
map sheet 24



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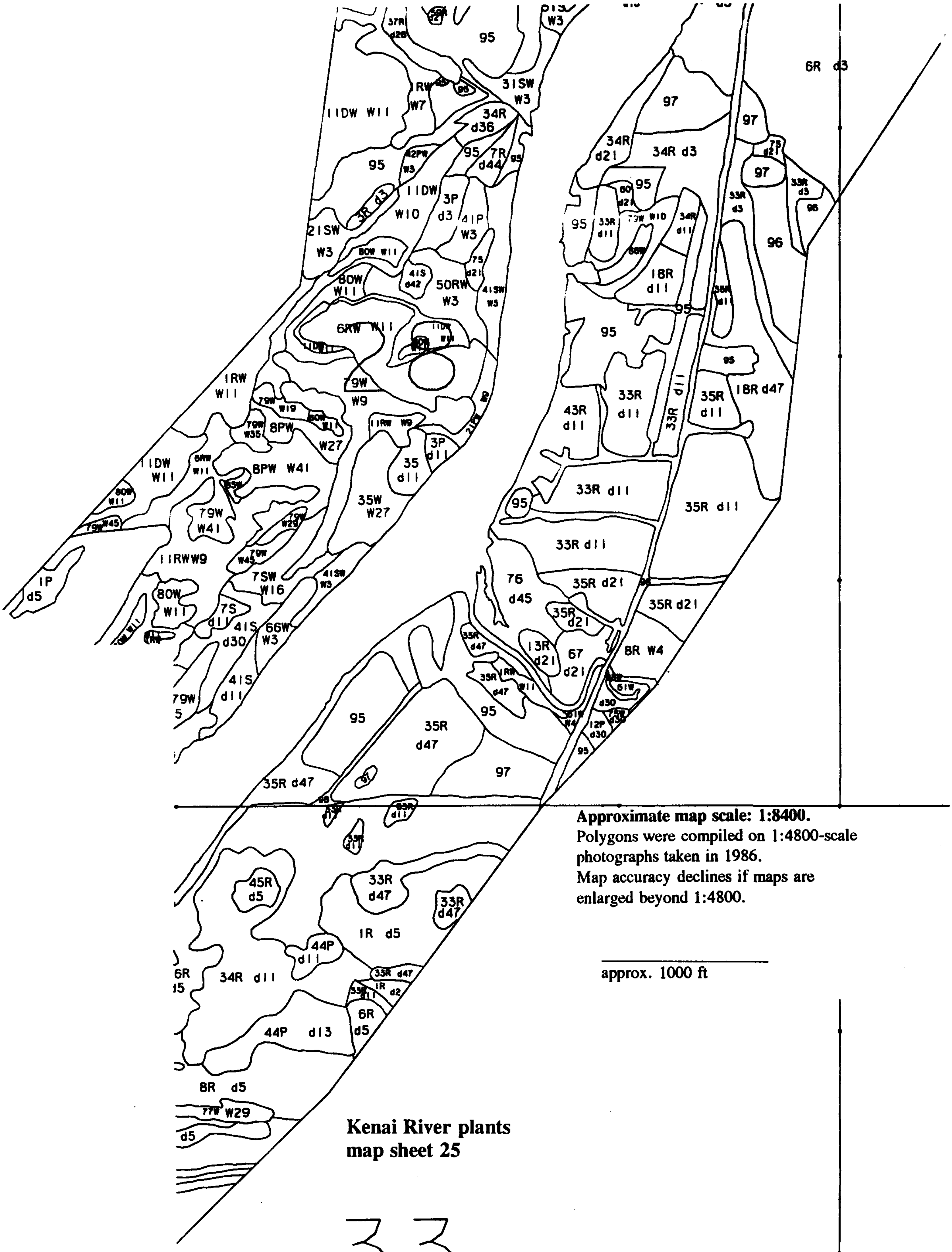

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approx. 1000 ft

Kenai River plants
map sheet 25

Kenai River plants
map sheet 26

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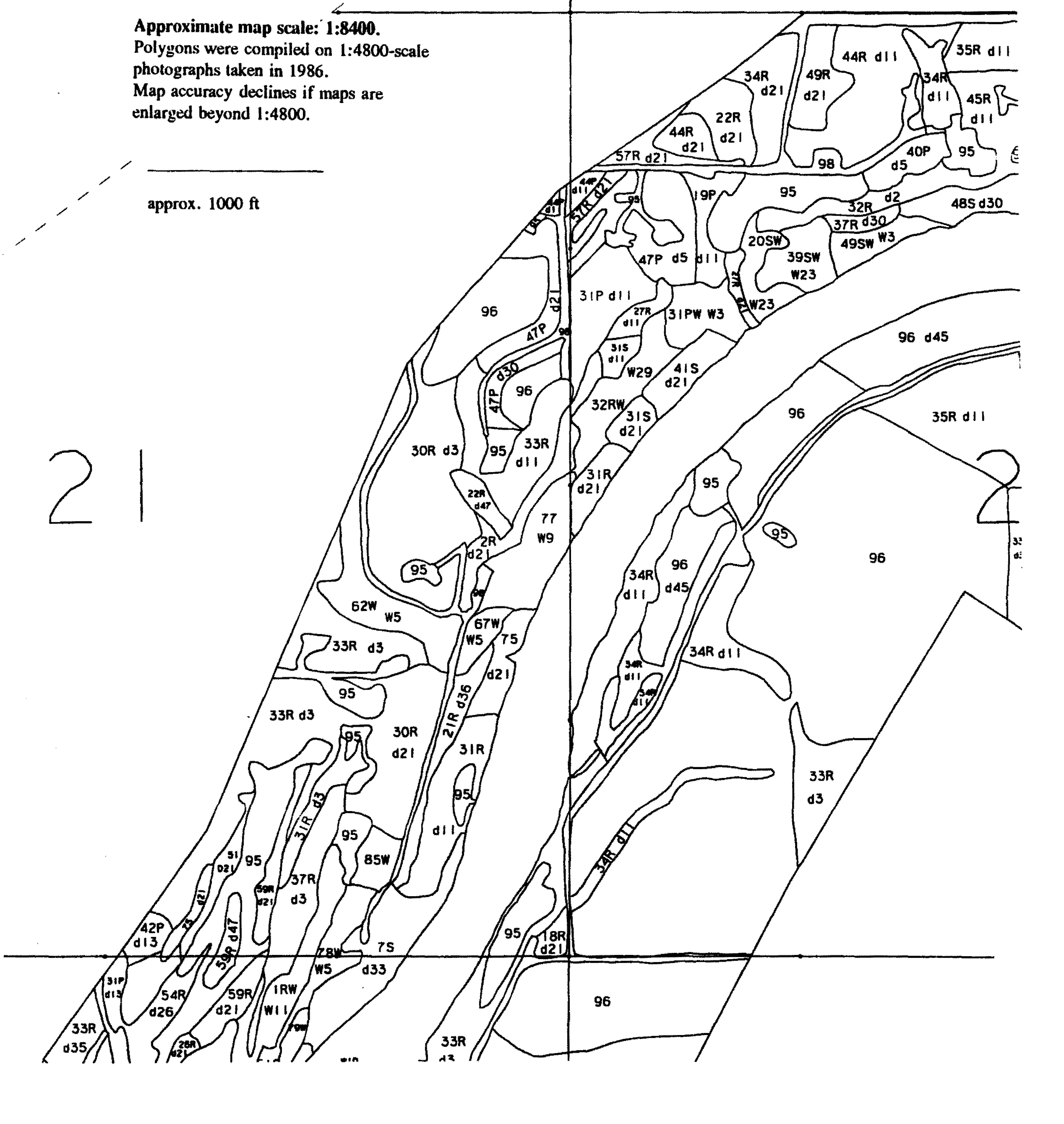
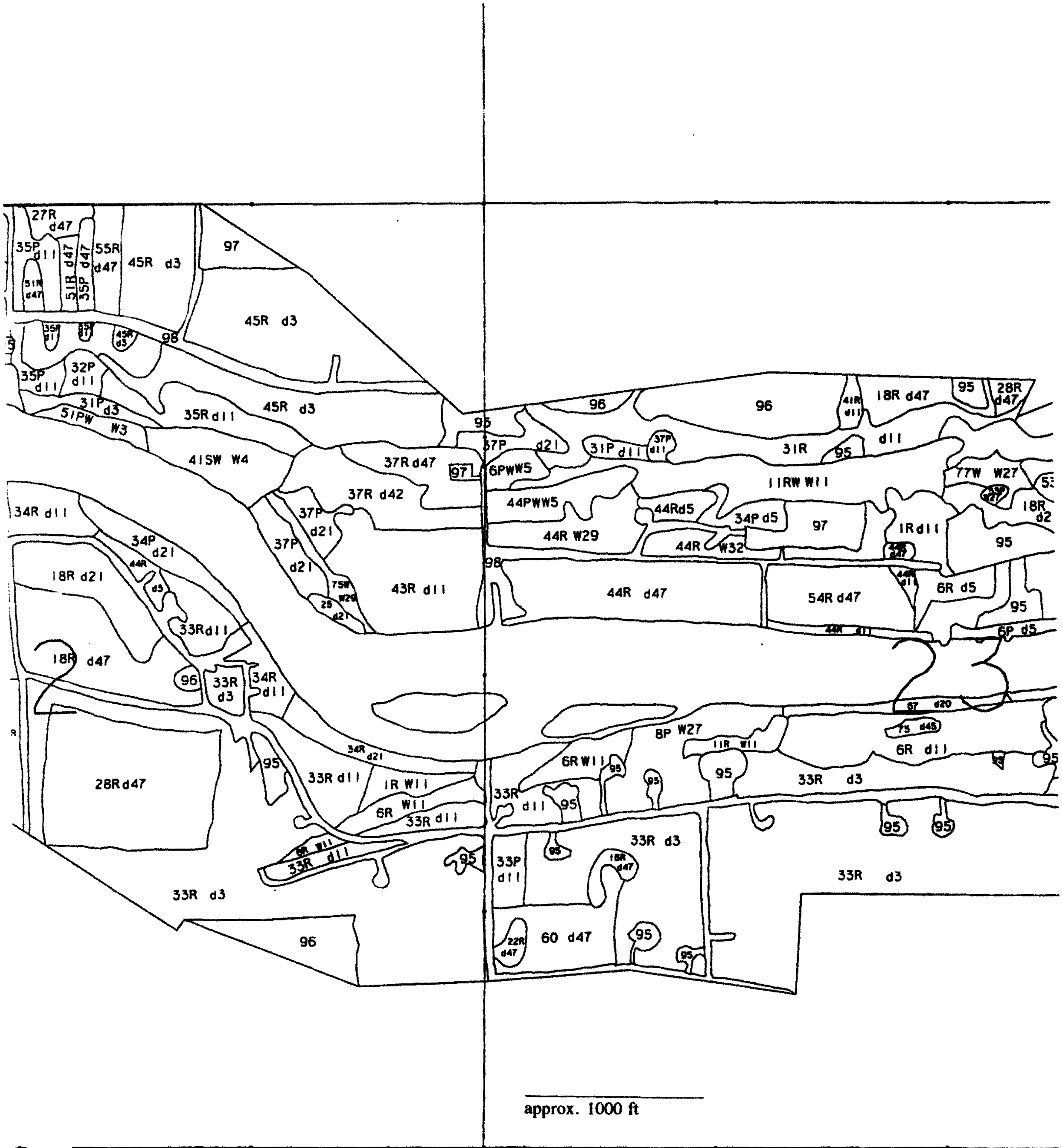
approx. 1000 ft



Kenai River plants
map sheet 27



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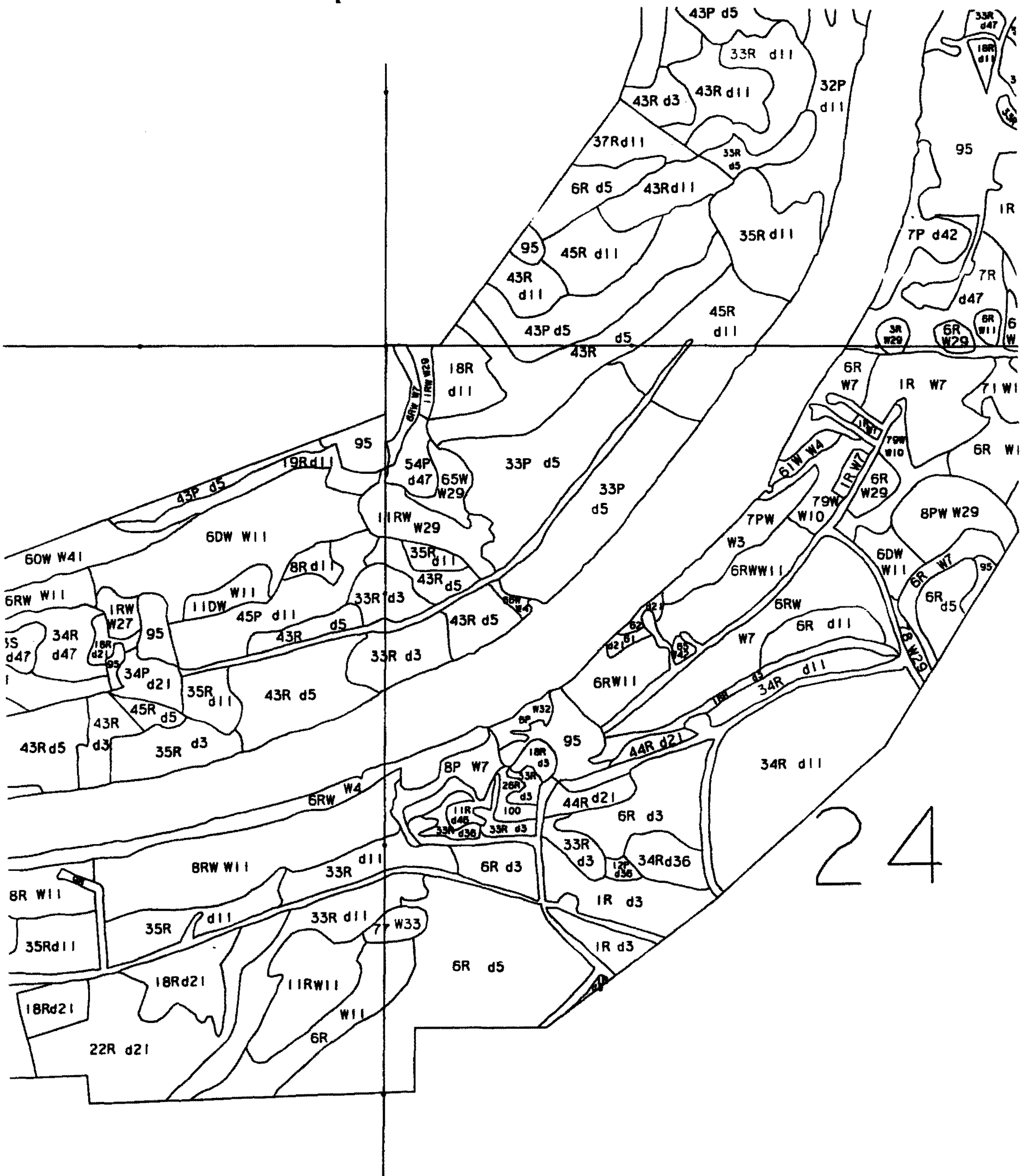
Kenai River plants
map sheet 28



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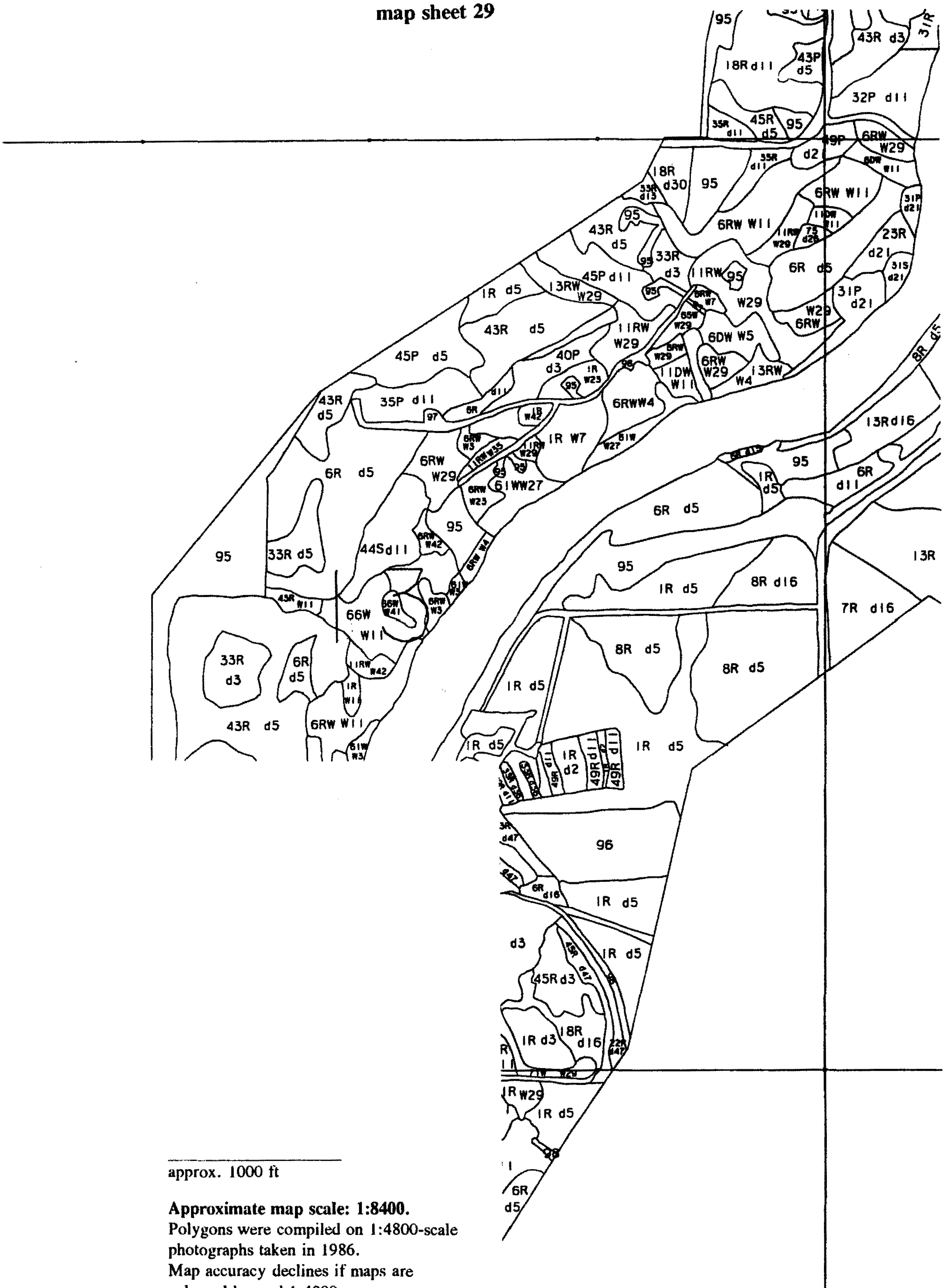
Kenai River plants
map sheet 29



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Map accuracy declines if maps are enlarged beyond 1:4800.

Kenai River plants
map sheet 30

approx. 1000 ft

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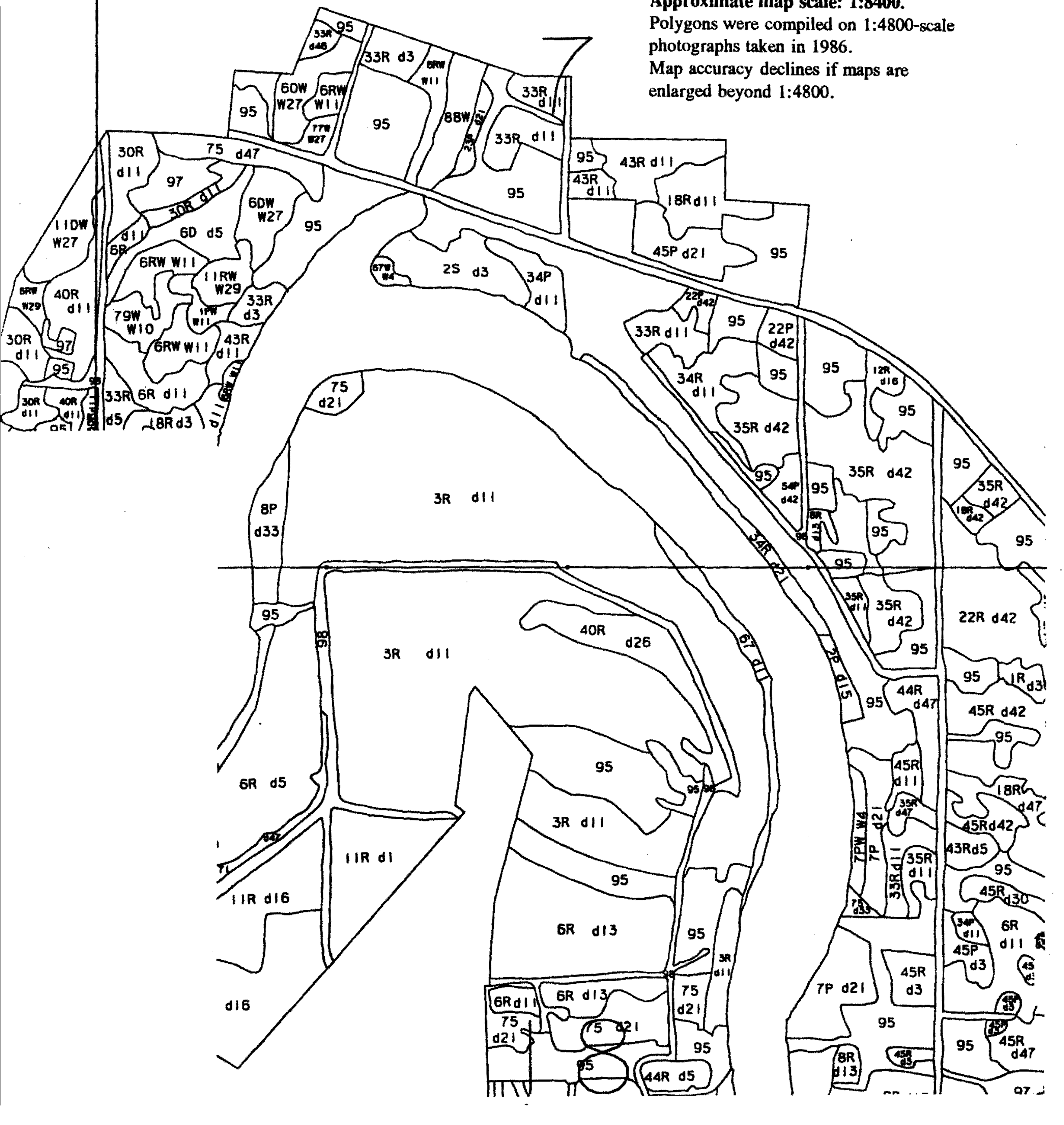
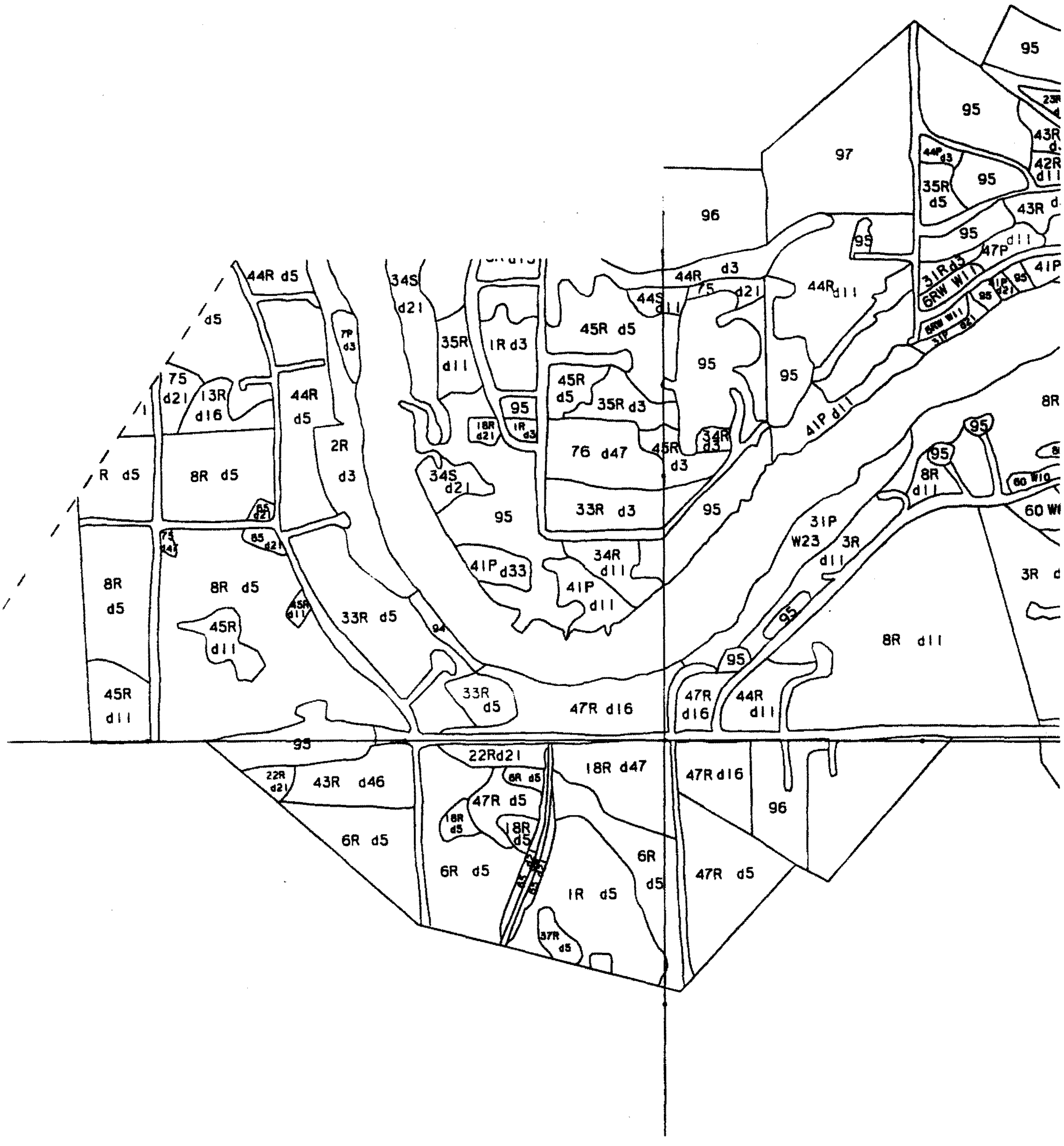


Kenai River plants
map sheet 31



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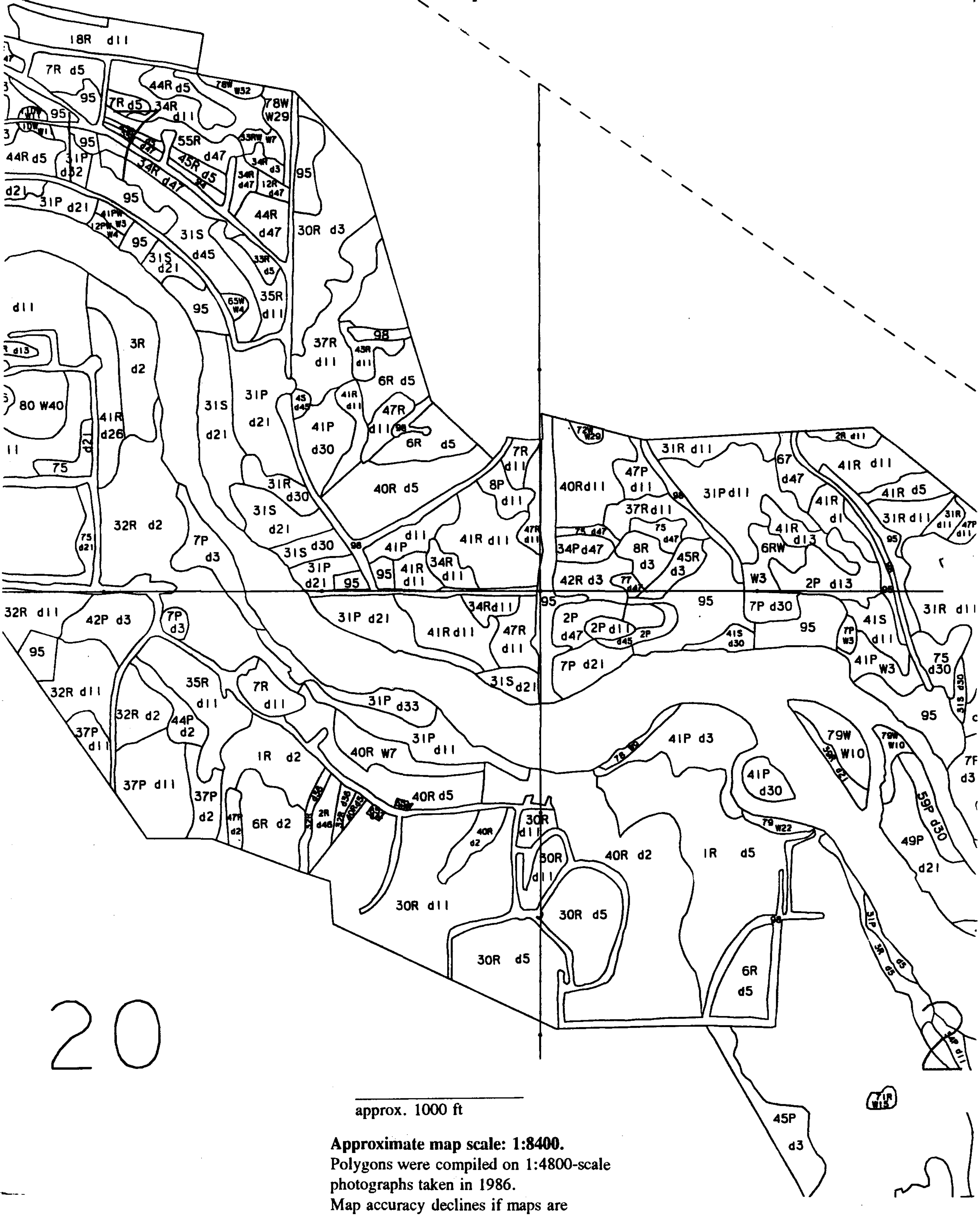
Kenai River plants
map sheet 32



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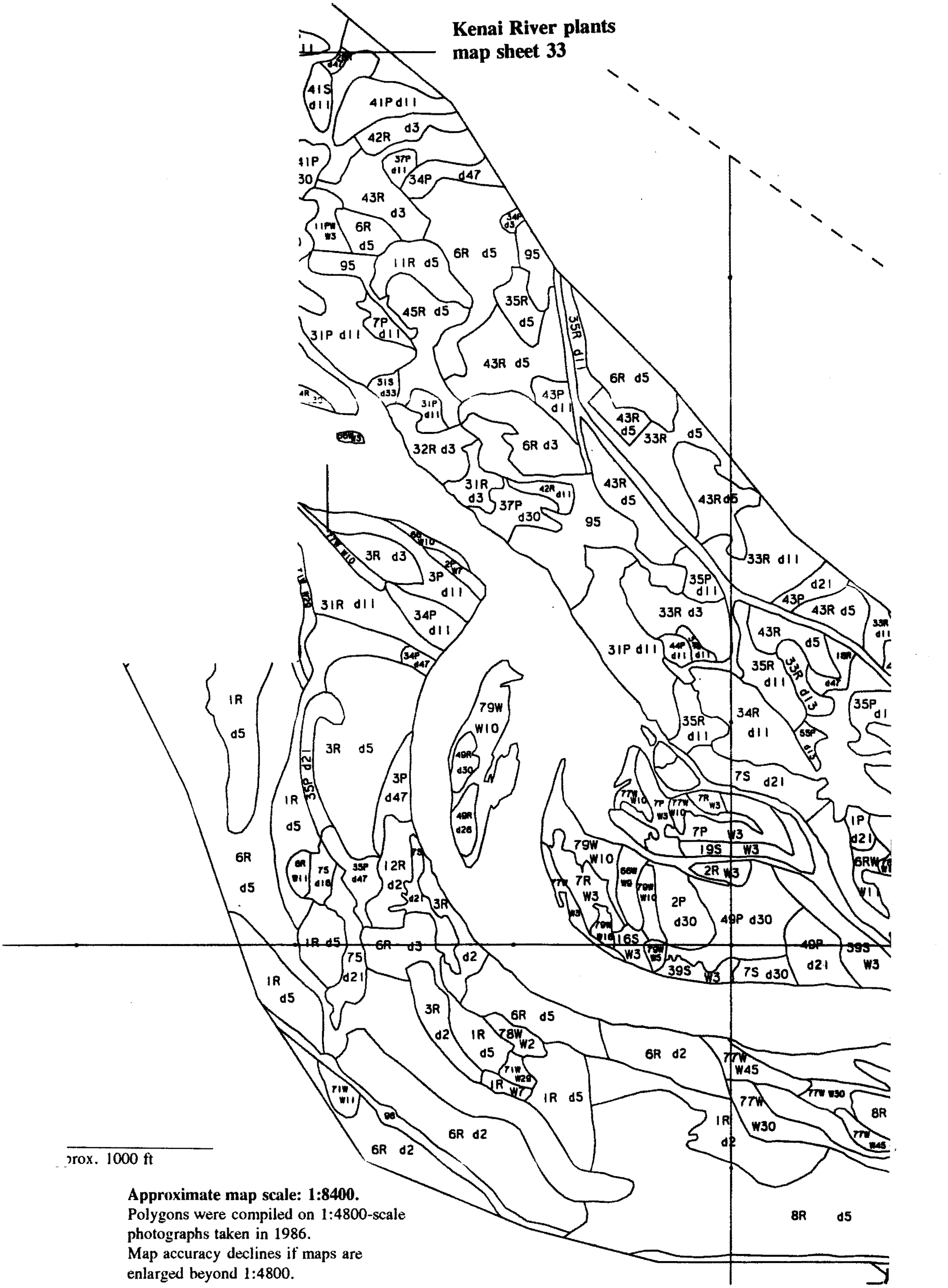
Kenai River plants map sheet 33



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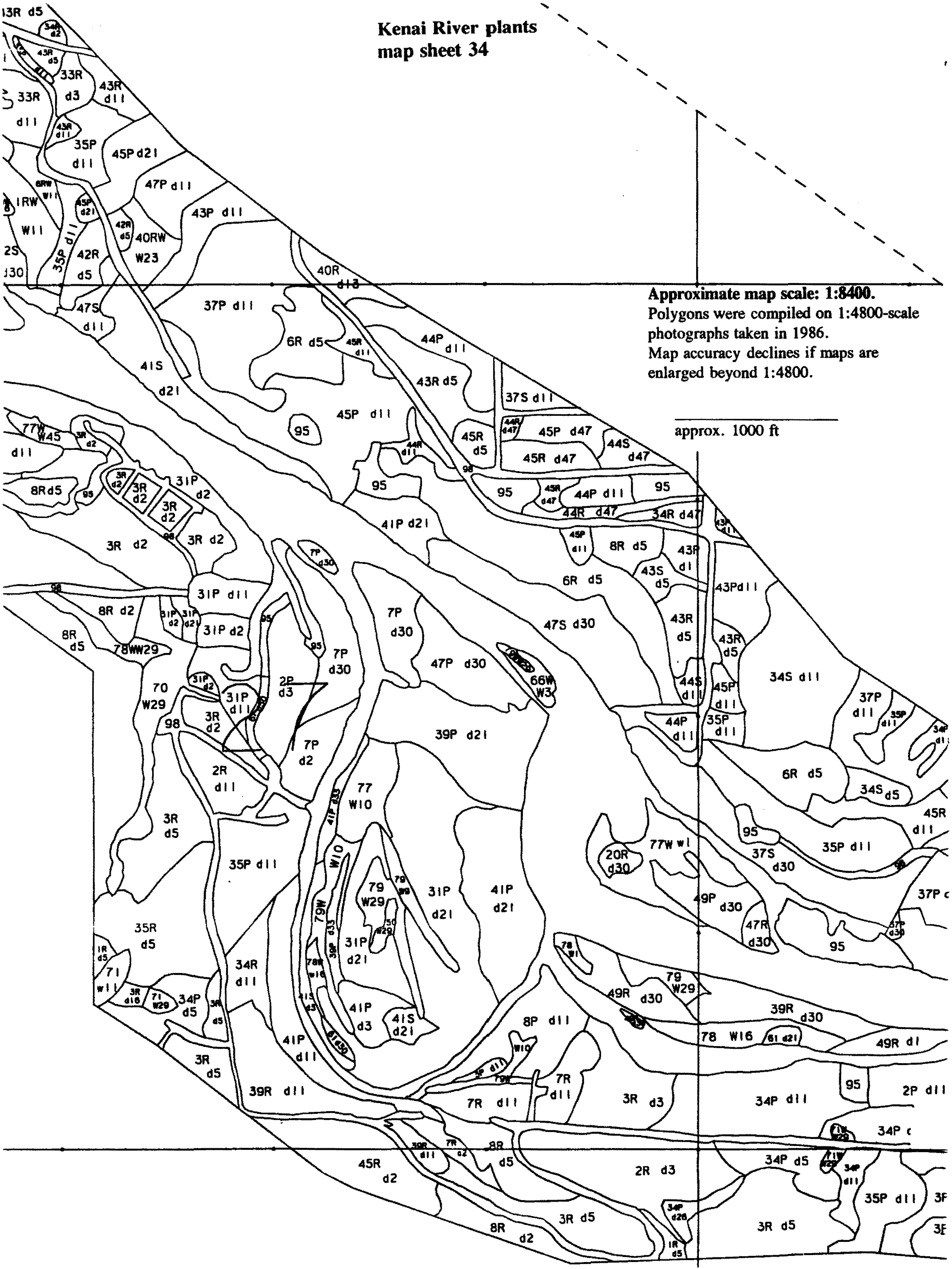
Kenai River plants
map sheet 34



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Polygons were compiled on 1:4800-scale photographs taken in 1986.
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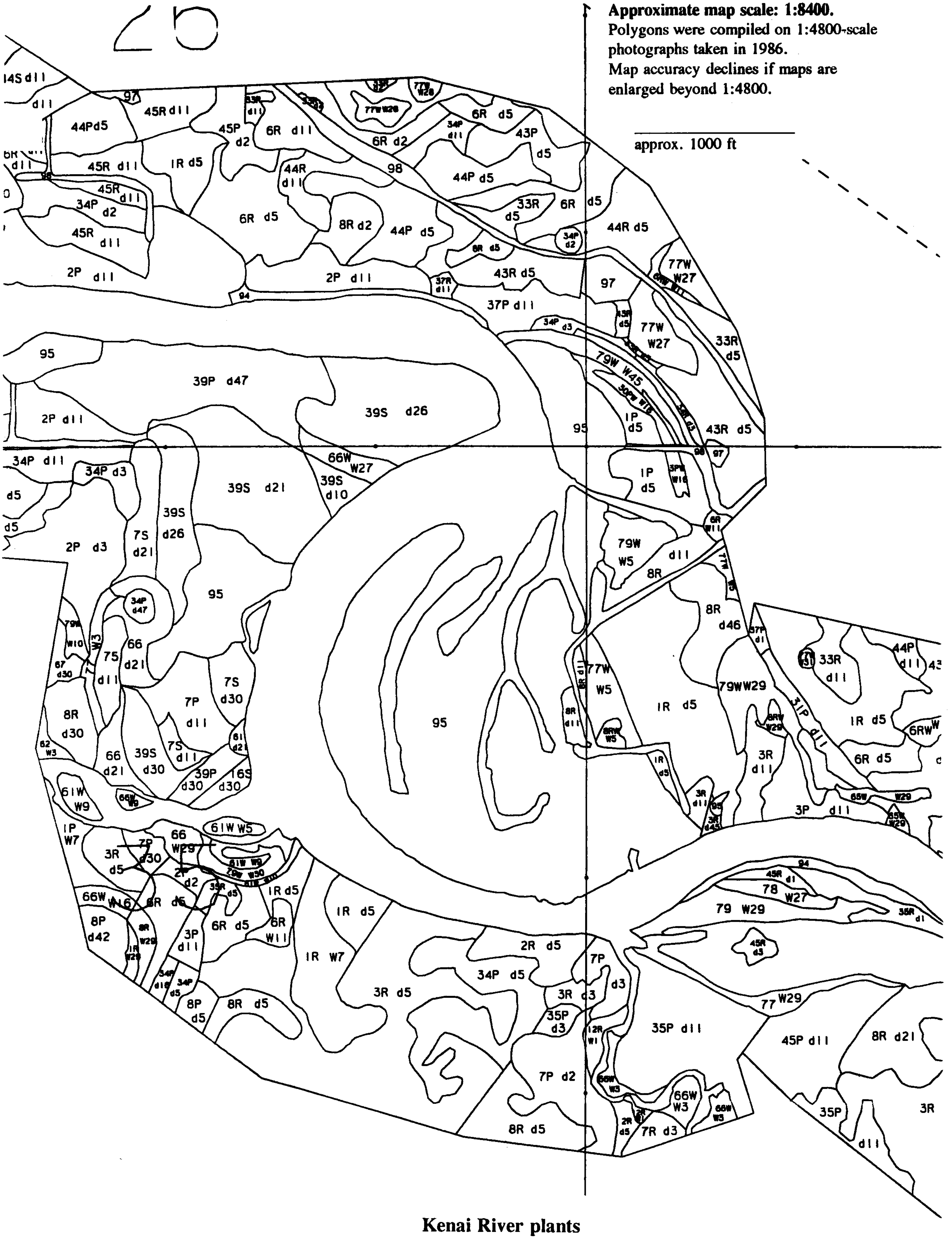
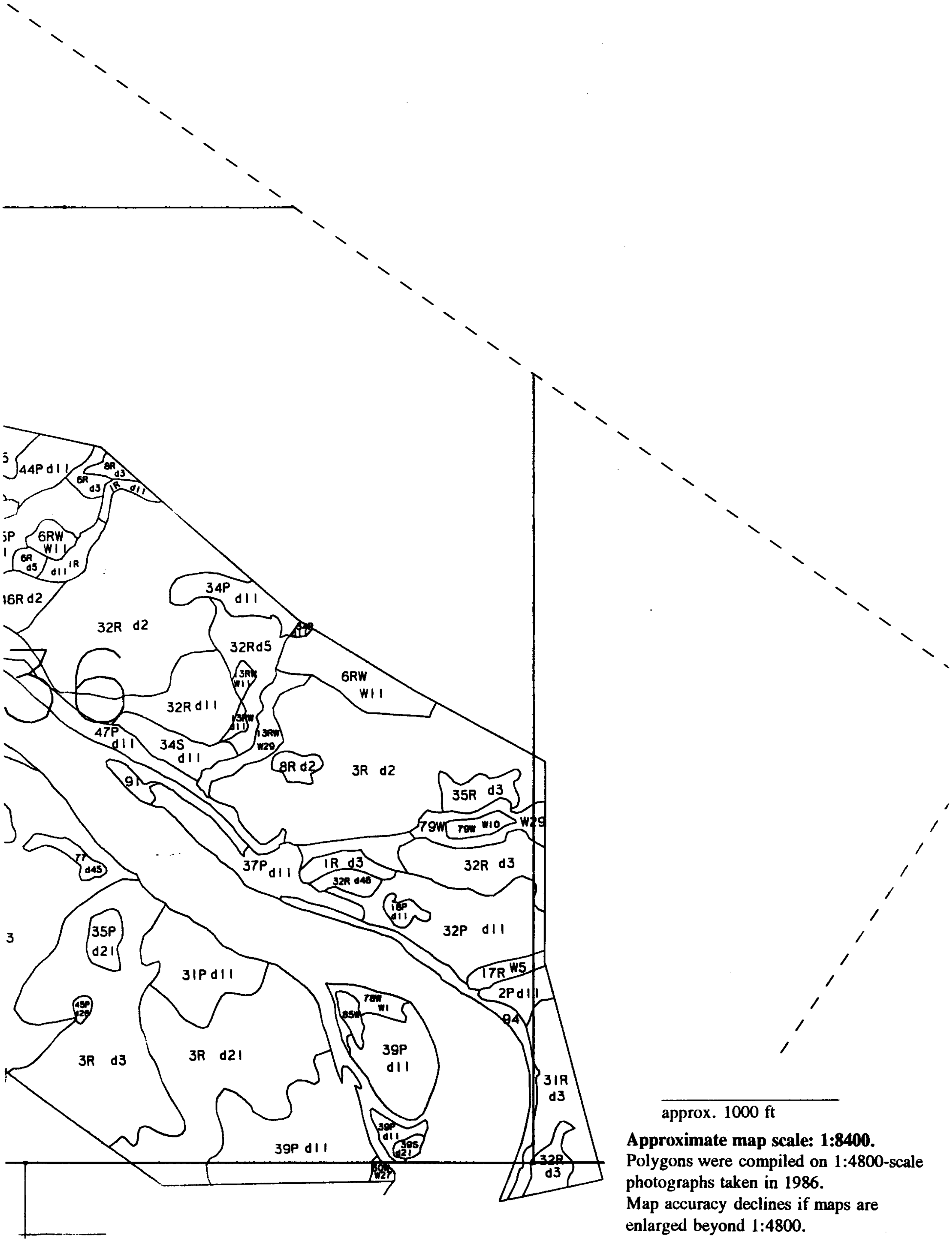


Kenai River plants
map sheet 35

Kenai River plants
map sheet 36



approx. 1000 ft

Approximate map scale: 1:8400.
Polygons were compiled on 1:4800-scale photographs taken in 1986.
Map accuracy declines if maps are enlarged beyond 1:4800.

VIII. REFERENCES

This list includes references we've cited in the text, as well as additional references of interest on particular topics. Most references can be ordered from the publisher or through a local bookstore. If the publisher's address was identified in the reference, we included it here to make ordering easier. If you'd like a publisher's address not shown here, call a nearby bookstore or Directory Assistance in the publisher's city. References published by agencies or written for them are usually available from the particular agency. Agency addresses and phone numbers are listed in Chapter VI, Section C. If a reference is expensive, you may want to suggest that the local library order a copy so it can be available to many landowners.

Alaska Agricultural Statistics Service, 1991, *Alaska Agriculture Statistics, 1991*, USDA, National Agricultural Statistics Service; University of Alaska, Agriculture and Forestry Experiment Station; Alaska Department of Natural Resources, Division of Agriculture; University of Alaska, Cooperative Extension Service, 39 pp.

Alaska Department of Environmental Conservation (DEC), 1990, *Alaska Nonpoint Source Pollution Control Strategy*, Alaska Department of Environmental Conservation, Division of Environmental Quality, Water Quality Management Section, P. O. Box O, Juneau, AK 99811-1800, 93 pp. plus Appendixes

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Finally, we would like to acknowledge staff at the Kenai Peninsula Borough. Dick Troeger, Planning Director, ensured that the Borough more than fulfilled its commitments to the Kenai River study. The staff of the Borough's Geographic Information System (GIS) Division: Dale Bertelson, Chris Clough, and Mary Toll, spent hours digitizing maps, inputting field data, printing draft maps for review, and responding to numerous requests for products. Their help has been critical to the success of this Guide; we look forward to working with them on the "Technical Report" of the Kenai River Study.

APPENDIX

SELECTED CHRONOLOGY OF THE KENAI RIVER BASIN COOPERATIVE RIVER BASIN STUDY COORDINATED BY THE USDA SOIL CONSERVATION SERVICE (CURRENT THROUGH 1992)

(Note: the first time an agency name appears, it is printed in boldface, along with its acronym.)

1984 The **Alaska Legislature** finds that the Kenai River and adjacent lands are an "...important natural resource..." that "... must be protected and preserved for the maximum benefit of all Alaskans" and that the "vitality" of the Kenai River is being threatened by overuse and stream bank development. The Legislature sets up the **Kenai River Special Management Area (KRSMA)** under AS 41.21.500-514. The KRSMA, encompassing all state lands along the river and the entire river channel below "ordinary high water," is placed under the jurisdiction of the **Alaska Department of Natural Resources (DNR), Division of Parks and Outdoor Recreation (DPOR).** The Legislature directs DPOR to develop a comprehensive plan for the river by June 1986 in consultation with a 19 member citizen/agency advisory board **(KRSMA Advisory Board)** and the **Kenai Peninsula Borough (KPB).**

1985 The KRSMA Board requests that DNR organize and coordinate a program of resource mapping and analysis to provide data needed for Kenai River planning. The Board identifies five resource categories of particular concern: "riparian areas," the "100-year floodplain," "shorelines with high erosion potential," "contiguous wetlands," and "other important habitat areas." DPOR requests that the **Alaska Department of Fish and Game (ADF&G)** take the lead in achieving mapping objectives and quantifying and filing an application for instream flow water rights for fish and wildlife. ADF&G begins meeting with other agencies to identify potential sources of mapping assistance. ADF&G learns that the Kenai River 100-year floodplain has been mapped by the **U.S. Army Corps of Engineers (COE)**, which has also developed preliminary maps of wetlands. ADF&G determines that the main data deficiencies outlined by the KRSMA Board are locations of (and criteria for defining) riparian areas, shorelines with high erosion potential, and other important habitat areas.

February 1985 The ADF&G meets with the DPOR and the **Soil Conservation Service (SCS)** to discuss applicability of the USDA Cooperative River Basins Program to Kenai River planning. At that meeting, SCS familiarizes ADF&G and DPOR with the role of local soil and water conservation districts in channeling SCS assistance. During discussion of potential contributions to a cooperative study, ADF&G indicates that, in addition to its ongoing Kenai River instream habitat studies, it will likely be able to contribute $40,000 to obtain aerial photography for use in resource mapping, as well as providing ongoing staff support for interagency coordination and data collection. ADF&G does not, however, expect to be able to contribute funds for ground-truthing or map interpretation. DPOR in a February 12 letter summarizing the meeting reiterates the need for a resource inventory and notes that the "...the SCS River Basins program would appear to be the best opportunity to bring a multi-disciplinary, multi-agency perspective..." to comprehensive planning for the KRSMA.

February 1986 The ADF&G develops a proposal to photograph the Kenai River and its tributaries using low-altitude color infrared photography. ADF&G also develops a proposal to use air photo interpretations to delineate and classify riparian zones along the Kenai River. The former proposal receives funding; the latter does not.

March 1986 The ADF&G requests SCS assistance in interpreting and ground-truthing low-altitude aerial photography along the Kenai River.

April 1986 The KRSMA Board in a phone call to SCS expresses interest in a Cooperative River Basins Study on the Kenai River. The Board learns that SCS assistance is channeled through local conservation districts and is told to discuss research needs with the **Kenai Soil and Water Conservation District (KSWCD).**

The Kenai SWCD discusses the needs for Kenai River inventory data with the KRSMA Board and the Kenai Peninsula Borough. The KSWCD adds the perspective that, in addition to data needed for implementing DPOR's Kenai River plan, soil and vegetation data would be useful to Kenai River landowners interested in developing private parcels in environmentally sound ways. The KSWCD asks the SCS to develop a draft proposal outlining a Cooperative River Basins Study for the Kenai River.

May 1986 The Kenai Peninsula Borough sends a letter to the KSWCD requesting that the District "undertake a soil mapping effort for lands adjacent to the river."

The KSWCD sends a letter to the Commissioner of DNR outlining a proposal for a detailed inventory of soil and related resources along the Kenai River and asks for DNR's response to the proposal.

ADF&G sends out the request for proposal to obtain color infrared Kenai River photography at a scale of 1:4800 (1 inch = 400 ft). (This photography becomes the photo base used by the SCS in its Kenai River inventory.)

June 1986 SCS meets with DNR (including the Deputy Commissioner and DNR staff from DPOR, **Division of Geological and Geophysical Surveys (DGGS) Hydrologic Survey Unit,** and **Division of Lands and Water Management (DLWM)** to discuss the proposed Kenai River study and to lay out potential agency responsibilities. DGGS indicates its intention to take responsibility for a bank erosion element of the study.

Alaska SCS sends a letter to SCS's Basin and Area Planning Division in Washington, D.C. requesting funding for a 2-year Kenai River soil and vegetation inventory. SCS estimates study costs at approximately $600,000.

July 1986 DNR sends SCS a letter noting that its participation in the proposed Kenai River study "...will depend on the funds available to the department..." and expresses support for SCS's inventory efforts.

Alaska SCS receives preliminary approval from SCS national headquarters to begin planning a Kenai River soil and vegetation inventory and starts developing the Proposal to Study (PTS) needed for formal funding approval.

September 1986 U.S. Geological Survey (USGS) requests funding to develop a geographic information system for the Kenai River Basin. SCS inventory data, as well as other Kenai River resource information, would be incorporated in the system. Although the DNR, ADF&G, KPB, SCS, **U.S. Forest Service (USFS)**, and **U.S. Fish and Wildlife Service (USFWS)** express formal support for the proposal, it is not funded.

November 1986 DNR adopts the *Kenai River Comprehensive Management Plan* required by statute. The Plan is binding within the KRSMA and advisory on all other Kenai River lands. The Plan provides guidelines for the use and management of Kenai River lands, but notes that "...there is a shortage of the comprehensive and detailed data necessary for site specific management decisions." The Plan reiterates the recommendation that DNR "...organize and coordinate an intensive program of resource mapping and analysis..." The KRSMA Advisory Board disbands upon completion of the plan.

Winter - Spring 1986/1987 SCS works on a Proposal to Study for the Kenai River Cooperative River Basin Study. As part of this process, SCS meets with KSWCD, DPOR, ADF&G, KPB, and other land managers and data users to clarify data needs and potential applications.

April 1987 In cooperation with the Kenai SWCD and the USFS, the SCS finalizes the Proposal to Study, submits this to its Washington headquarters, and distributes copies to interested entities, including the Borough, ADF&G, DPOR, **City of Kenai**, **City of Soldotna**, USFWS, USGS, COE, and the local media. SCS also begins selecting sites along the river to map during June 1987 as part of a "pilot study" designed to: a) assist with final selection and fine-tuning of mapping methods, b) produce example study products that can be reviewed by potential information users, and c) evaluate the accuracy of the existing published Kenai-Kasilof Soil Survey.

June 1987 SCS conducts a 10-day pilot inventory on Kenai River lands. Three sites, totaling 110 acres, are mapped using three levels of soil mapping intensity and two vegetation inventory methods. The COE, to ensure consistency between its wetlands maps and SCS soil and vegetation maps, schedules its preliminary field verification of Kenai River wetlands maps to coincide with SCS field work. The COE observes SCS field procedures.

July 1987 DGGS sends SCS a letter explaining that it will not be able to fund a comprehensive erosion study on the Kenai River and that the PTS may need revision to reflect this lack of DGGS involvement. DGGS states its willingness to review whatever study SCS performs.

October 1987 SCS receives formal approval to develop a Plan of Work (POW) for a Kenai River Cooperative River Basin Study.

Fall - Winter 1987/1988 SCS develops example maps and interpretive products based on the pilot study and starts developing the full-scale Plan of Work. The KPB begins using SCS field data in a pilot project to test and demonstrate capabilities of a computerized geographic information system (GIS) it has begun developing.

December 1987 SCS holds an informational meeting at the KPB offices to: a) "...explain to interested groups details of the proposed Kenai River Basin Study," b) solicit feedback on example products developed from the pilot study, and c) obtain comments on the draft version of the Plan of Work. In addition, the Borough introduces participants to its new GIS. Borough Mayor Don Gilman opens the meeting with a statement of support for the Kenai River inventory. Others attending include representatives from the Kenai SWCD, USFS, ADF&G, DPOR, and City of Soldotna.

May 1988 The final *Kenai River Cooperative River Basin Study Plan of Work* is signed by SCS, Kenai SWCD, USFS, KPB, ADF&G, DPOR, and City of Soldotna.

SCS and the Borough begin developing a cooperative agreement outlining their related responsibilities. Among its tasks, the KPB agrees to digitize SCS inventory data into its GIS and to assist the SCS in identifying Kenai River landowners. The KPB also agrees to provide office space to the SCS field crew during the 1988 field season. The Borough projects its in-kind contributions during the River Basin Study at approximately $47,000. (Difficulties in estimating the value of its in-kind services delays final Borough signing of the cooperative agreement until November 1989.)

SCS begins mailing out an information flier to all Kenai River property owners whose lands will be mapped during the 1988 field season. The flier introduces them to the study and offers them an opportunity to meet with the field crew during mapping. (Fliers are mailed to landowners each field season 2-4 weeks before SCS begins mapping in their areas.)

June - October 1988 SCS conducts its first full field season of soil and vegetation mapping along the Kenai River. Lands are mapped on the north side of the Kenai River, from the upstream boundary of Soldotna downstream to Cook Inlet. Because funding shortfalls preclude hiring additional soils staff to assist the SCS Homer field office soil scientist, the 2-year study is rescheduled as a 4-year study.

ADF&G agrees to an SCS request for occassional boat transportation support whenever possible. SCS also begins exploring with ADF&G ways to accomplish a riverbank erosion study.

August 1988 The Kenai Borough coordinates the first meeting of an interagency "Kenai River Basin Steering Committee" in Anchorage to review ongoing Kenai River studies and additional data needs. At that meeting, the Kenai River erosion study is identified as the highest priority research need remaining. Best management practices applicable to development of Kenai River lands are identified as the second highest remaining priority.

Winter 1988 With the possibility that some funding might become available through the Borough's Coastal Zone Management allocation, the SCS begins developing a methodology for inventorying streambanks. SCS staff from Alaska and the West National Technical Center (WNTC) examine Kenai River banks with staff from ADF&G and DPOR. SCS then chairs an interagency work session at the Borough offices to review reconnaissance findings and lay out a preliminary streambank inventory method. Representatives from ADF&G, DPOR, KPB, and the KRSMA Board participate in the work session.

June - October 1989 Second summer of SCS field work. Lands are mapped on the south side of the Kenai River, from the upstream boundary of Soldotna downstream to Cook Inlet.

October 1989 SCS conducts 2-week field test of bank erosion methodology developed in May. First week of field testing involves SCS staff from Alaska and WNTC. During second week of testing, ADF&G provides larger boat and an operator and SCS staff is joined by staff from ADF&G and DPOR. The field test is documented in *Kenai River Streambank Erosion Special Report* (F. Reckendorf, 1989, SCS WNTC).

November 1989 SCS gives brief presentation to KRSMA outlining work to date on soil and vegetation inventory and bank erosion study. KRSMA Board passes resolution requesting the State Legislature to match SCS dollars and help fund a Kenai River bank erosion study. The City of Soldotna raises the possibility that it may be able to cost-share on the bank study within Soldotna city limits if funding is not obtained from the State.

February 1990 ADF&G files for two instream flow reservations on the Kenai River. This fulfills an objective identified in the *Kenai River Comprehensive Management Plan.*

March 1990 The City of Soldotna appropriates $18,000 to fund a bank erosion study within Soldotna city limits. The City signs a cooperative agreement with the Kenai SWCD, which takes responsibility for overall study coordination. SCS responsibilities are also outlined in the agreement. The City makes office space available for SCS use during the entire 1990 field season.

May 1990 SCS inventories 14 miles of streambank within the City of Soldotna and begins developing related study products, particularly potential alternatives for stabilizing streambanks.

June - October 1990 Third summer of SCS field work. Soil and vegetation are mapped on lands on the north side of the river, from the upstream boundary of Soldotna upstream to just below Skilak Lake. (The study corridor ends at the boundary of the Kenai National Wildlife Refuge.) At the end of the field season, three-fourths of the Kenai River corridor have been mapped.

August 1990 The SCS meets with the City of Soldotna, KPB, and the KSWCD as part of ongoing coordination of the bank erosion study. (SCS bank data are being entered into the Borough's GIS by a contractor working for the City.)

September 1990 The SCS chairs an interagency meeting to solicit feedback on various proposed bank stabilization practices. The meeting is attended by representatives from the KRSMA Board, City of Soldotna, KPB, ADF&G, DPOR, KSWCD, USFWS, and the public.

October 1990 SCS gives another status update to the KRSMA Board. The Board passes a resolution articulating continued support for SCS River Basin activities and commending the SCS for its efforts to date.

January 1991 SCS and KSWCD update the KRSMA Board on status of ongoing Kenai River mapping. The Board expresses strong support for the City of Soldotna bank inventory, and the City of Kenai expresses interest in funding a bank study within its city limits.

February 1991 A draft report by the SCS West National Technical Center discussing the City of Soldotna stream bank inventory is distributed for review (draft is titled: Kenai River Soldotna Reach Special Report; final version is titled: City of Soldotna, Alaska, Kenai River Bank Inventory Report). The report describes inventoried stream reaches and illustrates a variety of alternatives for stabilizing and rehabilitating eroding stream banks. The draft is distributed to a variety of groups and agencies for comment.

April 1991 SCS and KSWCD hold an interagency meeting to discuss issues raised by the draft Kenai River bank inventory report and to clarify how the Soldotna bank inventory fits into the overall Kenai River Cooperative River Basin Study. Those attending include: City of Soldotna, ADF&G, DPOR, and the Executive Director of the **Alaska Soil and Water Conservation Board (ASWCB)**. Review period for the bank inventory report is extended. An interagency workshop is scheduled for early June to permit further review and discussion of bank rehabilitation/stabilization options potentially applicable to particular sites within the City of Soldotna.

June - October 1991 Fourth and final summer of SCS field work. Lands are mapped on the south side of the Kenai River, from the upstream boundary of Soldotna upstream to the Refuge boundary just below Skilak Lake.

June 1991 The KSWCD sponsors a 2-day interagency workshop to review options for potential bank rehabilitation/conservation trials within the City of Soldotna. Over 40 individuals attend. Agencies and groups represented include: KSWCD, SCS, City of Soldotna, USFS, DPOR, COE, ADF&G Habitat, Sport Fish and Commercial Fish Divisions, **Alaska Plant Materials Center (PMC)**, KPB, **Alaska Department of Transportation and Public Facilities (DOTPF) Environmental Section, National Marine Fisheries Service (NMFS)**, KRSMA Advisory Board, as well as local contractors involved in bank stabilization. Also participating are three staff members from Robbin B. Sotir and Associates, a consulting firm specializing in "soil bioengineering" (the use of live plant materials to create "living structures" for soil stabilization). Traditional engineering and bioengineering approaches for bank rehabilitation are presented and the group visits three publicly owned sites that are candidates for demonstration field trials. Participants discuss specific land use goals and potential rehabilitation approaches as they apply to these sites. Group discussions are summarized in writing by the SCS, with copies sent to all workshop participants. The group indicates strong support for conservation trials that would demonstrate and field test several bioengineering approaches.

August 1991 The Kenai SWCD delivers the final version of the *City of Soldotna, Alaska, Kenai River Bank Inventory Report* to the City of Soldotna.

The DLWM is divided into two divisions: **Division of Land (DOL)** and **Division of Water (DOW)**. The Hydrologic Survey Unit of DGGS is integrated into the new Division of Water.

May 1992 The ADF&G **Division of Fisheries Rehabilitation, Enhancement, and Development (FRED)** releases the final report of a Kenai River water quality investigation. The investigation, begun in the fall of 1989, provides an assessment of current water quality and establishes a baseline for evaluating future water quality impacts.

May - December 1992 The SCS Homer field office (FO) prepares a *Kenai River Landowner's Guide*. The *Guide* "...is envisioned as a manual on 'how to' live with the river in ways that allow landowners to work towards their goals while protecting fish and other river resources."

In July, the FO sends an informational letter about the *Guide* to over 70 potential reviewers representing agencies, Kenai River landowners, the media, and other groups and individuals. The letter includes: (a) the *Guide's* proposed general table of contents, (b) individual chapter tables of contents, (c) a draft version of the "Introduction," and (d) draft sections of Chapter IV, "Living with the Kenai River." The letter invites recipients to review and comment on material provided and/or to specify which additional proposed sections they would like to review. Preparation of the *Guide* is announced in the *Peninsula Clarion* on August 4, along with an invitation to landowners to assist with review.

In August, September, and October, additional draft write-ups are sent to agencies, landowners, and others having expressed interest in reviewing all or some draft sections of the *Guide*. Specific material is also sent to appropriate professionals for technical review.

June 1992 The DPOR begins a study of the Kenai River's social/recreational "carrying capacity" and the impacts of crowding on river-related experiences. Groups whose experiences are surveyed include: driftboat and powerboat anglers, fishing guides, bank anglers, non-fishing recreationists, and landowners.

July 1992 The ADF&G Habitat Division begins a 3-year study to "identify primary, secondary and cumulative impacts on fish habitat resulting from riparian zone development along the Kenai River." The study is also intended to "develop assessment methodology and management policies that will avoid and/or reduce future development impacts on fisheries habitats."

August 1992 The City of Soldotna contacts the SCS to determine if the SCS can assist them in planning, designing, and/or implementing soil bioengineering demonstration projects at Centennial Campground and Soldotna Creek Park. In response to the city's request, SCS Alaska staff, as well as a Landscape Architect and Erosion Control Engineer from the WNTC, schedule a work session with the city and Kenai SWCD for September.

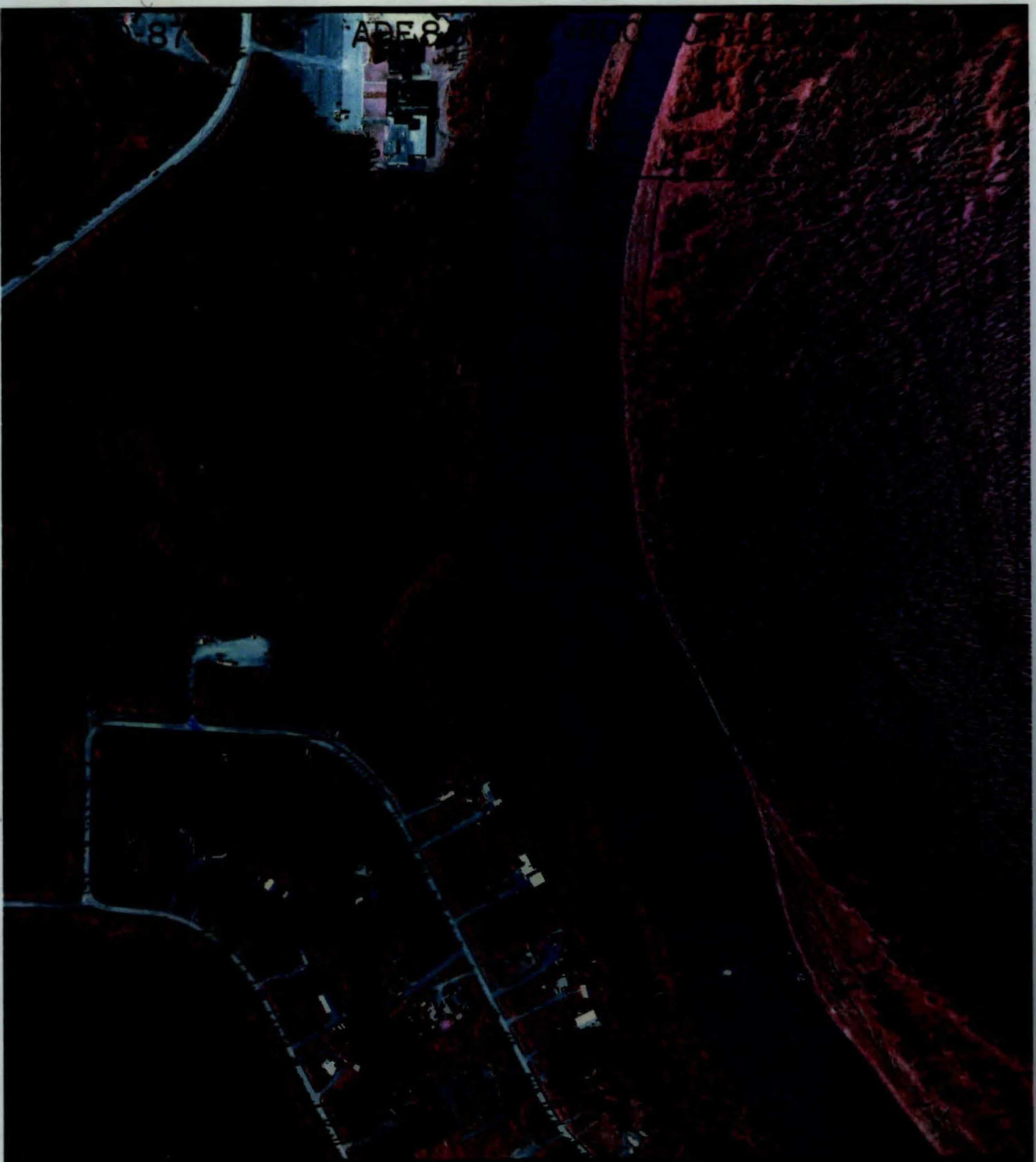
The SCS is contacted by members of **Kenai River Sportfishing, Inc.** who are organizing the **Kenai River Habitat Protection Association (HabPro)**. The proposed goal for HabPro is to provide guidance and positive incentives to Kenai River landowners to encourage and assist them to maintain and/or restore instream, bank-edge, and riparian habitats for the benefit of Kenai River fish and other resources. Kenai River Sportfishing, Inc. requests SCS technical assistance for the HabPro program.

September 1992 SCS Homer FO staff makes a presentation to an Anchorage meeting of the **Kenai River Property Owner's Association (KRPOA)**. Property owners are given an update on the Kenai River Cooperative River Basin Study and drafts of the *Guide* are made available for review. The membership of the KRPOA votes to "...make copies of the *Kenai River Landowner's Guide* available to all members of the Association." In a subsequent letter documenting this action, the KRPOA states: "The development of this guide meets a need expressed by property owners for many years, the need for reliable information to be used as we plan development of our private property."

SCS WNTC and SCS Alaska staff meet with the City of Soldotna and the Kenai SWCD to discuss soil bioengineering demonstration projects in Centennial Campground and Soldotna Creek Park. The SCS agrees to provide: (a) "conceptual site plans" for the parks, (b) assistance with public information efforts during project planning and installation, and (c) assistance with project monitoring and evaluation, as well as "technology transfer," after project completion. Following meetings with the city, SCS meets with DPOR in Soldotna and ADF&G in Anchorage to familiarize them with proposed activities and invite their involvement.

November 1992 SCS Homer FO staff makes a presentation to a Soldotna meeting of the Kenai River Property Owner's Association. Property owners are given an update on the Kenai River Cooperative River Basin Study, draft versions of the *Guide* are made available for review, and property owners are invited to write down their personal thoughts about the Kenai River for inclusion in the *Guide*.

November and December 1992 An advisory board for the Kenai River Habitat Protection Association meets once in each month to discuss organization, technical criteria, etc. related to the Association's "Kenai Eagle" award for "keeping an eye on our river's future." The advisory board includes representatives from Kenai River Sport Fishing, Inc., SCS, DPOR, ADF&G, Kenai SWCD, **Cook Inlet Professional Sportfishing Association**, KRPOA, KRSMA Advisory Board, and the **Kenai River King Salmon Fund**. At the December meeting, the advisory board agrees that land use guidelines outlined in the *Kenai River Comprehensive Management Plan* and the *Kenai River Landowner's Guide* will constitute initial land use criteria recommended to landowners by the HabPro program.



Color infrared photograph with a scale of 1:4800 (1 inch on the photo equals 400 ft on the ground). "CIR's" like this provided the photo base for Soil Conservation Service mapping of soils and plant communities along the lower Kenai River. This photograph shows soil "map units" or "polygons" along Slikok Creek (just upstream from Kenai Peninsula College), as well as soil map units across the river. (This photography was flown in 1987 under contract to the Alaska Department of Fish and Game.)