Michigan's Native Landscape

As Interpreted from the General Land Office Surveys 1816-1856

prepared by:
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Township 51 North, Range 43 West (Ontonagon County)

"...The N[orth] side of the Township is quite regular and uniform ascending from the shore in a smooth and open timbered land. Though toilsome, the scene that presents itself fully compensates the labor from the point which I have estimated at 1050 feet above Lake Superior. A part of the NW coast of the lake maybe seen the extremity of Keweenaw Point thence the line of Trap hills which skirts the horizon S. Westerly to their junction with the Porcupines in which you stand, 20 miles distant, with the vast expanse of Lake, altogether forms a beautiful and varied landscape scarcely equalled among the Alps of Italy...

...The beauty of the Sugar groves...can scarcely be conceived. The ground is smooth underfoot and free from undergrowth whith a great variety of wild flowers spring up where you head filling the air with perfume. What would prevent the settlement of so fine a region; the temperature this day May 26 is about 60 degrees and I am informed that the temperature in these parts winter has not been below the zero point but once during that time..."

Sylvestor W. Higgins, Deputy Surveyor
Bela Hubbard, Deputy Surveyor
1846

Township 50 North, Range 39 West (Ontonagon County)

"...The best point of observation, which is the highest in the town, is in sec. 16. The view from this point is truly grand. A deep basin like Valley lies before you, reaching almost to your feet, in the distance, deep gorges are seen descending between the hills, pouring along a continual flood, the cascades & falls send up long columns of vapor, and clouds low down mantle over the lakes, and small expanses of water collected between the hills. The landscape presents one sea-like rolling umbragous wilderness, while the vision strained to the utmost, is bounded by the circular trending of the great Huron Primitive range many miles to the South, sweeping from Huron River round to Fond Lac, enclosing within the arc of its great circle the trap range on which you stand - like two giants of equal altitude, though not of equal age - both having a common origin - the elder has scattered his disrupted masses - his granite and syanite upon the highest peaks and lowest valleys of the younger. The war of elements which began, can only end the eternal strife between them..."

Sylvestor W. Higgins, Deputy Surveyor
1847

..." The country was what is termed 'rolling'...with some fancied resemblance to the surface of the ocean...the trees, with very few exceptions, were... 'burr-oak'...and the spaces between them, always irregular, and often of singular beauty, have obtained the name of 'openings' ...'Oak Openings'...the trees were of very uniform size, being little taller than pear trees... and having trunks that rarely attain two feet in diameter...in places they stand with regularity resembling that of an orchard, then, again, they are more scattered and less formal, while breadths of the land are occasionally seen in which they stand as copses, with vacant spaces, that bear no small affinity to artificial lawns, being covered with verdure. The grasses are supposed to be owing to the fires periodically lighted by the Indians in order to clear their hunting grounds..."

James Fenmore Cooper, *The Oak Openings*
Kalamazoo County, 1812

Township 7 South, Range 4 West (Hillsdale County)

"...To have come this distance required 'Long legs, short thighs, Little head & no eyes' through the willows, the rose briars and prickly ash..."

William Brookfield, Deputy Surveyor, 1825

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As Interpreted from the General Land Office Surveys 1816-1856

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INTRODUCTION

The growing awareness of the decline of biodiversity has been one of the driving forces behind changing views on land-use planning and land management. As pressure on land resources increases, planners and managers must find new ways to guide economic development while restoring and maintaining the integrity of the natural systems within their jurisdiction. Tools that enhance our understanding of natural patterns and processes across large landscapes can provide insights for land-use planning and land management.

Knowledge of the type, location, and ecological context of Michigan's native vegetation, as it appeared prior to widespread European settlement in the 1800s, provides an important building block for ecologically meaningful management strategies. By comparing historical data with more recent data, spatial changes of vegetation types for a given land unit may be analyzed and more easily assessed. A historical database provides an important reference point for understanding cumulative impacts to natural systems caused by fragmentation, degradation, and conversion. Patterns we see today in species distributions, wetland hydrology, and ecosystem function become more meaningful when placed in a historical context.

Natural disturbances such as wildfire, windthrows, and beaver floodings played an important role in the development of vegetative pattern across Michigan's native landscape. Clarifying the type, location, and ecological context of natural disturbances provides useful insights for developing ecological models. These models can lead to management strategies that more efficiently mimic natural processes.

Native Americans also used fire as a land management tool and played a role in the development and maintenance of Michigan's native vegetation (Jones & Kapp 1970, Whitney 1994). It is helpful to know where their activities were most concentrated so that vegetative patterns can be viewed in the most accurate context.

Of course natural ecosystems are quite dynamic, and the pattern of Michigan's native vegetation, natural disturbances, and Native American activities changed continually over the past 16,000 years since the last glaciation (Delcourt & Delcourt 1981). However, a clear picture of the patterns and processes as they appeared just two hundred years ago, immediately prior to the logging era and intensive agricultural development of the nineteenth century, has many applications for our understanding of current conditions.

General Land Office Surveys

The township plat maps and transcribed field notes of the initial land surveys provide the best available record on Michigan's native landscape (Bourdo 1954). The General Land Office (GLO) was established by the federal government in 1785 to survey the nation's western territorial lands. Lands of what was then the Michigan Territory (until statehood in 1837), had to be surveyed prior to their sale to private individuals. The surveys were conducted in Michigan by Deputy Surveyors of the General Land Office between 1816 and 1856, prior to widespread European settlement (Base and Meridian lines were established several years earlier). The survey was, therefore, conducted just before the logging-era, which saw the most dramatic transformation in Michigan's natural landscape since the last glaciation.

Survey methods are described in detail by White (1984) and the communications between the Surveyor General and Michigan's Deputy Land Surveyors are found in Caldwell (1990). Surveys were organized around a 36 square mile grid (Figure 1). Each grid would form a township. Townships were organized in association with previously established Meridian and Base lines, forming the familiar layout known as "Township and Range." The Base line was an east-west line from what is now the Van Buren-Allegan County line, east to Lake St. Clair. The Meridian line extended north-south, from Sault Ste. Marie to the Hillsdale-Lenawee County line. As an example, Township 32 North, Range 15 West, locates an area 32 townships north of the Base Line and 15 townships west of

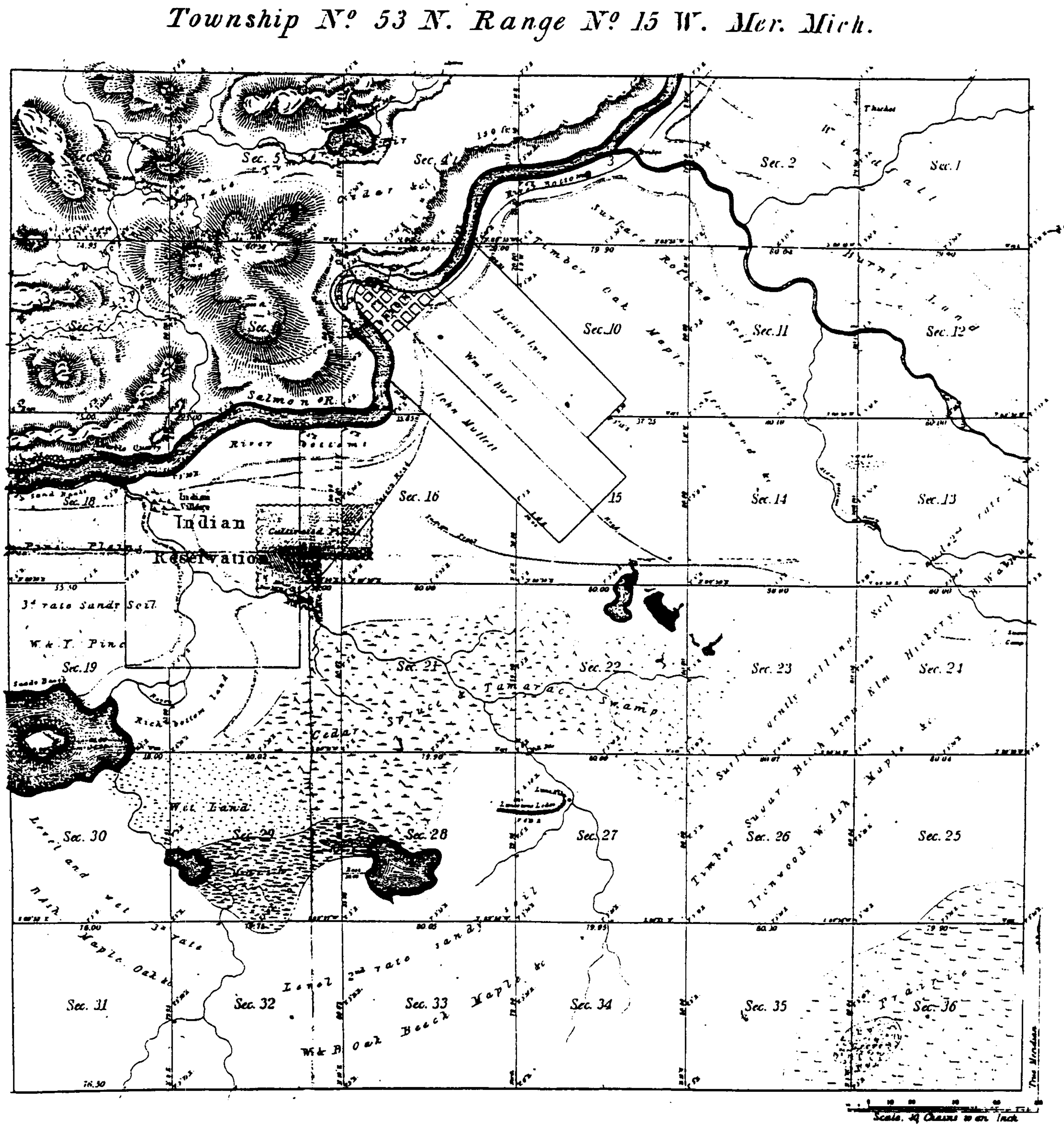


Figure 1: Hypothetical Township Plat Map used to train surveyors in Michigan.

the Meridian line. In most of Michigan, outside township boundaries were established several years before the individual square-mile sections were subdivided.

Surveyors were attempting to create an accurate picture of the land resources of the territory and leave markers to indicate township and section boundaries for future settlers. They needed to include enough land resource information for settlers to make a sight-unseen land purchase, and mark the lands well enough for the settler to be able to later find the parcel on their own.

In order to complete this task, they used a compass and "chain" to make accurate measurements. Chains were made up of 100 "links" that totaled 66 feet in length (80 chains per mile). As they measured out the boundaries of townships and sections, surveyors made notes on the topography, soils, and vegetation they encountered along each one mile section line. At each section corner and half-mile point, they pounded a wooden post into the ground. That post would later be used to establish legal property boundaries. In two to four quadrants around the post they marked "witness trees." The witness trees were to aid the settler in locating the survey post that had been pounded into the ground.

As with the information noted along each section line, information on witness trees was entered into the surveyor's field notebook. When they had completed the survey of a 36 square mile township, surveyors drew a plat map, depicting in general terms, the types of land resources they encountered within that township.

This square mile grid of the state, surveyed during the establishment of counties and 36 square mile townships, formed the framework for surveyor's maps and field notes, which provided the core of historical data for this project.

The township plat maps in Michigan vary considerably in their quality. They were produced at the time of the surveys without the benefit of a topographic map. Maps produced in early years of the surveys (southern, Lower Michigan) contain little information, often limited to the locations of lakes and streams. As the surveys progressed to the north, increasingly more information was included on the plat maps. Those produced in Northern Michigan include much information on natural and cultural features. Figure 1 illustrates a hypothetical township plat map that was used to train surveyors on the types of features they needed to include in their reports. They included abrupt topographic features, rivers and streams, lakes, wetlands, existing settlements, trails, and roads. There were also general comments on bedrock outcrops, soils, and vegetation written across the sections where those features were found.

Although survey methods saw minor modifications during the course of the Michigan surveys, the transcribed surveyor's notes are much more consistent in quality throughout the state than the township plat maps. Surveyors were instructed to note the exact location of wetlands, lakes and streams, comment on the agricultural potential of soils, and note the quantity and quality of timber resources as they were encountered along each section line (White 1984, Caldwell 1990). Wherever they marked trees, surveyors noted their species and diameter at breast height. Tree species and diameter was also noted when they occurred along the section lines. At section corner and half-mile points, witness trees were selected from nearby trees in the northeast, northwest, southeast, and southwest quadrants. Often just two trees were marked and noted around each corner post. The exact bearing and distance of each witness tree in relation to the associated corner post was also measured and recorded. Recently burned areas, windthrows, and beaver floodings were recorded along the section lines, as were various cultural features, of either Native American or early European settler origin.

These detailed records formed the basis for the development of our presettlement vegetation maps. Our maps were compiled by plant ecologists familiar with Michigan's tree species, surface geology, and soils. This report will discuss the methods used in map production, provide some general considerations for using the maps, then give a regional overview of native vegetation, natural processes, and historic land use throughout the state. This report is intended as a guide to be used along with Michigan's presettlement vegetation maps.

Previous efforts

Previous state-wide attempts at mapping Michigan's presettlement vegetation were completed by Marschner (1940) and Veatch (1959). Marschner utilized maps and field notes from the original land surveys to complete a map of Michigan, Wisconsin, and Minnesota.

The Marschner map (scale 1:2,500,000), as re-drawn by Perejda (1946), depicted the location of eight different categories of vegetation including swamp, hardwood forest, hardwood-conifer forest, pine flats (hemlock, white pine, cedar, fir, and spruce), pine plains (jack pine, "Norway"pine, and white pine), wet and dry mixed forest, marsh and wet prairie, and prairie (Figure 2).

Veatch relied to a large extent on soil association maps, but also utilized surveyor's data and local histories.

J.W. Trygg (1964) produced composite maps for the Upper Midwest using the surveyor's township plat maps. His maps differentiate between prairie, marsh, bottom lands, and swamp. They do not indicate the dominant tree species of the swamps. Information on upland forest was limited to the locations of historical pineries. He also included cultural features.

Trygg completed no maps for southern Lower Michigan, due to the above mentioned lack of information on the township plat maps.

Although not a statewide treatment, Brewer et al. (1984) produced a detailed presettlement vegetation map for southwest Lower Michigan using GLO survey data combined with information on historic prairies. Their interpretations differ from ours primarily in the methodology used for delineating savannas.

Our presettlement vegetation map of Michigan is the first attempt to create a detailed view of the entire state's presettlement vegetative pattern and natural disturbances within a digital environment. The utility of this spatial database is greatly enhanced by the ability to conduct spatial analyses within the electronic environment of a computerized Geographic Information System (GIS).

METHODS

Map Production

We used the transcribed General Land Office survey notes (1890), which were made available to our mapping team by the State Archives of Michigan. Township plat maps produced by surveyors were copied from microfilm available from the Real Estate Division of the Michigan Department of Natural Resources and State Archives of Michigan. We attached matte mylar to the most recent 7.5 minute, U.S. Geological Survey topographic maps, which for Michigan, are available in 1:24,000 and 1:25,000 scales and include topographic contour intervals of five, 10, and 20 feet depending both on the date of map publication and local topographic relief. A scale indicating chains (at 1:24,000 and 1:25,000 scales) was used for precise measurements along each section line.

We plotted all information extracted from the GLO survey notes and maps onto the mylar overlays and map margins. Information in the transcribed surveyor's notes is organized in a systematic pattern, reflecting the measurement of each section line in the township (Figure 3). We abbreviated common names of tree species in 3-5 letter combinations to speed the plotting of data (Table 1). Surveyors noted some tree species more generically than others. For example "elm", "ash", and "maple" were commonly used without distinguishing among the several native species that could have been encountered. We consulted published floras and other sources (Hutchinson 1988) to determine which old common names referred to which tree species; (e.g. "spruce pine" = jack pine, "yellow pine" = red pine). Tree abbreviations reflect the common name used by the surveyors. We plotted tree species and diameter along each section line at the approximate distance (in chains) where they were mentioned in the notes. At each section corner, we plotted tree species, diameter, bearing, and distance information. Although distance information exists for witness trees at all half-mile posts, we recorded that information only in open savannas.

Surveyors often included a list of tree species (generally ranked by relative abundance, but sometimes biased by surveyor's view of their

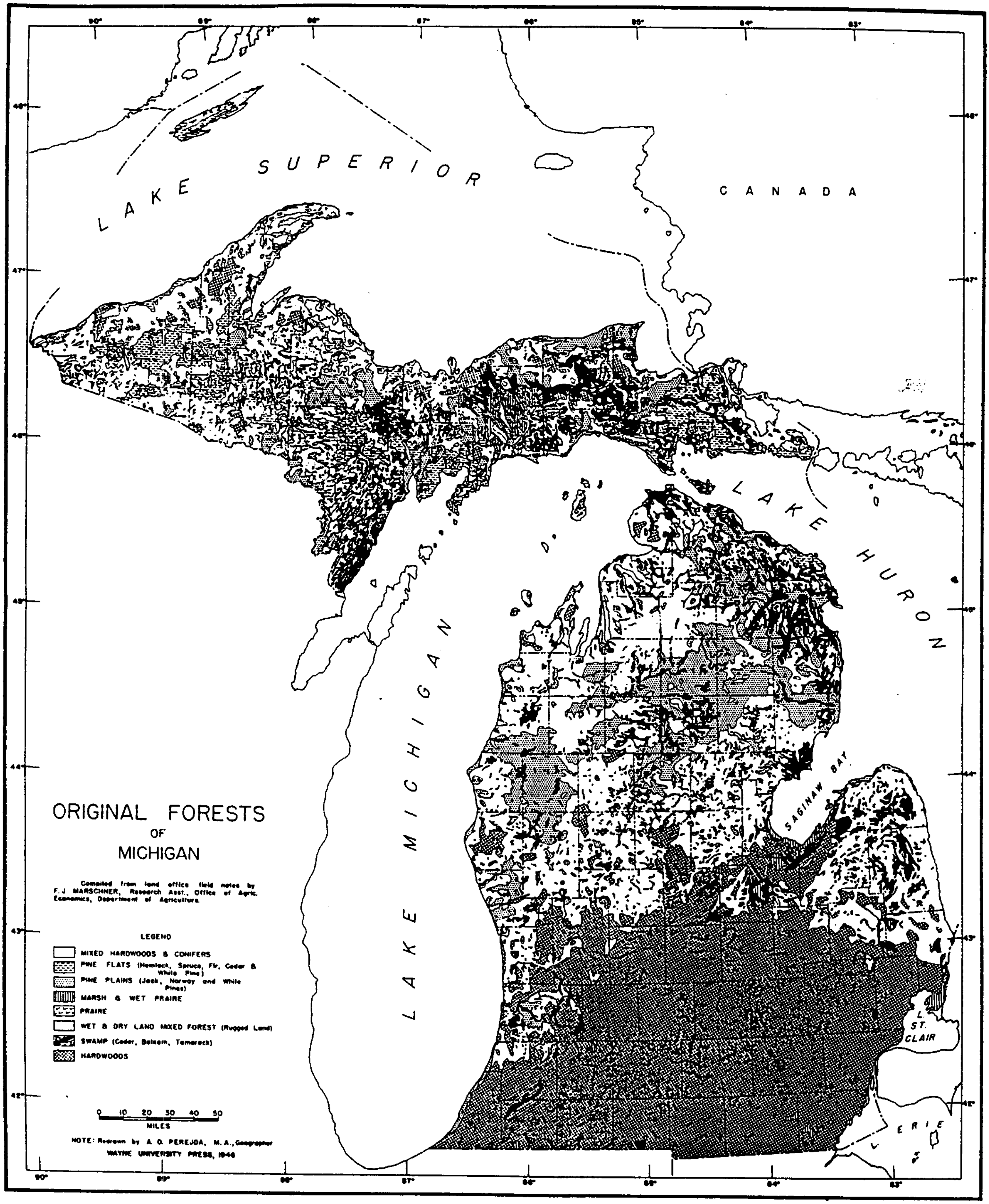
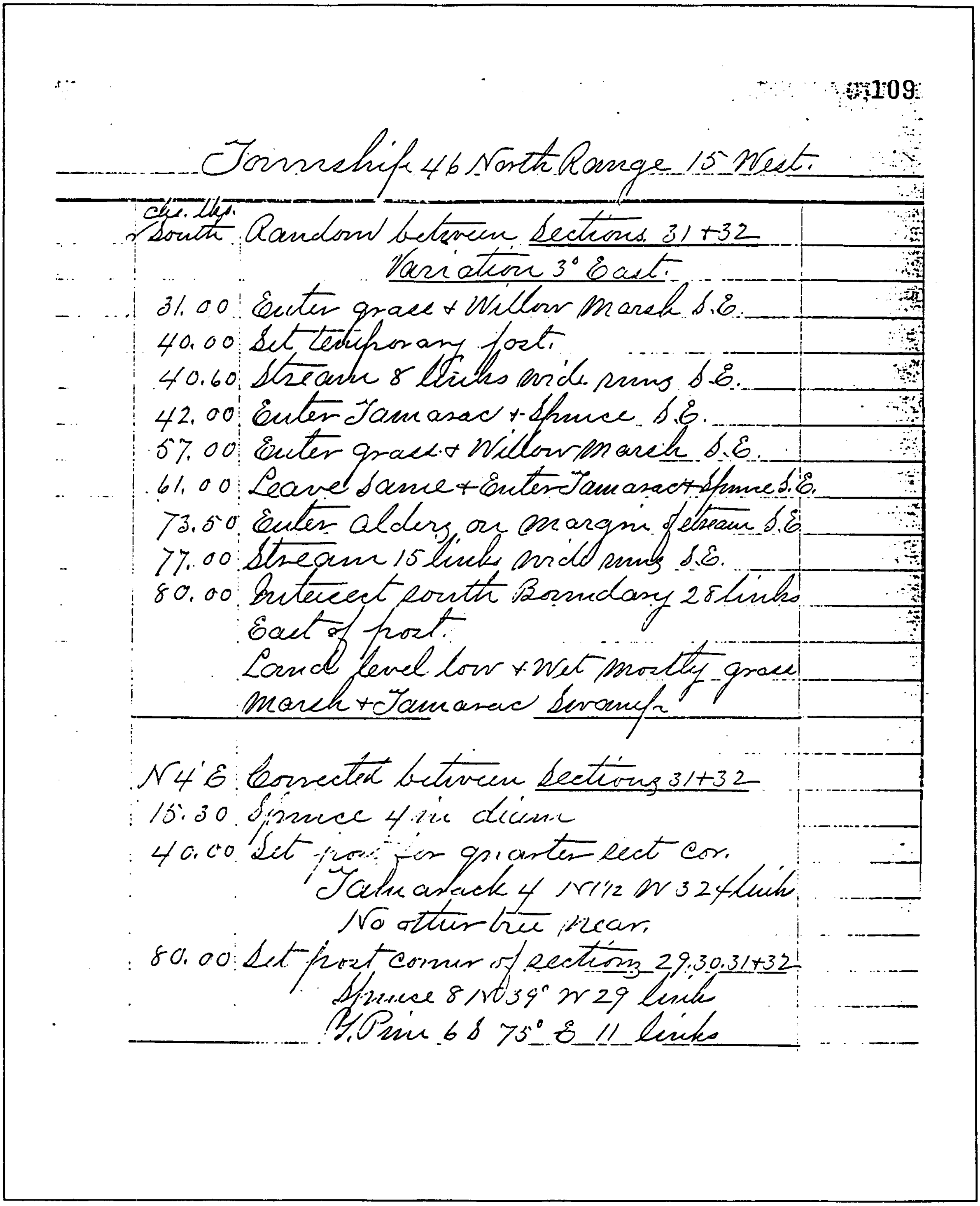


Figure 2: Marschner's Original Forests of Michigan redrawn in 1946 by Perejda. (Wayne State University Press)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Township 46 North Range 15 West.

chs. lks.
South Random between Sections 31 + 32
Variation 3° East.
31.00 Enter grass + Willow Marsh S.E.
40.00 Set temporary post.
40.60 Stream 8 links wide runs S.E.
42.00 Enter Tamarac + Spruce S.E.
57.00 Enter grass + Willow Marsh S.E.
61.00 Leave Same + Enter Tamarac + Spruce S.E.
73.50 Enter alders on margin of stream S.E.
77.00 Stream 15 links wide runs S.E.
80.00 Intersect south Boundary 28 links East of post.
Land level low + Wet mostly grass Marsh + Tamarac Swamp

N4°E Corrected between Sections 31+32
15.30 Spruce 4 in diam
40.00 Set post for quarter sect cor.
Tamarack 4 N1½ W 324 links
No other tree near.
80.00 Set post corner of sections 29.30.31+32
Spruce 8 N 39° W 29 links
Y. Pine 6 S 75° E 11 links

Figure 3: Sample page of transcribed GLO field notes from Schoolcraft County, Michigan.

Table 1: Presettlement Vegetation Maps: species abbreviation, alias, comments, and scientific name.

ABBREV	SPECIES	ALIAS	COMMENTS	SCIENTIFIC NAME
ALD	SPECKLED ALDER	tag alder		*Alnus rugosa*
APPLE	APPLE			*Malus spp*
ASH	ASH		white, black, or red	*Fraxinus spp*
ASP	ASPEN		quaking or bigtooth	*Populus spp*
BASH	BLACK ASH			*Fraxinus nigra*
BCH	BEECH			*Fagus grandifolia*
BLASH	BLUE ASH			*Fraxinus quadrangulata*
BLBCH	BLUE BEECH	muscle wood, water beech		*Carpinus caroliniana*
BO	BLACK OAK	yellow oak	pin oak and N. pin oak	*Quercus velutina*
BPOP	BALSAM POPLAR	balm of Gilead		*Populus balsamifera*
BRC	BIRCH			*Betula spp.*
BUCK	OHIO BUCKEYE			*Aesculus glabra*
BUR	BUR OAK			*Quercus macrocarpa*
BWALN	BLACK WALNUT			*Juglans nigra*
BXWD	BOX ELDER	boxwood		*Acer negundo*
CED	NORTHERN WHITE CEDAR			*Thuja occidentalis*
CHER	BLACK CHERRY	cherry		*Prunus serotina*
CHEST	CHESTNUT			*Castanea dentata*
COTN	COTTONWOOD			*Populus deltoides*
DOG	DOGWOOD			*Cornus spp*
ELM	ELM		American or slippery	*Ulmus spp*
FIR	BALSAM FIR	balsam		*Abies balsamea*
GHEM	CANADA YEW	ground hemlock		*Taxus canadensis*
GRAPE	GRAPEVINE			*Vitis spp.*
GUM	BLACK GUM	pepperidge		*Nyssa sylvatica*
HACK	HACKBERRY			*Celtis occidentalis*
HAZL	WITCH HAZEL			*Hamamelis virginiana*
HCK	HICKORY		species uncertain	*Carya spp*
HEM	EASTERN HEMLOCK			*Tsuga canadensis*
IRON	IRONWOOD	hornbeam		*Ostrya virginiana*
KYCOF	KENTUCKY COFFEE TREE	coffee nut		*Gymnocladus dioicus*
LOC	LOCUST			*Gleditsia triacanthos*
LYN	BASSWOOD	lyn		*Tilia americana*
PAW	PAW PAW			*Asimina triloba*
PIN	PIN OAK	jack oak	use uncertain	*Quercus palustris*
PLUM	PLUM		species uncertain	*Prunus spp*
POPL	BIGTOOTH ASPEN	poplar		*Populus grandidentata*
PRASH	PRICKLY ASH			*Zanthoxylum americanum*
QASP	QUAKING ASPEN			*Populus tremuloides*
RBUD	RED BUD			*Cercis canadensis*
RCED	RED CEDAR	juniper		*Juniperus virginiana*
RO	RED OAK		pin oak also	*Quercus rubra*
SAS	SASSAFRAS			*Sassafras albidum*
SM	SUGAR MAPLE	sugar tree, hard maple		*Acer saccharum*
SMAPL	SOFT MAPLE		red or silver	*Acer spp*
SP	JACK PINE	spruce pine, pine		*Pinus banksiana*
SPICE	SPICEBUSH			*Lindera benzoin*
SPR	SPRUCE		species uncertain	*Picea spp.*
SWO	SWAMP WHITE OAK	swamp oak		*Quercus bicolor*
SYC	SYCAMORE	buttonwood		*Platanus occidentalis*
TAM	TAMARACK	tamarach		*Larix laricina*
THORN	HAWTHORN	thorn, thornapple	species uncertain	*Crataegus spp.*
WBRC	WHITE BIRCH			*Betula papyrifera*
WIL	WILLOW		species uncertain	*Salix spp*
WMAPL	SILVER MAPLE	white maple	not consistent	*Acer saccharinum*
WO	WHITE OAK			*Quercus alba*
WP	WHITE PINE	pine		*Pinus strobus*
WSPR	WHITE SPRUCE			*Picea glauca*
WTWD	TULIP TREE	whitewood		*Liriodendron tulipifera*
WWALN	BUTTERNUT	white walnut		*Juglans cinerea*
YBRC	YELLOW BIRCH			*Betula alleghaniensis*
YO	CHINKAPIN OAK	yellow oak	possibly black	*Quercus muehlenbergii*
YP	RED PINE	yellow or Norway pine		*Pinus resinosa*

relative importance), impressions of soil character, and drainage characteristics along each surveyed mile. These comments, where they added significant ecological information, were copied to the mylar overlays in quotes along the section line. We located wetland boundaries along each section line at the chain distances mentioned in the field notes. Surveyor's comments on the character of rivers and streams were also copied to the mylar overlays. We found that the township plat maps accurately represent the chain distances described in the notes. The same was true for the locations of natural disturbances such as windthrows and recent fires. In Northern Michigan, surveyors often provided several paragraphs of description for each township. We copied this information on the margins of each topographic map to aid in later interpretation

With this information plotted over topography, we interpreted cover type boundaries primarily using the locations of dominant tree species and associated landforms. Wetland boundaries were interpolated between section lines by using associated elevation lines as they were depicted on the topographic maps. There were a few cases where surveyors did not note their entrance and exit points for wetlands along the section line, but instead used comments such as "...last mile, wet and swampy." These situations were most common on flat topography where the land was a complex mosaic of uplands and wetlands. When this occurred, the wetland boundary was determined using the comments and tree species that were encountered along the section line. We depicted wetlands falling entirely within interior sections as they were indicated on the topographic map. Typically, the smallest wetlands we included were 15-20 acres in size.

We consulted surface geology maps, soils maps, and earlier vegetation maps throughout the process of interpretation. Michigan Natural Features Inventory (MNFI) maps from field surveys of Great Lakes marshes (MNFI 1987-1989) and wooded dune and swale complexes (MNFI 1993) were used to clarify wetland boundaries in areas that had been sampled on the ground along the Great Lakes shoreline. Great Lakes shoreline boundaries were interpreted from points of intersection with section lines and the prevailing orientation of current shorelines (where not obviously manipulated artificially). Surveyor's notes on meanders along the shoreline were not used, since normal water level fluctuations resulted in inconsistencies along the shoreline, depending on the year of the survey.

We interpolated boundaries for natural disturbances such as wildfires and large windthrows between section lines taking the directions noted by surveyors ("entered land burnt from southwest to northeast..."), topography, and likely fire breaks into account. Cultural features, both Native American and early European, were placed on the mylar overlays as they were mentioned in the notes.

We developed cover type codes to identify all vegetation types, natural disturbances, and cultural features. The code system was designed to capture the complexity of plant communities that were distinguishable in the survey notes (Table 2). The code system for vegetation is based on the natural community classification currently in use by MNFI (1990). The classification reflects existing scientific literature and experience of MNFI staff. Additional codes were created throughout the course of this project to reflect previously unrecognized associations of dominant tree species that were repeatedly encountered and described by surveyors. The code system is structured to distinguish uplands from wetlands, and describes forested, unforested, sparsely vegetated, and aquatic systems. It is important to note that, while the four-digit code system mirrors the land cover code system used by the Michigan Resource Information System (MIRIS), the codes themselves represent differing assemblages of vegetation. As with all different vegetation classifications, they need to be carefully cross-walked before map comparisons are made.

Upland forest codes reflect the two to three most abundant species, as determined by the map interpreter. While a quantitative analysis and characterization of species composition within each cover type was not completed for this project, typically, the dominant tree species were encountered among at least 60% of the witness trees within the mapped area. Individual species named with each code (e.g. beech

Table 2: Vegetation and wetland grade codes for presettlement vegetation maps.

WETLAND

NON-FORESTED WETLAND

Emergent Marsh / Meadow / Prairie

- **6221** EMERGENT MARSH
- **6222** GREAT LAKES MARSH
- **6223** INTERDUNAL WETLAND
- **6224** WET MEADOW
- **6225** INLAND SALT MARSH
- **6226** LAKE PLAIN PRAIRIE
- **6227** INLAND WET PRAIRIE
- **6228** INTERMITTENT WETLAND

Mud Flats

- **6231** MARL FLATS

Shrub-Dominated Wetland

- **6121** BOG
- **6122** ALDER, WILLOW, BOG BIRCH THICKET
- **6123** BUTTONBUSH, WILLOW SWAMP
- **6124** PATTERNED PEATLAND
- **6125** MUSKEG

Upland/Wetland Complex

- **911** WOODED DUNE / SWALE COMPLEX

FORESTED WETLAND

41 Hardwood / Conifer - hardwood dominant

- **414** LOWLAND HARDWOOD
  - **4141** BLACK ASH
  - **4142** ELMS
  - **4143** SILVER MAPLE, RED MAPLE
  - **4144** COTTONWOOD
  - **4145** BALSAM POPLAR
  - **4146** ASPENS
  - **4147** WHITE BIRCH
  - **4148** BLACK WILLOW

42 Conifer / Hardwood - conifer dominant

- **423** LOWLAND CONIFER
  - **4231** CEDAR
  - **4232** BLACK SPRUCE
  - **4233** TAMARACK
  - **4234** BALSAM FIR, WHITE SPRUCE
  - **4235** BALSAM FIR
  - **4236** JACK PINE
  - **4237** HEMLOCK
  - **4238** WHITE PINE

LAKES AND RIVERS

- **51** MAJOR RIVER
- **52** LAKE OR POND
- **54** GREAT LAKES

WETLAND GRADE

- **I = INTACT**; well buffered, no altered hydrology
- **D = DEGRADED**; lacking complete upland buffer
- **M = MANIPULATED**; any activity altering hydrology
- **E = ELIMINATED**; all or most of area gone

UPLAND

NON-FORESTED

Grassland

- **31** HERBACEOUS - UPLAND GRASSLAND

Savanna

- **331** LAKE PLAIN OAK OPENING
- **332** OAK BARRENS
- **333** PINE BARRENS
- **334** OAK-PINE BARRENS
- **335** BUR OAK SAVANNA
- **336** OAK OPENING

FORESTED

Northern Hardwoods

- **4111** BEECH, SUGAR MAPLE, YELLOW BIRCH
- **4115** SUGAR MAPLE, YELLOW BIRCH, FIR
- **4117** SUGAR MAPLE, BASSWOOD
- **4119** BEECH, HEMLOCK
- **413** ASPENS, PAPER BIRCH

Central Hardwoods

- **4121** BEECH, SUGAR MAPLE, BASSWOOD
- **4122** WHITE OAK, BLACK OAK, HICKORY
- **4123** BLACK OAK, WHITE OAK
- **4124** PIN OAK, BLACK OAK

Pine

- **4211** WHITE PINE
- **4212** RED PINE
- **4213** JACK PINE
- **4215** RED PINE, JACK PINE
- **4216** RED PINE, WHITE PINE
- **4217** WHITE PINE, WHITE OAK
- **4218** RED PINE, OAK
- **4219** WHITE PINE, BEECH, RED MAPLE

Other Upland Conifer

- **4221** WHITE SPRUCE
- **4222** HEMLOCK, CEDAR
- **4223** FIR, SPRUCE, CEDAR
- **4226** HEMLOCK
- **4227** HEMLOCK, WHITE PINE
- **4228** HEMLOCK, SUGAR MAPLE
- **4229** HEMLOCK, YELLOW BIRCH

SPARSELY VEGETATED

- **72** BEACH, RIVERBANK
- **73** OPEN SAND DUNE
- **74** EXPOSED BEDROCK
  - **741** ALVAR
  - **742** BEDROCK GLADE
  - **743** SINKHOLE
  - **744** LIMESTONE LEDGE / OUTCROP
  - **745** SANDSTONE LEDGE / OUTCROP
  - **746** IGNEOUS-METAMORPHIC LEDGE / OUTCROP

NATURAL DISTURBANCES / CULTURAL FEATURES

- **92** WILDFIRE
- **93** WINDTHROW
- **94** BEAVER FLOODING
- **95** GREAT LAKES LEVEL CHANGE
- **96** CULTURAL FEATURE
- **97** JACK PINE THICKET (response to recent fire)

and hemlock) were found among at least 30% of the corner and section line trees. The determination of the relative percentages of individual species was a subjective determination of the map interpreter.

We made the distinction between forest and savanna primarily by using the distance information from individual witness trees. Because surveyors needed to use trees close to the section corner post, the distance from those trees to the post can be used to indicate the typical distance between trees (Anderson and Anderson 1975). Typically, when distance measures increased beyond 75 links (about 50 ft.) for both trees from opposing quadrants, there was an open forest canopy. When two or more adjacent section corners or half mile points included distances greater than 75 links, the area was coded as savanna and boundaries were established. Surveyors used a variety of names for savannas, some of which were misleading and used inconsistently. Terms included "opening," "barrens," and "plains." Because the distance information from section corners provided the most objective information, it was used to overrule more subjective surveyor's descriptions, when the two were in contradiction. The reader is encouraged to see comments under the regional descriptions for more detailed discussion of the variation in Michigan's native savannas.

We coded wetlands according to the same method as uplands where they were large enough to include several section corners. Smaller wetlands were often called "cedar swamp," "tamarack swamp," or "wet prairie," by surveyors, and we coded them as such. Small wetlands falling entirely within sections were coded based on an interpretation of surrounding wetlands and the basins where they occurred.

Mapped wetlands were also graded according to the type of changes that were apparent from the topographic maps (Table 2). A grade code was assigned to each wetland. The wetland grade codes include:

- **I for intact**; signifying a well buffered (>300 feet of relatively intact vegetation on all sides), undisturbed wetland;
- **D for degraded**; signifying an incomplete buffer;
- **M for manipulated**; signifying some man-made alteration that could affect the hydrology of the wetland, e.g. roads, drains, upstream impoundment;
- **E for eliminated**; signifying the apparent complete (or nearly complete) destruction of the wetland, also applied to drained marshes that are now apparently upland.

The only exception to this practice was where surveyors noted in more general terms where the wetland occurred ("last mile, wet and swampy..."), typically limited to areas of flat glacial lake plain. We felt that it was important to distinguish wetlands where our interpretation of wetland boundaries was based on this much more general information. These areas are coded as wetlands (414 or 423) and can be distinguished by their lack of a wetland grade.

Digital Map Production

Once cover type boundaries were interpreted and assigned codes, the maps were proofed and then digitized using Intergraph MicroStation™ software. Both cover type boundaries and associated codes were digitized. To avoid cluttering the final digitized maps, surveyors comments were included (in quotes) only where they added significant information. For many upland cover types, a tree species list, ranked in order of relative abundance, was included in one or two locations within each township to reflect the relative composition of tree species. A similar approach was utilized for large wetlands. An example in this case would be a large swamp dominated by three conifer species. This area would be given a three digit code 423 (indicating mixed lowland conifer), and a ranked list of those species would appear as text (Appendix A).

During the digitizing process, current cover type maps from the Michigan Resource Information System (MIRIS) were occasionally utilized for direct comparisons with the historical interpretations. We did this primarily in coastal wetlands of the Lower Peninsula where small wetlands fell mostly within section lines. If there was a difference between historical interpretation and current cover type for those wetlands that were traversed by surveyors (those intersecting section lines), the historical interpretation was maintained. For apparently intact wetlands occurring entirely within the interior portions of a section, the MIRIS interpretation was sometimes used to code the map. In these cases, adjacent to the wetland code, the (MIRIS) notation was added to indicate the source of that information. The same procedure was used to indicate where other information sources, such as the National Wetlands Inventory (NWI) maps, were utilized. Several other historical maps were utilized in southeast Michigan. The authors and dates of those maps are indicated in those cases.

Digitized maps were stored as multiple layers of information, organized by county (Table 3). Any combination of these layers may be turned "on" or "off" depending on the type of information desired by the user. For example, if levels 1,3, and 5 were turned on, vegetation boundaries, vegetation codes, and surveyors comments would appear on the map. GIS processing was completed for vegetation cover boundaries with Modular GIS Environment MGE PC-1™ and MGE/SX™. Labels were rechecked using C-Map™ software. Maps created in an Intergraph Microstation™ vector format can be translated to DXF (Data Exchange Format).

Table 3: Description of presettlement cover layers in design file.

LEVEL	DESCRIPTION
* 1	vegetation borders
3	text (selected surveyors comments & species list)
5	label (code; grade: D (degraded), E (eliminated), I (intact), M (manipulated), and source: (if MIRIS, NWI, or other historical source)
7	wildfire border (92)
8	windthrow border (93)
9	beaver flooding border (94)
10	impact of Great Lakes level fluctuation border (95)
11	Native American settlement border (96)
12	trails
13	upland/wetland complex border (911)
14	county boundary
15	label for 92
16	label for 93
17	label for 94
18	label for 95
19	label for 96
20	label for 911
22	jack pine thicket (97)
23	label for 97
38	U.S.G.S. quad tics
39	U.S.G.S quad lines
40	U.S.G.S quad names
41	section numbers
42 or 63	section lines

* Level 1 is the only level that has been GIS processed: "lineweeder" (tolerance of 10 feet) and "linecleaner" were run using MGE-PC 1™ and MGE/SX™ and labels (level 5) were checked using C-Map™.

DISCUSSION

Surveys as a Data Source:

There are limitations associated with the use of the General Land Office surveys that should be clear to all users of presettlement vegetation maps. Given that these surveys were not undertaken as a scientific sample of vegetation, they should not be considered as such. However, they do provide a wealth of detailed information available nowhere else. There have been a number of discussions of surveyor's bias in their selection of witness trees (Delcourt and Delcourt 1974, Delcourt and Delcourt 1977, Grimm 1984). The selection of witness trees was undoubtedly "biased" to some degree for practical reasons. Surveyors needed to find easily marked trees that aided the later relocation of the section corner post that they had pounded into the ground. Their instructions indicated that they should choose long-lived trees greater than four inches in diameter for marking. However, this obvious source of "bias" was severely limited by the number of trees that were also immediately adjacent to the corner post. Surveyors could not, for very practical reasons, travel very far to mark a more preferred tree, because they would defeat the purpose of marking a "witness." One should assume that easily marked, long-lived species such as American beech, northern-white cedar, and white oak were used more often than their actual frequency on the landscape. Shorter-lived species, such as aspens and paper birch, or typically small diameter species, such as speckled alder, sassafras, and hop hornbeam, were used less often than their actual frequency.

We used records from the original surveys where they had been found to be adequate by the Surveyor General. There was a number of townships re-surveyed because the original surveys were found to be either very inaccurate or completely fraudulent. In these cases, we used the records from the re-surveys completed during the 1840s and 1850s. These survey records were found to be quite reliable, since their stated measurements corresponded quite well with features on current topographic maps.

Historical Context

Given that the native landscape maps depict a "snapshot in time" taken at the time of the surveys, it is important to place the maps within the context of the times when the surveys were conducted. Aspects of long-term climatic cycles, Native American activities, and the European fur trade, all had the potential to influence natural patterns on the landscape traversed by surveyors in the nineteenth century.

Climate: There are numerous studies of the changes in climate and its influence on vegetation that have occurred in the Great Lakes region since the last glaciation (Davis 1981, Webb et al. 1993). The mosaic of vegetation described by surveyors was one that had been influenced by multiple climatic cycles, ranging from tens to thousands of years. While long-term climate changes were obviously important to the migration of species, shorter-term cycles in temperature, humidity, and precipitation probably had significant effects at the local level by varying the frequency of natural disturbance processes such as wildfire and flooding. These factors also influenced the rate of vegetative succession following natural disturbances.

Generally, temperatures increased steadily during the first 9,000 years following the last glacial maximum. Maximum warmth and dryness was reached 6,000 years ago in the Midwest, with July temperatures 1-2° F greater than today (Webb et al. 1993). It is likely that many plant communities most associated with wildfires, such as dry prairies, pine barrens, and oak savannas, reached their maximum extent in Michigan at that time. Since then, there has been a slight decrease in average temperature and increase in humidity (Webb et al. 1993). The "Little Ice Age," from roughly 800-600 years before present, was a shorter-term interval of cool and arid climate. It was characterized as having reduced summer precipitation and enhanced westerly winds in winter. It is possible that it affected fire regimes, by increasing the probability of "dry lightning" during the cool, dry summers. While, as a general rule, the distribution of vegetation lags behind climatic trends, the pattern of vegetation described by surveyors in the nineteenth century reflected, in large part, the climatic regime of the previous 2-4,000 years (Webb et al. 1993).

Native American Activities: Native Americans certainly played a role in shaping the mosaic of vegetation that surrounded their principle centers of activity. However, it is important to consider both the various ways their activities influenced vegetation, and how that influence varied in location and intensity over time. An excellent overview of existing knowledge on Native Americans in the Great Lakes region is found in Tanner (1987). Much of the following discussion is derived from that source.

Archeological evidence indicates that early human inhabitants of Michigan fall into the Woodland Culture, which apparently entered the state as glaciers receded. Their numbers and character changed over time with the influx of immigrants from the Atlantic coast and with alliances with cultures further west and south. Subsistence activities among Native Americans in the Michigan fell into four general categories: tending domesticated plants, fishing, hunting, and collecting wild rice. Fishing and collecting wild rice was most common in the marshes and waters off of the Upper Peninsula, and probably had minimal influence on vegetation. Clearing fields for domesticated crops was most concentrated in the southern half of the Lower Peninsula, but took place wherever the growing season reached about 120 days. Hunting took place throughout the state, sometimes involving fires set to herd animals toward a harvesting zone (Whitney 1994). Fire was apparently also used to maintain trails and forest openings to ease travel, encourage wild food plants, fertilize cropped land, and remove cover for potential enemies (Driver and Massey 1957, Chapman 1984, Albert and Minc 1987). The relative influence these practices had on Michigan's landscape was most likely in proportion to the concentration of native populations that used them. Tanner (1987) estimated approximately 14,000 Native Americans resided in Lower Michigan in 1830. They were found in 131 villages mostly concentrated along the St. Joseph, Kalamazoo, Grand, Shiawassee, Saginaw, and St. Clair rivers. Ottawa tribes were most common on the west side of the peninsula, from the Kalamazoo River north to the straits area. Ojibwa tribes were dominant near Lake St. Clair, Saginaw Bay, and along Lake Huron extending into the Upper Peninsula. Potawatomi were mostly found in southwest Lower Michigan, extending into the Chicago region.

We can assume that Native American's influence on vegetation varied as populations and land management practices varied over time. Disruptions in Native American populations within a century prior to the surveys could have affected what surveyors saw and described. Tribal disruption during the Iroquois Wars of the seventeenth century was stimulated in part by friction over the fur trade, and is said to have reduced much of the Great Lakes region to a "No Man's Land" (Mason 1981), but this is difficult to verify. Although most of the fighting took place outside of Michigan, tribal dislocations did occur around Detroit, Niles, Michilimackinac, and Sault Ste. Marie (Tanner 1987). Epidemics brought by Europeans also had a disastrous impact on native populations. Smallpox, whooping cough, and typhoid were among some of the diseases that wiped out villages around Detroit, Lake St. Clair, Saginaw Bay, and Michilimackinac during the seventeenth and eighteenth centuries. The decade of the 1830s was particularly notable for the sudden rise in European population and a rapid series of treaties involving land cessation and movement of Native American populations (Tanner 1987).

Because Native American population density, farming, and hunting were most concentrated in the southern Lower Peninsula, it can be assumed that Native American influences were greatest in that area. It is at least possible that some of the burned areas that surveyors recorded in northern portions of the state had their origin in Native American hunting activities.

Fur Trade: Fur-bearing animals play a variety of roles in Michigan's ecosystems, so we should assume that the impact on fur-bearer populations brought about by the early European fur trade may have had some effect on the landscape being described by surveyors in the nineteenth century. Unfortunately, any realistic estimate of the actual impact of the fur trade is all but impossible to establish. But, it is helpful to keep the relative impact of the fur trade in mind while using presettlement vegetation maps.

It could be said that the European fur trade began in Michigan in 1635 with the first visit to the Straits of Mackinac by Nicolet. In 1660, Radisson and Groseiliers returned to Montreal from Michigan with 60 canoes full of fur (Bradt 1947). Over the years, intense competition developed involving the French "coureurs de bois," English, American, and Native American tribes, often causing violent conflicts, and resulting in a severe depletion in fur-bearer populations. The fur trade involved a variety species. A 1796 ledger from Michilimackinac gives some idea of the variety of furs being traded at the time: "...sold 99 packs composed of 5 bears, 5 pound beaver, 10 fishers, 58 cats, 74 doe, 78 foxes, 108 wolves, 117 otters, 183 minks, 557 bucks, 1,231 deer, 1,340 muskrats, and 5,587 racoons" (Johnson 1971).

From the standpoint of impact on the landscape, the beaver population should have been by far the most significant, so this would be the species for which the depletion in populations most likely altered the landscapes later described by surveyors. We will never know just how many beaver lived within Michigan prior to the fur trade, but estimates of fur traders catch gives us some notion. In 1767, for example, 50,938 beaver skins were shipped through Michilimackinac (Lart 1922). The trade in beaver pelts was still on the rise at that time, so considerably more were likely taken in later years. Principle fur trading posts in Michigan were at Michilimackinac, Sault Ste. Marie, Detroit, Grand Rapids, and Niles. Since Michilimackinac was the principle trading post for the entire Upper Great Lakes region, we must assume that many pelts passing through there were actually taken from Wisconsin and beyond. The range-wide decline in beaver populations occurred throughout the nineteenth century, causing the prices of pelts to increase. In 1920, Michigan's beaver trapping season had to be closed to allow populations to recover (Bradt 1947).

As for the actual influence beavers had on Michigan's native vegetation, we can only speculate. Bela Hubbard considered beaver to be the principle cause for the development of wet prairies in the Detroit area (Hubbard 1887). We now know this to be an overstatement, given the importance of the hydrology on the sand lake plain, and the fragments of prairie on the lake plain today (Comer et al. 1995). However, they may have played some role in creating what surveyors described as "wet prairie" and "marsh" throughout the southern Lower Peninsula. Further north, it is possible that the decline of beaver populations impacted the relative abundance of aspen-dominated wetlands in the years leading up to the surveys.

Technical Aspects of Digital Maps

Cover type boundaries should be assumed to be most reliable where they intersect section lines. The interpolated boundary line between each section line should be considered an approximation that could differ on the ground depending on local variation not apparent on topographic maps. Upland and wetland boundaries in interior sections should be most accurate where topography is abrupt. We were unable to represent much of the small-scale variation one normally encounters in natural environments. One should assume that wetlands which naturally occur as relatively small, complex shapes, totaling less than 50 acres in area, are under-represented in these maps. The accuracy of aerial coverage should be assumed to increase with the typical natural size of the unit. The aerial coverage of smaller vegetation units, such as alder-willow swamp, emergent marsh, and beaver floodings are most certainly underestimated. Because aspen-birch forest often resulted from windthrows smaller than 50 acres, they too are likely under-represented in the map. The cover type codes, when taken to the fourth digit, should be interpreted by the user to indicate the most abundant tree species of the area, not the only tree species present. Users should consult with published reports and local experts for expanded plant and animal species lists which would likely be associated with the specific cover type.

OVERVIEW OF MICHIGAN'S PRESETTLEMENT CONDITIONS ORGANIZED BY REGIONAL LANDSCAPE ECOSYSTEMS

Vegetation, as it occurred across the landscape, is best understood within the context of broad landscape ecosystems. The following discussion of Michigan's presettlement vegetation, natural disturbances, and cultural fetaures will therefore be framed within the context of Michigan's Regional Landscape Ecosystems as defined by Albert (1995). These landscape units were derived by integrating climatic, landform, soil, and vegetative factors. They provide a useful framework for understanding the variation in vegetation composition and landscape processes as they occur throughout the state. Using this approach, landscape ecosystems are defined in a hierarchy of three levels in a nested series, from broad landscape regions down to district and subdistrict levels (Figures 4 and 5; Tables 4 and 5). The names and numbers for each ecological region, district, and subdistrict were taken directly from Albert (1995), which encompasses Michigan, Wisconsin, and Minnesota. Michigan's four regions are therefore numbered VI, VII, VIII, and IX out of eleven regions delineated for the three-state area. This discussion is intended as an aid to users of presettlement vegetation maps.

Climatic factors for each of the four landscape ecosystem regions of Michigan will be briefly discussed prior to more detailed descriptions of climate, landform and soils, presettlement vegetation, natural disturbances, and human influences for each district and/or subdistrict which comprises that portion of the state. Much of the following discussion on climate, geology, soils, and land use was taken from Albert (1995), Albert (1990) and Albert et al. (1986). Discussions of presettlement vegetation were derived primarily from data collected while compiling the presettlement vegatation maps. Glacial landforms are continually referred to in the following text. It is helpful to have the Quaternary Geology of Michigan (Farrand & Bell 1982) on hand when reviewing the following text, in addition to the presettlement map.

Table 4: Regional Landscape Ecosystems of Lower Michigan, Regions VI and VII.

No.	District	Subdistrict	Site Condition
Region VI: Southern Lower Michigan			
1.1	Washtenaw	Maumee	lake plain
1.2		Ann Arbor	fine and medium-textured moraine
1.3		Jackson Interlobate	coarse-textured end moraine, outwash, and ice-contact typography
2.1	Kalamazoo	Battle Creek	outwash and ground moraine
2.2		Cassopolis	coarse-textured end moraine and ice-contact terrain
3.1	Allegan	Berrien Springs	end and ground moraine
3.2		Benton Harbor	lake plain
3.3		Jamestown	fine-textured end and ground moraine
4.1	Ionia	Lansing	medium-textured ground moraine
4.2		Greenville	coarse-textured end and ground moraine
5.1	Huron	Sandusky	lake plain
5.2		Lum	medium and coarse-textured end moraine ridges and outwash
6.0	Saginaw Bay		lake plain and reworked till plain
Region VII: Northern Lower Michigan			
1.1	Arenac	Standish	lake plain
1.2		Wiggins Lake	fine-textured end and ground moraine
2.1	Highplains	Cadillac	coarse-textured end moraine
2.2		Grayling	outwash
2.3		Vanderbilt	steep end and ground moraine ridges
3	Newaygo		outwash
4	Manistee		end moraine, dune sand, and sand lake plain
5.1	Leelanau	Williamsburg	coarse-textured end moraine ridges
5.2		Traverse City	coarse-textured drumlin fields on ground moraine
6.1	Presque Isle	Onaway	drumlin fields on coarse-textured ground moraine
6.2		Stutsmanville	steep sand ridges
6.3		Cheboygan	lake plain

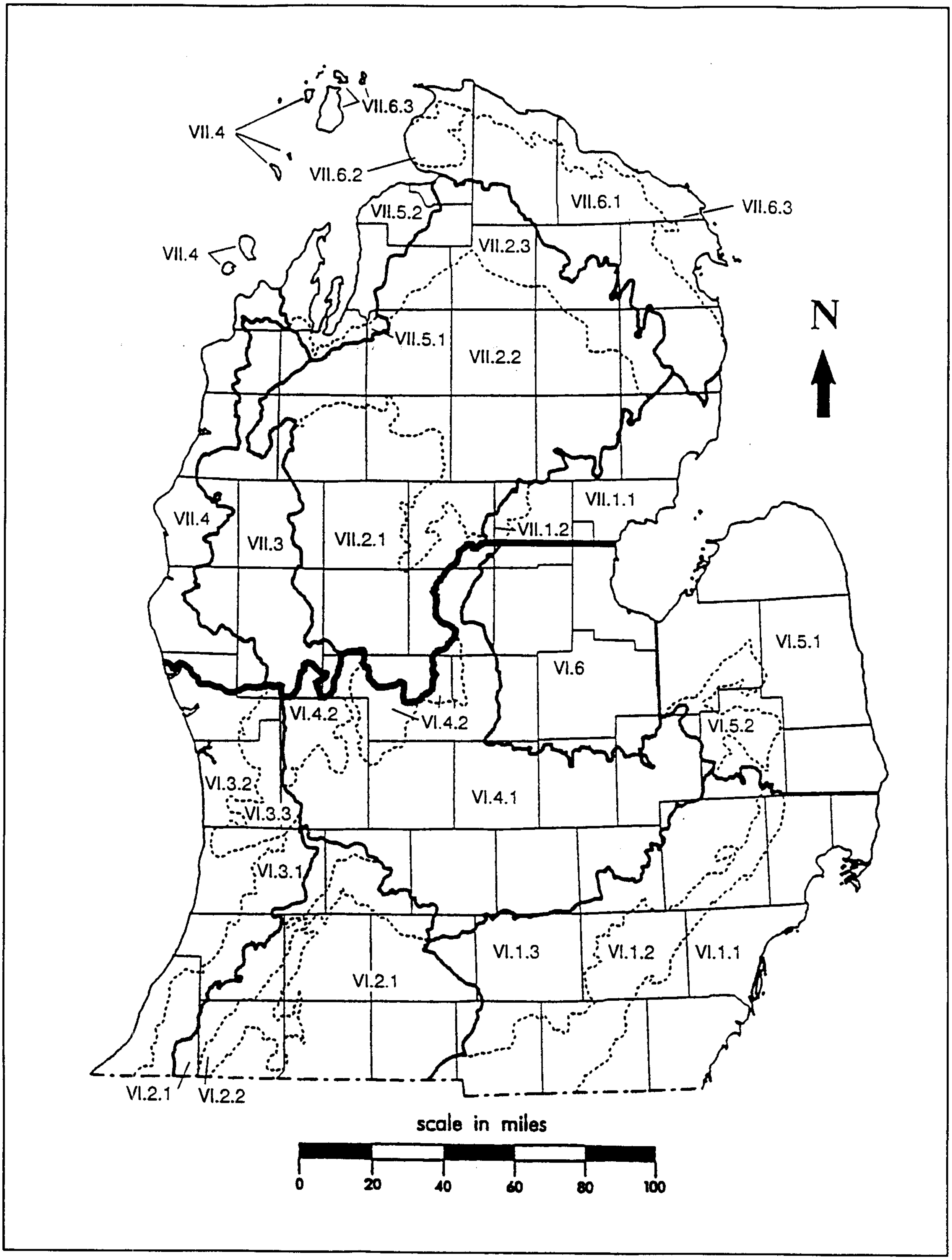


Figure 3: Regional Landscape Ecosystems of Southern Michigan.

Table 5: Regional Landscape Ecosystems of Upper Michigan, Regions VIII and IX.

No.	District	Subdistrict	Site Condition
Region VIII: Eastern Upper Michigan			
1.1	Mackinac	St. Ignace	limestone bedrock and sand lake plain
1.2		Rudyard	clay lake plain
1.3		Escanaba	limestone bedrock and sand lake plain
2.1	Luce	Seney	poorly drained sand lake plain
2.2		Grand Marais	sandy end moraine, shoreline, and outwash plains
3.1	Dickinson	Hermansville	drumlins and ground moraine
3.2		Gwinn	poorly drained sandy outwash
3.3		Deerton	sandstone bedrock and high, sandy ridges
Region IX: Western Upper Michigan			
1	Norway		till plain, outwash, sandstone bed-rock, and granitic bedrock
2	Michigamme		granitic bedrock
3.1	Iron	Iron River	drumlinized ground moraine
3.2		Crystal Falls	kettle-kame topography, outwash, and sandy ground moraine
5	Lac Veaux Desert		outwash plain
6.1	Bergland	Gogebic Iron Range	coarse-textured moraine ridges and metamorphic bedrock knobs
6.2		Ewen	dissected clay lake plain
6.3		Baraga	broad ridges of coarse-textured rocky till
7.1	Keweenaw	Gay	coarse-textured broad ridges and swamps
7.2		Calumet	igneous and sedimentary bedrock ridges and knobs
7.3		Isle Royale	island of igneous bedrock ridges and swamps
8	Lake Superior	Ontonagon	clay lake plain

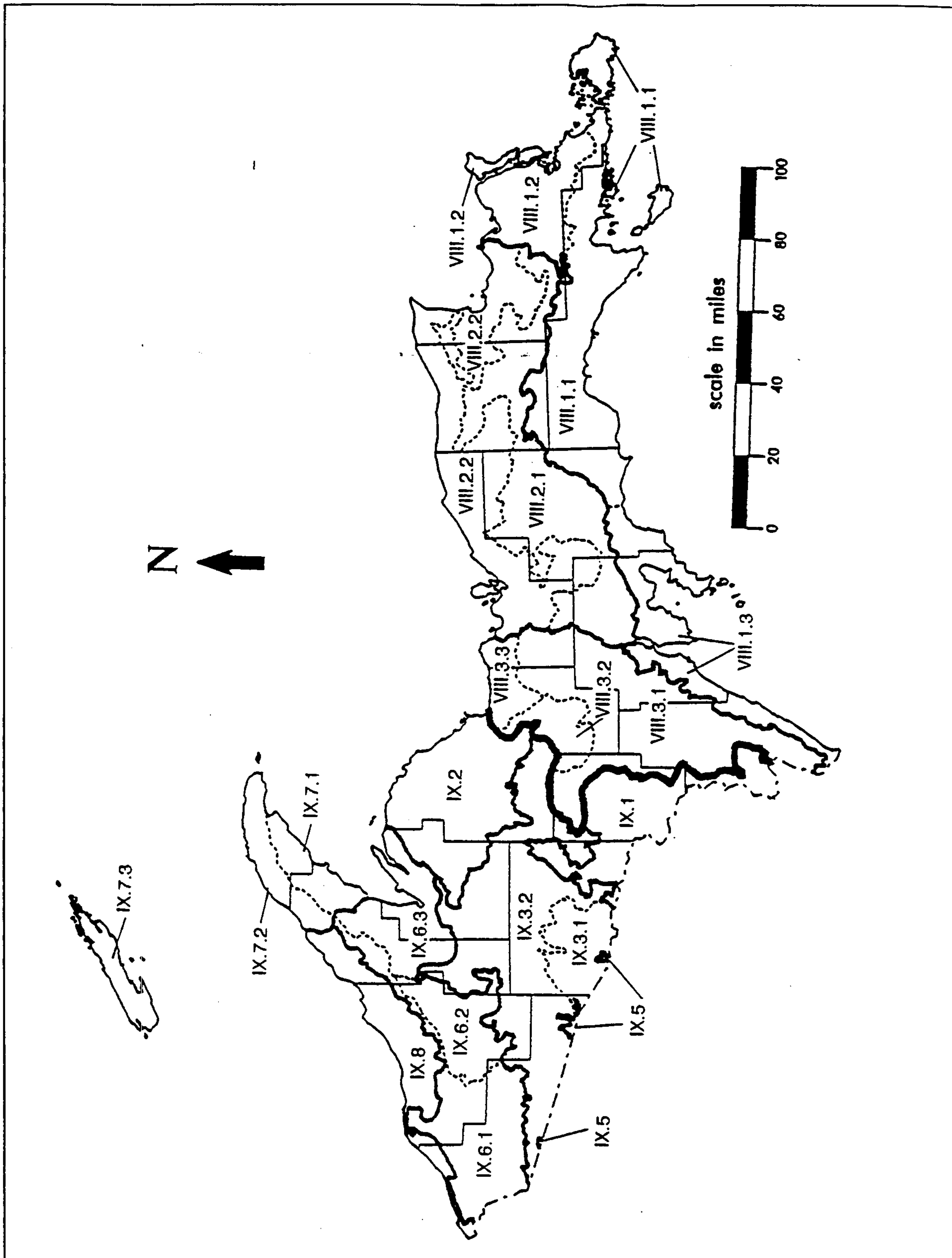


Figure 4: Regional Landscape Ecosystems of Northern Michigan.

REGION VI. Southern Lower Michigan.

REGIONAL CLIMATE: The southern Lower Peninsula of Michigan experiences a greater frequency of warm humid air masses originating in the Gulf of Mexico and a lower frequency of cold dry air masses of continental origin than the remainder of the state. The region experiences some lake-effect snows and moderation of temperature from Lake Michigan (Albert et al. 1986, Denton 1985, Eichenlaub 1979, Eichenlaub et al. 1990). Winter precipitation is high, reaching 7-10 inches (23-26 percent of annual precipitation). Annual precipitation reaches 32 to 38 inches (Eichenlaub et al. 1990). Annual average snowfall is 36 inches inland to 100 inches along the Lake Michigan shoreline. The growing season length is 130 to 170 days (Eichenlaub et al. 1990). Extreme minimum temperatures are relatively warm, from -16° F to -34° F, as a result of buffering by the Great Lakes.

DISTRICT 1 Washtenaw.

CLIMATE: Climate is somewhat moderated by Lake St. Clair, and Lake Erie. The growing season is generally long, ranging from 160 to 170 days at the southern edge of the district, and from 140 to 160 days at the northern edge. Growing season is longer near the shorelines of the Great Lakes and shorter inland. The extreme annual minimum temperature is -20° F in the south and -24° F in the north. Snowfall is relatively low throughout the district, ranging from 30 inches in the south to 80 inches in the north. Average annual precipitation ranges from 28 to 34 inches.

DISTRICT 1 Washtenaw.
SUBDISTRICTS 1.1. Maumee: lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The surface lacustrine deposits are underlain by Mississippian, Devonian, and Silurian marine and near-shore bedrock, including sandstone, shale, coal, marine limestone and dolomite, and gypsum and other evaporites. Bedrock is only locally exposed in stream banks and near the shorelines of Lake Erie. The oldest Silurian bedrock is near the surface in the south. Commercial deposits of rock salt and saline wells occur in the Silurian Salina Formation near Detroit (Dorr and Eschman 1984, Milstein 1987).

The subdistricts are part of a relatively flat plain of glacial lacustrine origin. The lacustrine deposits extend into Ohio along the western end of Lake Erie (Farrand and Bell 1982). Lacustrine sands and clays are thickest along the farthest inland edge of the lake plain and thinnest along the present shorelines of Lakes Huron, St. Clair, and Erie. Near Lake Erie, inland deposits are greater than 100 ft., whereas thickness less than five feet are common near the shoreline. Fine-textured end and ground moraine is located among the lacustrine deposits in northeast Wayne County (Farrand and Bell 1982).

Within the broad clay lake plain, there are several broad sand channels, created when sand was deposited into the shallow pro-glacial lakes by meltwater streams. These sand channels can be several miles wide, but the sand in them is generally only five to 10 feet thick. Poorly drained mineral soils characterize the clay plain. The sand-channel deposits were reworked by wave action during higher levels of the Great Lakes, creating small sand dunes and spits and intervening depressions. The soils of the dunes and spits is often excessively drained, whereas that in the swales is poorly or very poorly drained.

PRESETTLEMENT VEGETATION: The presettlement vegetation of the clay lake plain and sand lake plain often differed. The majority of the clay lake plain supported closed-canopy forest, either upland or wetland. In contrast, the sand lake plain supported oak savannas on the uplands and wet prairies or marshes in the lowlands.

The forests of the clay lake plain responded to slight differences in slope class and drainage. On the flatter portions (10 ft./mile slope or less) of the lake plain or in shallow basins or depressions, lowland hardwoods (414) were prevalent. In the closed depressions, black ash (4141) was dominant, along with American elm and basswood. As slope increased slightly and drainage conditions improved, American beech, white oak, white ash, and hickory became more common, but were generally less common than black ash and elm. Cottonwood, sycamore, quaking aspen, and (red or silver) maple were other common wetland species of the clay lake plain. Beech, sugar maple, and basswood forest (4121) occurred on those portions of the clay lake plain where drainage conditions were best, generally in those areas where streams had improved drainage conditions. These mesic forests also included American elm, and shagbark and bitternut hickories, and black walnut. Black ash was sometimes mentioned among these forests, and was probably occupying small depressions or vernal pools on the flat plain.

The beach ridges and low dunes of the sand lake plain supported savannas of white and black oak. These areas were known as lake plain "oak openings" (331). Small areas of dry prairie probably occurred on the ridges, but were much less prevalent than savannas. Depressions and flat portions of the sand lake plain were often poorly drained, and supporting wet, lake plain prairie (6226) and emergent marsh (6221). The mosaic of oak opening and wet prairie was most concentrated in central Monroe

County, southwest Wayne County, and in the St. Clair River delta. Remnants of these landscapes were documented by Comer et al. (1995). Within the wet prairie and marsh there were small beach ridges that supported scattered trees and swamp. White oak was the most common species among the wet prairies, but there were references to black oak, red oak, ash, and "pople" (cottonwood). Elm was second to white oak, probably occurring both on the moist edges of the prairie and within the swamps. Pin oak, presently a common species within the swamps of the sand lake plain (4124), was only referenced by surveyors in Monroe County, but it may have been mistakenly called black oak. Black oak, was also referenced by the surveyors within the wet prairies. It is also possible that pin oak was much less prevalent prior to drainage of the wet prairies and fire exclusion. Extensive Great Lakes marsh (6222) occurred along most of the Lake Erie and lake St. Clair shorelines. The marshes, which extended into 4-5 ft. deep water, were 1-2 miles wide in places, and extended for miles up major rivers such as the Huron. Upland of the marshes there was typically a broad zones of swamp forest, but locally along Lake St. Clair and Lake Erie, 1-3 miles wide expanses of wet prairie occurred.

The small area of the subdistrict mapped as end and ground moraine supported beech-sugar maple forest (4121) and white oak, black oak, and hickory forest (4122) in the uplands, and mixed, lowland hardwoods (414) and emergent marsh (6221) in poorly drained portions.

NATURAL DISTURBANCE: There were few references to natural disturbances such as fires or windthrows on this portion of the glacial lake plain. In wet prairies, however, one would not likely see the effects of spring fires, given the rapid re-growth of herbaceous vegetation. Extensive windthrown trees were at the extreme north edge of the subdistrict in portions of St. Clair County, along the Belle River, and in Macomb County, north and southwest of Armada. The windthrows were most extensive on the flat, clay lake plain, which supported swamp forest. Water level fluctuation of the Great Lakes, important for maintaining swamp forest, wet prairie, and marsh vegetation, was not well documented by surveyors in these subdistricts, but is well documented further north in subdistrict 5.1 and district 6 along Saginaw Bay.

HUMAN LAND USE: There is a long history of human land use on the lake plain, beginning with Native Americans, who settled along the shorelines of the Great Lakes, primarily upon beach ridges. They farmed the floodplain of some of the major rivers, including the Huron River. Tanner (1987) noted settlements (circa 1830) around Toledo, Dundee, Flat Rock, and on the shore of Lake St. Clair. They may have been responsible for fires that maintained the open conditions of the oak savannas and drier portions of the prairies. The land surveys began in this portion of the state in 1816. By 1830, there were French and American settlements at Monroe, Frenchtown, Brownstown, Detroit, Grosse Point, Mt. Clemens, Machonce, Cottrellville, St. Clair, and Bunceville. The clay soils of the lake plain were among the first areas in the state farmed by European settlers. Most clay lands have been ditched and tiled and are among the most productive agricultural lands in the state. A grid of rural roads and extensive highways are common throughout this subdistrict. Urban development dominates much of this subdistrict, centered on the Detroit metropolitan area, but is also found around Monroe, New Baltimore, Algonac, Marine City, and St. Clair.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Almost all of the beech, sugar maple, and basswood forests have been cut, with lands utilized for agriculture and urban development. The only remaining tracts are small, usually only 40-80 acres in size. Wetland loss since the 1800s has reached the extreme (80-90% loss) for the state within this subdistrict. Areas of lowland hardwoods and black ash swamp that remain are on either the sand lake plain or near the Great Lakes shorelines, where wetland drainage was not effective.

Some of the lowland hardwoods found today on the sand lake plain were historically wet prairies, but became forested as water tables dropped with drainage of surrounding lands (Comer et al. 1995). Many of the oak openings remain unfarmed, but fire suppression has resulted in conversion to oak-dominated forest. Some oak openings have been grazed. Many areas that were cleared for agriculture were abandoned due to low productivity and unstable, blowing, sandy soils. Drier portions of the lake plain prairies became available for agricultural use following drainage. Some of the largest, wettest areas of lake plain prairie persist, but edges of these large wetlands are now farmed and portions of the prairie have become swamp forest as a result of drainage. Lake plain prairie persists within State Game Areas, including St. John's Marsh, Harsens Island Wildlife Refuge, Petersburg, and Pointe Mouillee. Algonac State Park also supports wet prairie. At present, most of the wet prairie of the sand lake plain has converted to swamp forest, with pin oak, silver maple, and swamp white oak being common dominants. Black tupelo and bur oak are also relatively common within these swamps. Large expanses of Great Lakes marsh were destroyed as the ports of Detroit and Monroe were developed. Great Lakes marsh persists in several areas, but the upland edge, which was historically wet meadow, wet prairie, or swamp forest, has been developed for agriculture, and the shallow submergent and emergent beds have been degraded by wave action from shipping and by siltation resulting from agriculture.

DISTRICT 1 Washtenaw.
SUBDISTRICT 1.2. Ann Arbor: fine and medium textured moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock is not exposed in the subdistrict. Underlying bedrock is Mississippian and Devonian (Paleozoic Era) sandstone and shale (Dorr and Eschman 1984, Segall and Wilson 1987). Devonian sandstone and shale are localized along the eastern edge, Mississippian shale underlies the center, and Mississippian sandstone is in the southwest.

Glacial deposits are 100-250 ft. thick over the bedrock, with thickest glacial deposits near the center of the long subdistrict for much of its length. The subdistrict consists of narrow parallel bands of both end moraine and till plain (ground moraine). Over 80% of the ground moraine is flat, with slopes in the 0-6% slope class. Ground moraine forms a broad plain. Individual hills of the ground moraine are several miles in area, but are seldom higher than 80 ft. The topography of the end moraines is more rolling, with slopes in the 7-15% slope class. End moraine ridges are sometimes distinct ridges one to several miles across and several miles long, or they can be broken into several smaller ridges separated by glacial outwash channel and postglacial drainages. Most of the ridges are 30-80 ft. high, with the highest ridges, about 170 feet high, located at the northern edge of the subdistrict. There are few lakes in the subdistrict. Major rivers that cross the subdistrict are the Huron and Raisin.

Loam and sandy loam soils cover most of the subdistrict. Fine-textured soils, primarily silt loams and clay loams, are more common on the eastern edge. Poorly drained mineral soils are common on lower slopes of the ground moraine. Organic soils are restricted to outwash channels. The soils are classified as gently sloping Hapludalfs with some Argiaquolls and Argiudolls (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: The loams and sandy loams on end and ground moraine historically supported oak-hickory forest (4122) and dry forests of mixed oak (4123). White oak appeared to be the most common species of the oak-hickory forest. Black oak was common on the drier ridge tops and red oak was most common on lower slopes. Oak barrens (332), with white and black oak, occurred along outwash channels and on adjacent moraine ridges, where fires from the outwash could be frequently carried by westerly winds. White oak-dominated savanna, or "oak opening" (336) was limited within this subdistrict to central portions of Oakland County. Beech, sugar maple, and basswood forest (4121) was restricted to silt loams and clay loams, concentrated in central Lenawee and Hillsdale counties, and along the Washtenaw-Oakland County border.

Mixed hardwood swamp (414) was common in lower slope positions on both ground and end moraine. Common species in the swamps included black ash, red maple, American elm, swamp white oak, bur oak, and basswood. On major river floodplains, (silver) maple, hackberry, red elm, red ash, and American elm were common. Tamarack swamp (4233) was also commonly associated with poorly drained portions of this subdistrict. Emergent marsh (6221), wet prairie (6227), and willow-buttonbush swamp (6123) were also commonly noted as small wetlands throughout the subdistrict.

NATURAL DISTURBANCE: Windthrow was not noted by surveyors within the subdistrict, but probably occurred on the steeper end moraines and within the poorly drained swamp forests. Surveyors described one area north of Ann Arbor as recently burned, as was another at the northeast extreme of the subdistrict near Romeo. Native American fire management, generally concentrated on the sandier soils of subdistrict 1.3 and subdistrict 2.1, may have modified forests throughout this subdistrict, especially along major rivers.

HUMAN LAND USE: Most of this subdistrict was surveyed between 1816 and 1825. Tanner (1987) mapped Native American settlements circa 1830 at Romeo and near Pittsford (Hillsdale County). Early European settlements in 1830 were located at Tecumseh, Saline, Ann Arbor, Dexter, Woodruffs Grove, Ypsilanti, Dixboro, Farmington, Rochester, and Romeo. Most of the land was cleared for agriculture by the mid-nineteenth century. Almost all of the ground moraines have been farmed, whereas the steeper moraines remain forested with oak. Today, roads and major highways pass throughout the subdistrict, and urban development is spreading rapidly from the Detroit-Pontiac-Ann Arbor metropolitan areas. Other centers of urban development are at Adrian, Saline, and Romeo.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Most of the upland and wetland communities that dominated this landscape in the 1800s have been eliminated; first by agriculture, and more recently, by urban development. Over-all wetland losses, when compared with acreage in the 1800s, is somewhat less severe than on the adjacent lake plain, but it is likely that at least 50% of historic wetland acreages have been lost. Many forests that remain are small fragments of previous tracts that have seen dramatic change in species composition due to past logging. The suppression of wildfires probably caused many oak barrens and oak openings to succeed to closed-canopy oak-hickory forest. Some areas historically noted as oak-hickory forests have likely succeeded to beech-sugar maple forest as well.

DISTRICT 1 Washtenaw.
SUBDISTRICT 1.3. Jackson Interlobate: coarse-textured end moraine, outwash, and ice-contact topography.

CLIMATE: Growing season length: is 140-150 days (Eichenlaub et al. 1990). There is a danger of late spring frosts due to numerous lowland depressions (outwash and kettle lakes). Snowfall within the subdistrict reaches 40-50 inches. Annual precipitation averages 28-32 inches, and extreme minimum temperatures are -22° F to -28° F.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The underlying Mississippian and Pennsylvanian bedrock, primarily sandstone, is locally exposed at the surface in Jackson and Hillsdale counties (Akers 1938). The elevation of the district ranges from 900 to 1280 ft. The highest elevations are in northern Hillsdale and southwestern Jackson counties in the western part of the subdistrict and in southern Lapeer and northern Oakland counties at the eastern edge of the district.

Drift thickness is generally less than 100 feet in both counties. The subdistrict contains broad expanses of outwash sands that surround sandy and gravely end moraines and ground moraines. End and ground moraine remain as island-like hills surrounded by flat outwash. Both on the outwash channels and on the ground moraine ridges, slopes are generally in the 0-6% class, while slopes can be as steep as 25-40% on the end moraine and ice-contact ridges. Most of the small segments of end moraine surrounded by outwash have slopes predominantly in the 0-6% and 6-12% classes. Ice-contact topography is concentrated in Jackson, Livingston, and Washtenaw counties. Kettle lakes, kames, eskers, and segments of outwash channel are the predominant features of the ice-contact areas. Northeast of Jackson, steep, sandy kettle-kame topography is found. West of Jackson, the topography is more gentle, with broad, coarse-textured ridges surrounded by deposits of outwash sand. Portions of the Sharon Short Hills in southwestern Washtenaw County are very similar to the ice-contact topography near Pinckney.

The soils of the moraines are typically well and excessively drained. Drainage conditions on the outwash are more variable, ranging from excessively drained to very poorly drained. Thick outwash deposits are usually characterized by excessively drained conditions. Shallow outwash deposits are in some places underlain by bedrock or fine-textured till and lacustrine deposits, causing poor or very poor drainage conditions. On ice-contact topography, soils are typically excessively drained on the upland kames and eskers and poorly or very poorly drained in the kettles and outwash channels. The most common soil texture is sandy loam on the moraine ridges and sand on the outwash plains. The circumneutral glacial drift which forms the moraines is largely derived from the local limestone bedrock. Illuviation is responsible for the formation of a clay-rich (argillic) horizon in many of the soils on moraines, providing better water-holding capacity than many of the outwash soils. Many of the outwash soils do not display a well-developed argillic horizon. In the ice-contact areas, soils are sands and gravels.

PRESETTLEMENT VEGETATION: Throughout the glacial interlobate of southern Lower Michigan, from Lapeer County southwest through Cass County (subdistrict 2.1), surveyors used a number of different terms to describe the mosaic of tallgrass prairie, oak savanna and oak-dominated forest. The terms "barrens" and "oak openings" were sometimes inter-changeable among surveyors. Similar areas were also variously described as "barren with scrubby timber," or "scattering timber." A clearer pattern was discerned by utilizing dominant tree species and distance measures between trees at section corners. We used the term oak opening (336), to describe clearly open savanna (just a few trees per acre), mostly dominated by white oak. Surveyors sometimes called places "oak opening" where the distances between witness trees were consistently similar to closed-canopy, oak-hickory forest. From their descriptions, these areas probably experienced frequent, low intensity fires that cleared the understory. We mapped these areas as either black oak-white oak forest (4123), or oak-hickory forest (4122). They almost always occurred immediately adjacent to open savannas (332, 335, or 336) or grassland (31). We used the term oak barrens (332) to describe open savanna on dry, sandy areas dominated by black, white, and sometimes northern pin oak. Bur oak savanna (335) was used to describe clearly open savanna dominated almost entirely by bur oak.

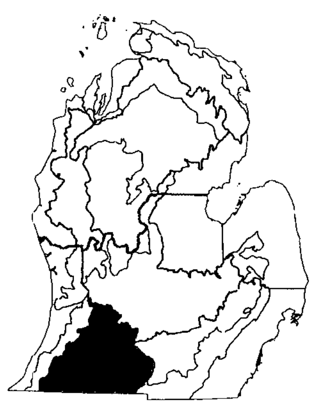
Vegetation within this subdistrict reflected the spatial pattern and underlying differences in landform and topography. In contrast to the rolling moraine and lake plain, where vegetation tended to be described as large, contiguous blocks, the highly dissected topography of the Jackson Interlobate resulted in a complex mosaic of vegetation, with few types exceeding a few thousand acres in area. Within the ice-contact and adjacent outwash deposits, oak barrens (332), with black oak and white oak on "thin soils" (thin A horizon over sand) were common. Barrens were often found within a mosaic of dry oak forest (4123) and oak-hickory forest (4122) in the uplands, and wet prairie (6227), tamarack swamp (4233), and willow-buttonbush swamp (6123) in small, pockety depressions. Kettles were sometimes completely occupied by either swamp or bog (6121). The outwash channels support large wetlands of several types. At the margins between the uplands and the outwash, calcareous seepages often support plant associations of calcophiles, called fens. Tamarack grew near the upland margins of the fens, and in most cases, these areas were probably described by surveyors as tamarack swamp (4233) or wet prairie (6227). Grass and sedge meadows (6224) were found growing adjacent to streams occupying portions of the outwash channels. Swamp forests were most common along margins of major streams on the outwash.

Oak openings (336) were located on gently sloping ground moraine and end moraine at the western end of the subdistrict in Jackson and Calhoun counties. Chinquapin oak ("yellow oak") and black oak were also common in a number of oak openings. Bur oak savanna (335) was typically overwhelmingly dominated by that species, but occasionally white oak and chinquapin oak were found within them. Most of the wetlands on the end moraines were shrub swamp (6122) or mixed hardwood swamps (414) located in lower slope position or in small depressions.

NATURAL DISTURBANCE: The prevalence of lightning-strike fires is not clearly documented. Surveyors made isolated references to fires resulting from Native American activities, and there are numerous historic references to Native American fires in the oak savannas or barrens of the subdistrict (Chapman 1984). It is likely that they played a significant role in maintaining open understory canopies among oak-dominated forests throughout this area.

HUMAN LAND USE: Most of this subdistrict was surveyed between 1816 and 1825. Tanner (1987) mapped Native American settlements circa 1830 at Bawbeese, Devils Lake, near Spring Arbor, Battise, Walled Lake, Orchard Lake, and Tipsico. Early European settlements in 1830 were located at Jacksonburg (Jackson), and Pontiac. Most of the land was cleared for agriculture by the mid-nineteenth century. Almost all of the ground moraines remain farmed, whereas the steeper moraines and ice contact topography were farmed, then abandoned. Most have succeeded to closed-canopy oak-hickory forest. Today, roads and major highways pass throughout the subdistrict, and urban development is spreading rapidly from the Pontiac, Ann Arbor, and Jackson areas. Other centers of urban development are at Albion, Marshall, Hillsdale, and Brighton. A number of State Recreation Areas and State Game Areas are found throughout this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Native Americans quite likely played a role in shaping the mosaic of upland vegetation within the subdistrict (Chapman 1984). Most of the upland and wetland communities that dominated this landscape in the 1800s have been dramatically altered. Both residential development and agricultural land use has resulted in rapid eutrification of lakes and degradation of many wetlands. Road construction and ditching has also modified the hydrology of many wetlands. Overall wetland losses, however, when compared with acreage in the 1800s, are probably much less severe than in the adjacent Ann Arbor subdistrict, given the poor soils and steep topography that limited agricultural development. Jackson County, which falls almost entirely within the subdistrict, has experienced an 11% loss in total wetland acreage since the 1800s (Comer in prep). Many forests that remain are small fragments of previous tracts and have seen dramatic change in species composition due to past logging. Oak barrens and savannas have been either converted to farm land or have grown into closed-canopy oak forests due to fire suppression. Fire suppression within remnant oak-hickory forest has also limited regeneration of oak species.



DISTRICT 2 Kalamazoo.

CLIMATE: The average growing season length ranges from approximately 140 days at the north edge of the district to over 160 days in the southwest (Eichenlaub et al. 1990). Average annual precipitation ranges from 32 inches in the north to 38 inches in the southwest. Average snowfall ranges from 50 inches in the east to over 60 inches in the southwest, near Lake Michigan. Extreme minimum temperatures range from -22° F in the south to -30° F in the extreme north.

DISTRICT 2 Kalamazoo.
SUBDISTRICT 2.1. Battle Creek: outwash and ground moraine.

BEDROCK GEOLOGY: This district is entirely underlain by Mississippian (Paleozoic) shale (Dorr and Eschman 1984, Segall and Wilson 1987). Glacial drift is shallow at the eastern edge of the district, where there are local exposures of shale, but as much as 350 ft. thick in the west and southwest (Akers 1938).

Outwash deposits of sand and gravel cover more than half of the subdistrict. Over 80% of the outwash is in the 0-6% slope class. Small "islands" of end moraine and ground moraine are scattered throughout the outwash plain. Slopes on the moraines are generally in the 0-6% or 6-12% slope classes. Ground moraine is concentrated in Branch County, where numerous low drumlin ridges are oriented from northeast to southwest. The drumlins, which are commonly separated by narrow outwash deposits, are low and broad, with slopes in the 0-6% slope class. Lakes are common on the outwash plain, where they occupy ice-block kettles or abandoned channels. Small streams are numerous; many of these small streams originate within wetlands on the outwash plain. The St. Joseph and Kalamazoo rivers drain much of the subdistrict.

Most of the outwash deposits are well or moderately well drained sands and loamy sands. Very poorly drained soils are common in the narrow outwash channels between drumlins and in ice-block kettles or abandoned stream channels. Peat accumulations can be 6-10 ft. thick. The soils on the end moraine and ground moraine are typically sandy loam or loamy sand, and most are well drained. A well-developed argillic horizon is common in these soils.

PRESETTLEMENT VEGETATION: Well drained soils on the outwash historically supported a diverse mosaic of oak-dominated forest, savanna, and tallgrass prairie (see comments on savanna under subdistrict 1.3). The configuration of this mosaic was probably determined in large part by the juxtaposition of droughty soils with natural fire breaks, such as large swamps and rivers. Black oak and white oak forest (4123) was found along with oak barrens (332) on the driest sites. A small area with both white oak-white pine-dominated forest (4217) and barrens (334) was located north of Gun Lake. Grasslands (31) were located on the broadest expanses of well drained outwash plain, where neither steep topography nor streams formed barriers to fire. The tallgrass prairie at Schoolcraft occupied areas as large as 20 square miles. Nearly 50 prairies were found in the subdistrict. Poorly drained outwash supported emergent marsh (6221), wet prairie (6227), tamarack swamp (4233), and mixed hardwoods swamp (414), with black ash and American elm most common.

Oak-hickory forest (4122) was most commonly found with white oak-dominated openings (336) on both outwash and moraine where soils were a sandy loam. The "islands" of sandy end moraine or ground moraine also supported bur oak savannas (335). Bur oak generally occurred on broad, gently sloping ridges, where fires were relatively frequent. Oak-hickory forest occurred on smaller, more steeply sloping features. Sugar maple, beech, and basswood forest (4121) dominated the drumlin ridges in Branch and Kalamazoo counties, as well as ground moraine and outwash deposits in central Cass County. Swamp forest, often dominated by black ash (4141) or tamarack (4233), occurred between the drumlins.

NATURAL DISTURBANCE: Fire was important for maintaining both the tallgrass prairie and oak savannas. The prevalence of lightning-strike fires is not clearly documented. Surveyors made isolated references to fires resulting from Native American activities, and there are numerous historic references to Native Americans setting fires in the oak savannas or barrens of the subdistrict (Chapman 1984). It is likely that they played a significant role in maintaining open understory canopies among oak-dominated forests throughout this area.

HUMAN LAND USE: Most of this subdistrict was surveyed between 1816 and 1825. Surveyors noted many trails and Native American wigwams between Gun Lake and the Thornapple River. Tanner (1987) mapped Native American settlements circa 1830 all around Kalamazoo, Notawasepe (a large reservation), Niles, Brush Creek, west of Mottville, Tekonquasha, Mickesawbe, Gun Lake, and Sagimaw. This was among the most densely populated portions of the state. Early European settlements in 1830 were located at White Pigeon and Mottville. The Detroit-Chicago Road passed through this subdistrict at the time of the surveys. Most Native American settlements, as with later European ones, concentrated around the prairies, where there was no need to remove the forest prior to planting crops. Most of the land surrounding the prairies was cleared for agriculture by the mid-nineteenth century. Almost all of the ground moraine has remained farmed, whereas the steeper end moraines and ice contact ridges were farmed, then abandoned. Nearly all of the savannas, if they were not cleared and plowed, have succeeded to closed-canopy oak-hickory forest. Today, roads and major highways pass throughout the subdistrict, and urban development is spreading rapidly around Kalamazoo and Battle Creek. Other centers of urban development are at Hastings, Paw Paw, Niles, Buchanan, Three Rivers, Sturgis, and Coldwater. Several State Game Areas are found within this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Native Americans quite likely played a role in shaping the mosaic of upland vegetation within the subdistrict, largely through their use of fire as a land management tool (Chapman 1984). Many of the remaining forests are small fragments of previous tracts and have seen dramatic change in species composition due to past land use. All of the original oak savannas have been either converted to farm land or have grown into closed-canopy oak forests due to fire suppression. Fire suppression within remnant oak-hickory forest has also limited regeneration of oak species.

Most of the wetland communities that dominated this landscape in the 1800s have been dramatically altered. Both residential development and agricultural land use have resulted in the eutrification of lakes and degradation of wetlands. Most wet grasslands along streams have been used as pasture, introducing Eurasian weed species. Road construction and ditching have modified wetland hydrology. Most of the Dowagiac River has been channelized, as have many other small streams. Some large swamps occupying glacial drainageways and ice-block depressions still support native vegetation. Overall wetland losses within this subdistrict, when compared with acreage in the 1800s, are typical for the southern Lower Peninsula. Kalamazoo County, which falls almost entirely within the subdistrict, has experienced approximately a 50% loss in total wetland acreage since the 1800s (Comer in prep). The shorelines of many lakes are being developed for either recreational or residential use.

DISTRICT 2 Kalamazoo.
SUBDISTRICT 2.2. Cassopolis: coarse-textured end moraine and ice-contact topography.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: This entire district is underlain by Mississippian (Paleozoic) shale (Dorr and Eschman 1984, Segall and Wilson 1987).

Glacial drift is 250-350 ft. thick. Steep, narrow ridges of ice-contact and moraine are characteristic of the subdistrict. The ridges are broken periodically by outwash channels. The height of the ridges vary from 50 to 200 ft. Kettle lakes are common, as are linear lakes that occupy abandoned drainageways of glacial meltwater streams. Many small streams originate near the margins of the subdistrict.

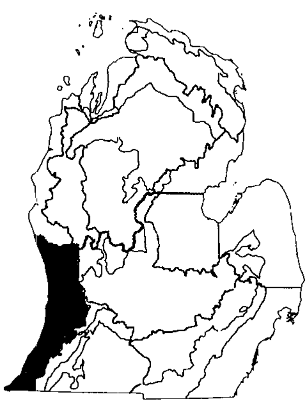
Well drained and excessively drained loamy and gravely sands characterize most of the uplands. Organic soils are common near the margins of the kettle lakes. Organic soils in the kettle bogs can be several feet thick.

PRESETTLEMENT VEGETATION: The steep upland ridges were historically dominated by oak-hickory forest (4122) and black oak-white oak forest (4123). Oak opening (336) and oak barrens (332), occurred on many south and west aspect slopes and on some of the more gently sloping ridges (see comments on savanna under subdistrict 1.3). Beech, sugar maple, and basswood forest (4121) was located on ground moraine and end moraine in several parts of the subdistrict; these areas were generally steeper than the landscapes dominated by prairie and oak opening, and were, for this reason probably less prone to burn. Some adjacent areas of outwash with fire protection offered by wetlands, were also dominated by forests of beech, sugar maple, and basswood. Kettle depressions supported mixed hardwood swamp (414), tamarack swamp (4233), shrub swamp (6123), and bog (6121). An extensive wet prairie (6227) was noted on an outwash channel in southwest Cass County.

NATURAL DISTURBANCE: Fire was important for maintaining both the tallgrass prairie and oak savanna. The prevalence of lightning-struck fires is not clearly documented. Native Americans were reported to have used fire as a management tool in this subdistrict at the time of European settlement (Chapman 1984).

HUMAN LAND USE: Most of this subdistrict was surveyed between 1816 and 1825. Tanner (1987) mapped Native American settlements circa 1830 concentrated at Prairie Ronde. Most of the land was cleared for agriculture by the mid-nineteenth century. Almost all of the ground moraines have been farmed, whereas the steeper moraines and ice contact topography were farmed, then abandoned. Most abandoned farmland has succeeded to closed-canopy oak-hickory forest. Several State Game Areas are located within this subdistrict. Today, roads and major highways passes through the subdistrict, and urban development is centered around Dowagiac and Cassopolis.

INFLUENCE OF HUMAN LAND USE ON VEGETATION:
Human land use is almost identical to that described in subdistrict 2.1 (see text of subdistrict 2.1, the Battle Creek subdistrict). The topography in the subdistrict is steeper and the soils are often droughtier than in subdistrict 2.1; as a result, a greater portion of this subdistrict remains forested.



DISTRICT 3 Allegan.

CLIMATE: The climate is warm due to its southerly location and is also highly moderated by Lake Michigan. This combination gives the Allegan district a long, warm growing season. Compared to areas at the same latitude farther east, the last freezing temperatures occur earlier in the spring and maximum daytime temperatures are reduced. Winters are mild. Extreme minimum temperature range from -22° F to -34° F. Considerable lake-effect precipitation falls during the late fall and winter months.

DISTRICT 3 Allegan.
SUBDISTRICT 3.1. Berrien Springs: end and ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The subdistrict is entirely underlain by Paleozoic bedrock; Devonian shale occurs in the southern half, and Mississippian shale, sandstone, and gypsum occur farther to the north (Dorr and Eschman 1984, Segall and Wilson 1987). Bedrock of the entire subdistrict is covered with 150-350 feet of glacial deposits (Akers 1938).

The subdistrict consists of a 10-20 mile wide band of ground moraine and end moraine ridges paralleling Lake Michigan. The moraines are bounded by flat lake plain to the west and outwash to the east. Most of the ridges are 60-100 ft. high with moderate to steep slopes. Kettle lakes, although present on the end moraines, are much less numerous than on the end moraines of adjacent subdistricts. There are also a few long, narrow lakes on the ground moraine. Several small streams originate on the upland ridges of the sub-subsection. Three large rivers, the Paw Paw, St. Joseph, and Kalamazoo, cut through the moraine ridges, creating steep ravines.

Soils of the northern three-quarters are sandy loams underlain by either clays or gravelly sands. Most of these soils are moderately well drained or well drained. Slopes are moderate to steep. Soils in the southern quarter are silt loams, often underlain by clay subsoils. These soils are also generally well drained or moderately well drained. Poorly drained soils were concentrated on the fine-textured ground moraine. Very poorly drained soils occur in kettle depressions on the end moraine.

PRESETTLEMENT VEGETATION: The upland ridges of end and ground moraine supported a similar mosaic of forests and wetlands throughout the subdistrict. Most were dominated by beech, sugar maple, and white oak forest (4121) or oak-hickory forest (4122), with the latter being most common in northern Berrien County. Kettle depressions support mixed hardwood swamp (414), black ash swamp (4141), tamarack swamp (4233), willow-button bush swamp (6123), and bog (6121). The ground moraine of central Berrien County has inclusions of sand lake plain that supported extensive areas of emergent marsh (6221) and lake plain prairie (6226). These marshes and prairies contained scattered trees of (black) willow, speckled alder, black ash, American elm, and red maple.

The St. Joseph River, which flows through the subdistrict, has a 1/4 to one mile wide border of sandy outwash along its margins. This outwash supported a broad swamp forest of lowland hardwoods (414) dominated by several species, including sycamore, black ash, (silver) maple, beech, elm, hackberry, and basswood. A small prairie (31) and conifer-hardwood swamp (42) were located along the St. Joseph River at Berrien Springs. Oak barrens (332) were noted on outwash deposits along the Paw Paw River, and white oak-white pine forest (4217), and oak-pine barrens (334) were mentioned along the Kalamazoo River, southeast of Allegan.

NATURAL DISTURBANCE: No natural disturbances were mentioned by surveyors. The oak barrens and oak-pine barrens associated with the major rivers may have been partly the result of Native American use of fire.

HUMAN LAND USE: Tanner (1987) noted several Native American settlements circa 1830 along the St. Joseph, Paw Paw, and Kalamazoo rivers within this subdistrict. Trygg (1964) noted several early sawmills were already located along the Kalamazoo River at the time of the surveys. Most of the land was cleared for agriculture by the mid-nineteenth century. Most of the uplands of this subdistrict, including the floodplain of the St. Joseph River, have been converted to orchards and vineyards. The only areas not farmed are the steep ravines along creeks and rivers and small wetlands on the end moraines. An extensive network of roads and highways passes through the subdistrict, and urban development is centered at Berrien Springs, Hartford, Allegan, and Wayland.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Native American use of fire may have influenced the development of barrens and grassland along major rivers. Most of the more gently-sloping ridges and even some of the steeper ridges have been converted to orchards and vineyards. The remaining forested areas are generally the more steeply-sloping, irregular ridges that are presently dominated by closed-canopy oak-hickory forests. The depressions that originally contained mixed hardwood swamp and shrub swamp were quite small, typically located within moderately sloping ridges. Most of the swamp forests within these small depressions have not been developed, but agricultural land use extends right to their boundaries. Emergent marshes and lake plain prairies have been almost completely drained and farmed.

DISTRICT 3 Allegan.
SUBDISTRICT 3.2. Benton Harbor: lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The underlying bedrock is of Mississippian age, consisting of Marshall Formation sandstones and dolomites and Coldwater shales (Deutsch et al. 1959). Drift is generally thick, ranging from 50 to 400 ft. (Akers 1938). Elevations increase gradually from the Lake Michigan shoreline, with the highest elevations at the southeastern edge of the district. Elevations range from 580-820 ft.

The surface of the subdistrict consists primarily of lake plain, but includes small areas of relatively flat ground and end moraine topography. On moraines, slopes of 6-12% are common. Sand dunes, up to 200 ft. high, and with slopes as steep as 30 degrees, form a narrow discontinuous band, 1-5 mi. wide, along the shore of Lake Michigan. Most of the dune formation occurred in Nipissing Great Lakes time, approximately 4,500 years ago, but the smaller foredunes formed during more recent low-water levels of Lake Michigan (Dorr and Eschman 1984). Small inland dunes occur east of the coastal dunes. These small dunes developed earlier than those on the coast, when proglacial predecessors of the Great Lakes stood at higher water levels than that of today (Dorr and Eschman 1984). There are a few small kettle lakes on the sand lake plain. The water level of many of these lakes fluctuates greatly, leaving them almost dry in some summers. These fluctuations result in a distinctive disjunct flora from the Atlantic and Gulf coastal plains along the lake margins. There are also a few small lakes on the moraines. Several of the larger rivers, including the Black, Kalamazoo, Grand, Muskegon, and White, have sand dunes where they meet Lake Michigan, creating small lakes behind the dunes.

Soil textures range from sand to clay. At the southern edge of the subdistrict, the texture of most of the lacustrine soils is clay loam or silt loam. To the north, the majority of the surface lacustrine deposits are sands. Some lacustrine soils are underlain by finer textured subsoils, causing poorly drained surface and cemented subsurface soils. The soils of the moraines are generally loams or clays. Soil drainage classes on the sandy lacustrine deposits tend to be excessively drained or poorly drained. The fine-textured soils on moraines tend to be well drained on uplands and poorly drained in depressions. Along the Muskegon River at the north edge of the subdistrict, the lacustrine sands are generally excessively drained. Low dunes are locally common. Poorly drained sands characterize a large area of Muskegon and Ottawa counties.

PRESETTLEMENT VEGETATION: The majority of the subdistrict was dominated by upland forest. In the southern part of the subdistrict, including Berrien, Van Buren, and Allegan counties, beech and sugar maple forest (4121) was most common on both fine-textured moraines and sandy lacustrine deposits. Within this same area, oak-hickory forest (4122) was common along the coastal dunes in Berrien County, and also on the bluffs and broad ridges above major rivers, including the Galien, St. Joseph, and Paw Paw. White pine was also common among the dunes near Bridgeman. Several large areas of open, blowing sand (73) were noted by surveyors, typically at the mouth of a major river. These areas, generally less than a half mile wide, extended as much as a mile inland from the shoreline. Hemlock forest (4226) occurred in small stream valleys on the lake plain. Farther north, in northern Allegan, Ottawa, and Muskegon counties, forests dominated by eastern hemlock and American beech (4119) occupied most of the sand lake plain and fine-textured moraines. Hemlock and beech forest also occupied the dunes as far south as Benton Harbor. North of the Black Creek in Muskegon County, the excessively drained lacustrine sands supported white oak-white pine forest (4217). This was also the dominant forest, in a mosaic with extensive oak-pine barrens (334), in west-central Allegan County.

Great Lakes marsh (6222) and mixed hardwood swamp (414) extended several miles up the major rivers, including the Galien, St. Joseph, Kalamazoo, Grand, Muskegon, and White. Black ash swamp (4141) was noted along the Black River, and (silver) maple swamp (4143) was noted along the Kalamazoo River. Both tamarack swamp (4233) and lowland hardwoods swamp (414) were located in bowl-shaped depressions behind many dunes. Further inland, small kettle depressions with areas of end moraine supported small marshes (6221), mixed hardwood swamp (414), and mixed conifer swamp (423). Broad depressions on both the flat sand lake plain and the ground moraine contained emergent marshes (6221), lake plain prairies (6226), and both lowland hardwoods (414) and mixed conifer swamps (423).

NATURAL DISTURBANCE: Blowouts, areas of destabilized sand that are moved landward by the wind, were noted by surveyors. Although blowouts are sometimes the result of intensive logging and/or plowing, the surveyors recorded the presence of large blowouts in the same areas where most of the present blowouts are located today, suggesting that natural disturbances regularly caused blowouts to form. Locally, there were references of burned land and windthrown trees along the Galien River. Surveyors referenced recent fires among the oak-pine barrens in west-central Allegan County.

HUMAN LAND USE: Tanner (1987) noted Native American settlements circa 1830 at New Buffalo, Saugatuck, Battle Point (near Grand Haven), Muskegon, and Wabamingo. Surveyors made references to farm fields near the mouth of the Kalamazoo River, and trails (of unkown origin) along the Grand River. Trails were also noted in the white pine-white oak forests near Muskegon Lake. Early European settlements in 1830 were limited to Saranac (now called St. Joseph). Logging of white pine began soon after the surveys along the Muskegon and White rivers (Benson 1989). Hardwoods were later harvested near the mouths of major rivers to fuel Great Lakes steamships. Most of the land in this subdistrict was cleared for agriculture by the mid-nineteenth century. Almost all of the sand lake plain, which characterizes most of the subdistrict, has been farmed. Where the natural drainage of the sand lake plain is poor, as between Hoffmaster State Park and Fruitport, most of the land is ditched. Blueberries are a common crop on the poorly drained acid sands. Large areas also support nurseries and fields of asparagus. Some of the lake plain supports orchards and vineyards. The coastal sand dunes have not been exploited for agriculture, but they are popular for residential development. Large portions of the dunes remain forested. Sand mining has been conducted in the coastal dunes, but is now restricted to one site near Bridgeman. Oil wells tap petroleum reservoirs in the underlying Devonian-age marine deposits (Dorr and Eschman). All but the steepest end moraine are farmed, and some of the steep sites have been converted to pasture and hay production. Several State Parks are located among the dunes within this subdistrict, and Warren Woods is located further inland along the Galien River. The Allegan and Muskegon State Game Areas fall within this subdistrict. An extensive network of roads and highways passes through this subdistrict, and urban development is concentrated at New Buffalo, St. Joseph and Benton Harbor, Paw Paw Lake, South Haven, Saugatuck, Holland, Grand Haven, Muskegon, and White Lake.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Farming of the droughtier sand soils of the lake plain resulted in severe wind erosion. Most of these lands have been abandoned, and the fields have regenerated to black cherry, bigtooth aspen, and quaking aspen. Signs of wind erosion are abundant. Fires following early logging destroying white pine regeneration and resulted in white oak and black oak forests. White pine regeneration is locally good, but most white pine is presently either understory or small overstory in size. Almost all areas once dominated by beech-sugar maple forest remain farmed, either for row crops or orchard. This includes broad expanses of both sand lake plain and fine-textured end and ground moraines. Beech-sugar maple forest persists on portions of the coastal dunes, as do pockets of hemlock, beech, and white pine.

Many Great Lakes marshes remain near the mouths of the large rivers, although some have been modified by boat channels. Near larger cities, these marshes have been partially filled for development of either industrial facilities or recreational facilities, such as marinas. Drainage of some organic soils on the sand lake plain also resulted in severe wind erosion and eventual abandonment. The mixed hardwood swamps in smaller, steeper depressions within the dunes or end moraines persist, as their drainage was impractical. At the northern edge of the subdistrict, in portions of Ottawa and Muskegon counties, greater areas of mixed conifer swamp persist than farther south.

DISTRICT 3 Allegan.
SUBDISTRICT 3.3. Jamestown: fine-textured end and ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Steep topography distinguishes this subdistrict. Glacial drift is generally thick, from 50 to 400 ft. (Akers 1938), over the Mississipian age sandstones and dolomites of the Marshall Formation and shales of the Coldwater Formation (Deutsch et al. 1959). Soils are loamy, except for the outwash deposits along the Grand River, where soils are generally well drained. The deeply eroded channel of the Grand River adds to the dissected nature of the topography.

PRESETTLEMENT VEGETATION: The majority of the flat ground moraine supported beech-sugar maple forest (4121). White pine, beech, and red maple (4219) were noted in a few places on the end and ground moraine. Hemlock and beech (4119) were co-dominant on outwash deposits at the north end of the subdistrict. Small areas of mixed hardwood swamp (414), black ash (4141), and alder-willow swamp (6122) were located in small depressions in the end moraine and ground moraine. poorly drained outwash supported much larger swamps dominated by mixed hardwoods (414), tamarack (4233), or conifer-hardwood swamp (42).

NATURAL DISTURBANCE: There was no mention of natural disturbances for the subdistrict.

HUMAN LAND USE: Surveyors, in the 1820s, noted Native American wigwams at Crockery Lake (Ottawa County), and numerous trails extending toward fur trading centers at Grand Rapids (Trygg (1964). There were also buildings associated with the fur trade along the Grand River within this subdistrict. Tanner (1987) noted no Native American settlements within this subdistrict circa 1830. Most of the land was cleared for agriculture by the mid-nineteenth century and remains in use, but some steeper slopes have reforested. A network of roads and highways passes through this subdistrict, and urban development is rapidly expanding west from Grand Rapids.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Most upland and wetland communities characteristic of the presettlement condition in this subdistrict have been dramatically altered or eliminated. Forests remain as small upland fragments or small hardwood-dominated swamps. Swamp forests along rivers and streams provide concentrations of contiguous forest. Development extending west from Grand Rapids has converted productive farm lands to residential lands.

DISTRICT 4 Ionia.

CLIMATE: The growing season ranges from approximately 130 days at the northern edge of the district, to 160 days at the western edge (Eichenlaub et al. 1990). It is the least lake-moderated district in southern Lower Michigan. Average annual precipitation ranges from 30 to 32 inches and average annual snowfall, from 40 to 80 inches, with highest levels in the west, near Lake Michigan. Extreme minimum temperatures range from -24° F to -36° F. In general, the extreme minimum temperature becomes lower farther north in the district, but there is also a large frost pocket in low-lying areas of northern Ingham and Ionia counties, near the center of the district.

DISTRICT 4 Ionia.
SUBDISTRICT 4.1: Lansing: medium-textured ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock exposures are rare within this subdistrict. Glacial deposits over bedrock are as thick as 350 or 400 ft. (Akers 1938). The subdistrict is underlain primarily by Paleozoic Era bedrock, primarily Pennsylvanian sandstone, shale, coal, and limestone, with Mississippian shale and gypsum occurring at the western edge (Dorr and Eschman 1984). There are also scattered occurrences of Mesozoic Era bedrock; these Jurassic "red beds" consist mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

The subdistrict consists of gently sloping ground moraine, broken by several outwash channels, and also by numerous end moraine ridges, many of which are little steeper than the surrounding ground moraine topography. Most of the gently rolling hills of ground moraine are only 40-60 ft. high, but hills up to 100 ft. are found on the east and west edges of the subdistrict. Elevations range from 640 to 1122 ft. The greatest elevation changes in the subdistrict, accompanied by steep slopes, are along the outwash channels, which are commonly 50-100 ft. lower than the adjacent ground moraine. Three large rivers, the Maple, Grand, and Thornapple, and several smaller rivers flow across the broad till plain. Many of the rivers and creeks occupy glacial outwash channels. The Grand River, which crosses the subdistrict, occupies a major glacial outwash channel 150-200 ft. lower than the surrounding till plain. The end moraine ridges, which cross-cut the till plain, typically form narrow bands 1-3 mi. wide. Usually the end moraines do not form single, well-defined ridges but rather groups of low ridges (less than 50 ft high) and swampy depressions. There are a few small lakes, both kettle lakes on the end moraines and lakes occupying more linear depressions on the till plain.

The undulating topography of the ground moraine forms alternating well and moderately well drained rises and poorly to very poorly drained linear depressions. Poorly drained soils also occupy small irregularities on the uplands. The postglacial drainage system is not well developed, and as a result, many of the depressions and glacial drainageways contain very poorly drained soils including accumulations of organic materials derived from the partial decomposition of grasses, sedges, or trees. A small area of sandy ground moraine, surrounded by the loam soils more typical of the subdistrict, occurs southwestern Shiawassee County.

PRESETTLEMENT VEGETATION: Upland portions of the ground and end moraines in this subdistrict were overwhelmingly dominated by beech, sugar maple, and basswood forest (4121). These were the predominant upland forests in the Lansing area. Common species within these forests included black maple, red oak, black walnut, and white ash. Black maple, which is presently encountered more in this subdistrict than in any other, (possibly because of the wet-mesic conditions and the circumneutral soils on the gently sloping ground moraine) was probably identified as sugar maple during the surveys. Some of the drier end moraine ridges throughout the subdistrict supported oak-hickory forests (4122) with red and white oaks. The driest sandy ridges of the outwash deposits, concentrated along the Grand, Maple, and Flat rivers, supported forest of black oak, white oak, and pignut hickory (4123), white oak opening (336), oak barrens (332), white oak-white pine forest (4217), and oak-pine barrens (334). A few small prairies were noted along the Maple River drainage in northern Clinton and eastern Ionia counties. Some of the fine-textured moraines probably experienced occasional catastrophic fires originating from adjacent subdistricts. This was likely the case in western and northern portions of this subdistrict where forests of white pine, beech, and red maple (4219) were common.

Throughout most of the fine textured moraines and poorly drained outwash, large swamp forest was often configured within long linear depressions, or along major river floodplains. Mixed hardwood swamps (414) were dominated by American elm, black ash, red ash, (silver) maple, and swamp white oak. Tamarack swamp (4233), mixed tamarack-hardwood swamp (42), willow-button bush swamp (6123), and emergent marsh (6221) were also among the common wetland types. Wet meadow (6224) was present along streams.

On coarse textured ground moraine, centered around Shaftsburg, there was a highly complex landscape with oak-hickory forest (4122) and oak barrens (332) common in the uplands, and tamarack swamp (4233) and wet prairie (6227) dominating poorly drained areas. Extensive wet prairie, bog (6121), tamarack swamp, and emergent marsh was located just north of East Lansing.

NATURAL DISTURBANCE: Windthrow was the most common form of natural disturbance within this subdistrict. Large windthrows were recorded by surveyors west of Owosso, while smaller clusters were found southeast of Flint and at Hubbardston. A long linear windthrow was recorded near Edmore. Recently burned areas were recorded northeast of Lake Lansing and west of Murrey Lake (Kent County).

HUMAN LAND USE: Native American settlements and trails were located in a number of location throughout the subdistrict at the time of the surveys (Trygg 1964). A village was noted where the Maple River enters the Grand River. Clusters of wigwams were noted further upstream along the Grand River, a few miles south of the Looking Glass River mouth. They were also noted near Three Lakes and Lowe Lake (Ingham County), and at the mouth of the Thornapple River. A network of trails connected the wigwams of Lowe Lake to others along the Huron River. Others further north were connected to the Grand River in various locations. Early logging camps were noted by surveyors between Hayworth Creek and the Maple River. Most of the land within this subdistrict was cleared for agriculture by the mid-nineteenth century. Drainage was necessary for agricultural use of the lowlands and some of the gently-sloping uplands. The number of drainage ditches in the subdistrict is second only to those of the Maumee and Saginaw lake plains. Tiling was the preferred method of drainage on the moderately well drained soils on uplands, whereas drainage ditches were necessary on poorly and very poorly drained soils. Organic soils were extensively drained for the production of mint and other specialty crops, as at St. Johns. The organic deposits are also extensively mined for sedge peat, used in gardening and landscaping. Several State Game Areas are found within this subdistrict, including Maple River, Portland, Lowell, Rose Lake, Dansville, and Oak Grove. A network of roads and highways passes through this subdistrict, and urban development is most concentrated in the Lansing, Flint, and Grand Rapids areas.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Most of the upland within this subdistrict has been converted to crop land, while most of the swamp forest has been converted to pasture. Swamp forest and wet meadow persists locally on the landscape, and is most concentrated along major rivers and on public lands. The largest wet prairies have been drained and largely converted to agricultural use. In Ingham County, which is characteristic of much of the subdistrict, approximately 45% of wetland acreage have been lost since the 1830s (Comer in prep.).

DISTRICT 4 Ionia.
SUBDISTRICT 4.2: Greenville coarse-textured end and ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock exposures are rare in this subdistrict, with glacial deposits over bedrock as thick as 350 or 400 ft. (Akers 1938). The subdistrict is underlain primarily by Paleozoic Era bedrock, primarily Pennsylvanian sandstone, shale, coal, and limestone, with Mississippian shale and gypsum occurring at the western edge (Dorr and Eschman 1984). There are also scattered occurrences of Mesozoic Era bedrock; these Jurassic "red beds" consist mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

The terrain of the subdistrict is generally hilly and dissected by outwash channels. Elevations range from 800 to 1122 ft. The hills, up to 140 ft. high, are moderately to steeply sloping. Both the ground moraine and end moraine are moderately to steeply sloping, but the ground moraine ridges are generally smaller than those of the end moraine. Many small kettle lakes, typically less than one square mile in area, are found on outwash, end moraine, and ground moraine.

Soils are well drained and excessively drained sands and loams on the uplands. Sand outwash deposits are common in lower slope position. The majority of the outwash soils are poorly drained.

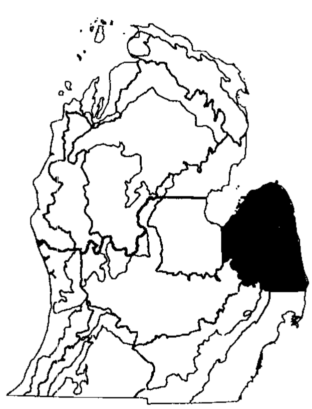
PRESETTLEMENT VEGETATION: The upland vegetation in the western portion of this subdistrict was a mosaic of forests, including: beech, sugar maple, and basswood (4121), and white pine, beech, and red maple (4219). White oak-white pine forest (4217) and oak barrens (332) were common in well drained outwash channels. Further east within this subdistrict, where soils are sandier, beech-sugar maple forest is much less common, and is replaced by oak-hickory forest (4122), black oak-white oak forest (4123), and oak opening (336). Bur oak savanna (335) was noted in several places along the Flat River.

Extensive mixed hardwood swamps (414) dominated by American elm, ash, and (silver) maple were common on poorly drained outwash, especially in the western portion of the subdistrict. The poorly drained portions of ground moraine in Montcalm County supported many small emergent marshes (6221), and larger tamarack swamps (4233) and black ash swamps (4141). Most of the swamp forests throughout the subdistrict also included species such as eastern hemlock, balsam fir, northern white-cedar, white pine, quaking aspen, and paper birch.

NATURAL DISTURBANCE: Fires were probably important for maintaining the oak-pine and oak forests and savannas. The surveyors recorded one recently burned area near Cannonsburg. Windthrows, probably relatively small in size due to the irregular, small ridges of the subdistrict, were more common in the beech-sugar maple dominated forests of the subdistrict. Several windthrows were recorded west of Belding, west of Sparta, and in southeast Newaygo County.

HUMAN LAND USE: Native American and early European fur trading activity was concentrated north of the Grand River at Grand Rapids. There were also wigwams recorded by surveyors around Camp Lake and along the Rogue River (Trygg 1964). Most of the land in this subdistrict was cleared for agriculture by the mid-nineteenth century. Portions of the area were farmed, both for row crops and pasture following logging, but much of the farmland has been abandoned due to low productivity and cold climate. Large parts of the subdistrict have reforested. Several State Game Areas are located within this subdistrict, including Rogue River, Flat River, Cannonsburg, Stanton, and Langston. There is an extensive network of roads and highways throughout the subdistrict, and urban development is concentrated in the Grand Rapids area, Sparta, Rockford, Greenville, Belding, and Stanton.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Native American use of fire may have played a role in maintaining savannas in this subdistrict. Most agricultural activities in this area have been concentrated in uplands with the richest soils, and has resulted in significant forest fragmentation. Swamp forests along major rivers provide concentrations of contiguous forest.



DISTRICT 5 Huron.

CLIMATE: This district is cooler than most of the rest of southern Lower Michigan. The growing season is 130-160 days (Eichenlaub et al. 1990). Most air flows entering this district are from a westerly direction, so this district experiences less lake moderation than districts on the west side of the state. During spring and summer, showers caused by air-mass instability are common. Average extreme minimum winter temperatures are from -24° F to -28° F. Annual precipitation ranges from 28 to 34 inches. Snowfall is generally light. Lake-effect precipitation may occur when winds are from the north and east.

DISTRICT 5 Huron.
SUBDISTRICT 5.1. Sandusky: lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The subdistrict is a relatively flat plain of glacial lacustrine origin. The lake plain is underlain by Paleozoic bedrock; shale, marine limestone and dolomite. Bedrock is exposed along the shoreline at Pointe Aux Barques, and locally inland.

The lacustrine deposits consist of sands and clays. The lake clays are 100-300 ft. thick near the inland margin of the subdistrict, and 50 ft. or less along Saginaw Bay. Within the broad clay lake plain, there are several broad sand channels, created when sand was deposited into the shallow pro-glacial lakes by glacial meltwater streams. These sand channels can be several miles wide, but only 5 to 10 ft. thick. The sand-channel deposits were reworked by wave action during higher levels of the Great Lakes, creating small sand dunes and spits and intervening depressions. Broad end moraine and ground moraine ridges of loamy and clay-rich till occupy portions of the subdistrict. Along the eastern edge of the subdistrict, these ridges are only 3 to 4 mi. inland from the St. Clair River and the Lake Huron shoreline. To the north, these moraines are further inland from the Saginaw Bay shoreline. Slopes are generally steeper on these moraines than on the clay lake plain (2-6% vs. 0-2%). There are no lakes in this subdistrict. Most of the streams are small, beginning on the moraines and forming relatively straight, shallow trenches across the lake plain before entering Saginaw Bay or Lake Huron. The exceptions are the Cass River and Black River. Both rivers flow several miles between parallel moraines before crossing the lake plain.

Poorly drained mineral soils characterize the clay plain. The soils of the dunes and spits are often excessively drained, whereas those in the swales are poorly or very poorly drained. On the end moraines, soils are moderately well and well drained.

PRESETTLEMENT VEGETATION: Almost the entire lake plain was forested. The forests responded to differences in slope class and drainage. The majority of the clay lake plain at the northern end of the subdistrict was dominated by eastern hemlock (4226). These forests were not considered swamps, but the soils were probably wet in places, with many vernal pools. Other common species in these forests were northern white-cedar, American elm, balsam fir, paper birch, and white pine. Further south, in southern Tuscola County, and in Sanilac and St. Clair counties, beech, sugar maple, and basswood forest (4121) dominated well drained areas. The flat sand plain and outwash deposits supported conifer forests of hemlock and white pine (4227). Also in these areas, hemlock was sometimes co-dominant with beech (4119), in forests that included white ash, black ash, basswood, red maple, and quaking aspen. Quaking aspen, paper birch, and white pine (413) were common in large windthrown areas of the lake plain.

On the flatter, poorly drained portions of the sand and clay lake plain, cedar swamp (4231), black ash swamp (4141), and varieties of mixed hardwood and conifer swamps (423, 414, 42) were common. On sand lake plain in northern Sanilac and southern Huron counties, extensive peatlands supported black spruce swamp (4232), tamarack swamp (4233), and mixed conifer swamp (423). Great Lakes marsh (6222) occurred along the entire coast of Saginaw Bay, and locally along the shore of Lake Huron southeast of Saginaw Bay. The marshes, which extended into 4-5 ft. deep water, were 1-2 miles wide in places. Upland of the marshes there was typically a broad zones of swamp forest, but on large expanses of Saginaw Bay, 1-3 mi. wide expanses of lake plain prairie (6226) occurred. The wet prairie changed along with the water level of Lake Huron. During periods of low lake levels, prairie grasses and forbs dominated the broad swales, whereas marsh grasses, sedges, rushes, and cattails expanded into the prairies during high water periods. Within the coastal marshes and wet prairies were low beach ridges and sand spits that supported scattered white oak and black oak. Cottonwood and quaking aspen also occurred within the wet prairie. The surveyors commented on the importance of the wet prairies for waterfowl, describing the Tuscola County shoreline as "unexcelled habitat for ducks, geese, shorebirds, and furbearers." Long bands of parallel beach ridges and swales, called wooded dune and swale complexes (911), occupied many post-glacial embayments along Saginaw Bay. White pine forest (4211) dominated the beach ridges, along with some white oak and black oak, which were most common near the shoreline. Quaking aspen and paper birch were also common on the ridges of the complexes. Oak-pine barrens (334), and oak barrens (332) were found on some of the highest dune ridges at Rush Lake, and on Sand Point. The wettest swales were dominated by floating and emergent aquatic plants, and were often noted as ponds by the surveyors. Ponds were typically found in the swales near to the shoreline, whereas further inland swales typically supported swamp forests of cedar, tamarack, and occasionally black ash.

Forests of beech and sugar maple (4121), hemlock and white pine (4227), and hemlock and beech (4119) were found on the end and ground moraine, which generally have better drainage conditions than the clay lake plain. The forests of the moraines also supported lesser quantities of basswood, white ash, and red maple. Wetlands were either in depressions within the moraines, on flat ground moraine, or at the base of slopes where moraines meet lake plain. Black ash swamp (4141) dominated many of the wetland depressions within the moraines. Cedar swamp (4231) occupied broad wetlands in footslope positions. These cedar swamps also contained tamarack, balsam fir, hemlock, and some white pine, along with birch and quaking aspen.

NATURAL DISTURBANCE: Extensive areas of windthrown forest were recorded by surveyors across southern Sanilac County, and around Cass City, and Bad Axe. These extensive windthrows are the result of a combination of strong winds off Lake Huron and poorly drained soils. Windthrow appears to have been more common within the wetlands and on the flattest parts of the lake plain. Water level fluctuations of 2-3 ft. are common along the Great Lakes shorelines, causing tree mortality, shoreline erosion, and major alteration in species composition of marshes and wet prairies.

HUMAN LAND USE: In the 1820s, surveyors noted Native American encampments along the Cass River near Ellington, and northeast of Vassar. Trails extended from the Vassar area northwest to Saginaw Bay and southeast to sugar camps in northern Lapeer County. There were also a number of French claims and early sawmills established at Port Huron, and upstream on the Black and Belle rivers. There was already a Chippewa Reservation established at Port Huron at the time of the surveys. Some of the earliest logging for white pine in the state took place along the Black and Cass Rivers (Benson 1989). Most of the uplands of the subdistrict were cleared by the mid-nineteenth century. Clay lands have been ditched and tiled and are among the most valued agricultural lands in the state. Portions of the sand plain were also ditched for agriculture, but the wettest areas remain, either as swamp forest, wet prairie, or marsh. Diking and pumping has allowed vast expanses of wet prairie and some areas of marsh to be farmed, especially along Saginaw Bay. Organic soils were burned to improve their suitability for agriculture. References to this practice are found in the Tuscola County (Deeter and Matthews 1931), and St. Clair County (Deeter 1934) soil surveys. One to four percent of the land surface of these counties had burned-over organic soils on clay. Following burning, most of the clay soils required further drainage to be suitable for agriculture. State Game Areas are found along the Saginaw Bay shoreline, and in several portions of the Cass River drainage. Public lands include wooded dune and swale complexes at Sleeper State Park and Port Crescent State Park. An extensive network of roads exists throughout the subdistrict, and urban development is concentrated at Port Huron, Lapeer, Caro, Sandusky, Vassar, Imlay City, Croswell, Bad Axe, Cass City, Sebewaing, Port Austin, and Harbor Beach.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Nearly all of the landscape of this subdistrict has been dramatically altered. Extensive agricultural drainage has caused losses of most wetlands. In Huron County, an estimated 78% of historical wetland acreage has been lost (Comer in prep). Remaining wetlands in the subdistrict are concentrated along the Saginaw Bay and Lake Huron shorelines, and within State Game Areas, such as Vernona and Minden City. Residential construction has caused the destruction of large portions of wooded dune and swale complexes. It is common to see numerous driveways built across swales, severely altering hydrologic processes. Portions of these complexes remain intact in and around Sleeper State Park, and at Pointe Aux Barques.

DISTRICT 5 Huron.
SUBDISTRICT 5.2. Lum: medium and coarse-textured end moraine ridges and outwash.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The underlying Mississippian and Pennsylvanian bedrock, primarily sandstone, is not exposed at the surface. Bedrock is overlain by 250-300 ft. of glacial drift.

The surface of the subdistrict is very similar to subdistrict 1.3 (Jackson Interlobate). It consists of flat, sandy outwash plains that surround coarse-textured end moraine and ground moraine. In the center of the subdistrict, the end moraines are small ridges surrounded by outwash. At the edges of the subdistrict there are large, linear end moraine ridges, only occasionally broken by narrow outwash channels. Kettle lakes, kames, eskers, and segments of outwash channel are common. The highest ridges are approximately 240 ft. high. Both on the outwash channels and on the ground moraine ridges, slopes are generally in the 0-6% class. Slopes can be as steep as 25-40% on the end moraine and ice-contact ridges.

The soils of the moraines are typically well and excessively drained. Drainage conditions on the outwash are more variable, ranging from excessively drained to very poorly drained. Thick outwash deposits are usually characterized by excessively drained conditions. Shallow outwash deposits are in some places underlain by fine-textured till, causing poor or very poor drainage conditions. Locally, fine-textured lacustrine deposits are also present beneath the outwash. Soils are typically excessively drained on the upland kames and eskers and poorly or very poorly drained in the kettles and outwash channels. The most common soil texture is sandy loam on the moraine ridges and sand on the outwash plains. The circumneutral glacial drift which formed the moraines is largely derived from the local limestone. Illuviation is responsible for the formation of a clay-rich horizon in many of the soils on moraines, providing better water-holding capacity than many of the outwash soils.

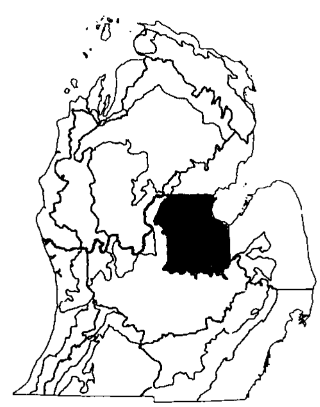
PRESETTLEMENT VEGETATION: On the sandy moraines in southern portions of the subdistrict, oak-hickory forest (4122) and oak opening (336) were found. Elsewhere, the moraines supported forest of beech and sugar maple (4121), beech and hemlock (4119), and white pine, beech, and red maple (4219). Poorly drained portions of the end moraines supported mixed conifer swamp (423) with tamarack, balsam fir, hemlock, and cedar. Similar swamps located in lower slope position or in small depressions. Wetlands on the lower slopes were either conifer-hardwood (42) or mixed hardwood swamps (414). Kettle lakes and swampy depressions typically support willow and buttonbush (6123), mixed hardwoods, or tamarack swamps (4233).

At present, the outwash channels support large wetlands of several types. At the margins between the uplands and the outwash, calcareous seepages support plant associations of calcophiles, called fens. Tamaracks grow scattered near the margins of the fens, so these wetlands were likely mapped as tamarack swamp or hardwood-conifer swamp. Where the topography is steep, organic soils are often 10-15 ft. deep. Grass and sedge meadows form adjacent to streams on the outwash channels. The meadows are maintained by high water levels throughout the growing season.

NATURAL DISTURBANCE: No natural disturbances were recorded by surveyors within this subdistrict.

HUMAN LAND USE: In the 1820s, surveyors noted Native American trails and sugar camps in central Lapeer County. Most uplands were cleared immediately after the surveys, and farmed both for row crops and pasture, but portions of the farmed lands were later abandoned due to poor soils and steep topography. Gravel mining is locally common, and Holloway Reservoir is located along the Flint River. Lapeer and Murphy State Game Areas fall within this subdistrict. There is a network of roads and highways passing through the subdistrict, but urban development is limited to a few small towns.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Nearly all of the upland and wetland portions of the subdistrict have been dramatically altered. Abandoned uplands have reforested to black oak, white oak, hickory, and aspen, or remain as old fields. Small fragments of second-growth beech-sugar maple forest remain. Oak openings were mostly cleared and farmed, or succeeded to closed-canopy oak forest due to fire suppression.



DISTRICT 6. Saginaw: lake plain and reworked till plain.

CLIMATE: The growing season of this district is as long (153 days) as in districts at the southern boundary of the state. Average annual extreme minimum temperature is 14° F. Toward the northern end of the district, there is a sharp climatic gradient due to characteristic positions of air masses. The Arenac district to the north is separated from the Saginaw district on the basis of this gradient, with the Saginaw district being notably warmer.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock is only locally exposed. The Paleozoic-era bedrock is primarily Pennsylvanian sandstone, shale, coal, and limestone (Dorr and Eschman 1984). At the western edge of the district there are scattered occurrences of Mesozoic Era bedrock. These Jurassic "red beds" consist mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum. Beneath the Pennsylvanian and Mississippian bedrock are extensive deposits of Devonian and Silurian shallow marine deposits that have yielded evaporites and brines important to the chemical industry in Midland and Saginaw. There are also important oil and gas fields associated with marine deposits underlying this district.

The surface of the district is a relatively flat plain of glacial lacustrine origin. The lacustrine deposits, which consist of sands and clays, are thickest along the farthest inland edge of the lake plain (up to 300 ft. thick) and thinnest along the present shorelines of Lakes Huron, where thickness is generally 50 ft. or less along Saginaw Bay. Clay sediments are generally quite thick on the lake plain, but several broad sand channels were created by glacial meltwater streams that deposited sand into the shallow pro-glacial lakes. Many of these sand channels are several miles wide in this district, but the sand in them is generally only 5 to 10 ft. thick. There are also low, sandy beach ridges and dunes scattered across the surface of the lake plain, most concentrated in Midland County. There were no natural lakes. There are several large rivers, which were important for floating white pine timber to mills along Saginaw Bay. These rivers include the Tittabawassee, Shiawassee, Saginaw, Pine, Flint, and Chippewa. Most of the rivers flow through broad sand plains.

Poorly drained mineral soils characterize the clay plain. The sand-channel deposits were reworked by wave action during higher levels of the Great Lakes, creating small sand dunes and spits and intervening depressions. The resulting features are typically higher and have steeper slopes than any found on the clay lake plain. The soils of the dunes and spits are often excessively drained, whereas those in the swales are poorly or very poorly drained.

PRESETTLEMENT VEGETATION: Beech, sugar maple, and basswood forest (4121) was common on the better drained portions of the lake plain at the southern half of the district. Drainage conditions were locally better along the Saginaw River, resulting in upland forests with more white oak near the river. Many of the upland forests on lake plain were probably fairly moist, as indicated by the abundance of American elm, and black ash. At the northern half of the district, forests dominated by hemlock (4226) or beech and hemlock (4119) were common on the lake plain. These forests also contained hardwoods such as black ash and American elm. Hemlock often grew in combination with white pine (4227) on sand lake plain. Northern hardwood (4111) began to replaced more southern hardwood-dominated forests at the northern end of the this subdistrict. These forests, though still dominated by beech and sugar maple, also included yellow birch, paper birch, white pine, balsam fir, and hemlock, and lacked species more common further south, such as black walnut and tulip tree.

Mixed hardwood swamp (414) dominated large expanses of the lake plain. Black ash, basswood, and American elm were common co-dominants, but tamarack and northern white-cedar were also present. The flat conditions resulted in an intergrading of upland and wetland hardwoods on the landscape. Swamp dominated by tamarack (4233) occurred on the flat, poorly drained clay plain near the boundary with sand lake plain. This was probably most common near the Quanicassee River, but occurred elsewhere in the district. Extensive Great Lakes marsh (6222) occurred along Saginaw Bay. The marshes, which extended into 4-5 ft. deep water, were 1-2 miles wide in places, and extended for miles up major rivers such as the Quanicassee and Saginaw. Along the western shore of Saginaw Bay, the marshes were generally 1/8 to 1/2 mile wide, much narrower than along the southern edge of the bay. Shoreward of the marshes were extensive zones of lake plain prairie (6226). These wet prairies extended several miles inland along the Quanicassee and Saginaw rivers. The wet prairies were quite variable in plant composition, ranging from true prairie grasses, such as big blue stem, Indian grass, and cord grass, to blue joint grass and sedges closer to the marsh edges and in wetter depressions. They also contained a diversity of other species, including rushes, bulrushes, cattails, reed grass, and willow or other shrubs. Within the coastal marshes and wet prairies were low beach ridges and sand spits that supported scattered white oak, bur oak, and black oak in lakeplain oak openings (331). There was also quaking aspen and other lowland hardwoods locally within the wet prairies. Among clusters of dune ridges and poorly drained sands on inland portions of the lakeplain, a complex mosaic of upland forest, such as white pine, beech, and red maple (4219), or hemlock and white pine (4227) was found with tamarack swamp (4233), emergent marsh (6221), or mixed hardwood swamp (414) in small depressions. A good example of this landscape was along the Saginaw-Gratiot County line.

Fine-textured ground moraine is often very flat and can be difficult to distinguish from lake plain. These moraines included upland forests dominated by hemlock (4226), beech and hemlock (4119), white pine, beech, and red maple (4219), and beech and sugar maple (4121). Poorly drained portions included mixed hardwood swamps (414), tamarack swamp (4233), and occasionally, cedar swamp (4231).

NATURAL DISTURBANCE: Although extensive areas of windthrown forest are generally common near the Great Lakes shorelines, this district had no areas of windthrow mentioned by surveyors. It may be that the district's location, at the southern and western edge of Saginaw Bay, provided protection from the prevailing winds, thus greatly reducing the amount of windthrow. One recently burned area was mentioned just southeast of Ashley. Water level fluctuations of 2-3 ft. are common along Saginaw Bay shorelines, causing tree mortality, shoreline erosion, and major alteration in species composition of marshes and wet prairies. The surveyors noted such water-level fluctuations just a few miles east of the district at Fish Point.

HUMAN LAND USE: Native American settlements and sugar camps were noted along the Pine and Tittabawassee rivers (Trygg 1964). Lakeplain oak openings may have been maintained on beach ridges near the shoreline of Saginaw Bay by Native American's use of fire (Jones and Kapp 1972). By the 1820s-1830s, when the surveys were done, a number of treaties had already been signed, and reservations were already established along major rivers. There were also early European villages at Saginaw and Ashley.

This portion of the Saginaw Basin saw some of the earliest intensive development in the state. Billions of board feet of white pine were logged between the 1830s and 1870s. Simultaneously, the salt industry and Saginaw Bay fishery were developing, resulting in the harvest of oak and ash for barrels to store and ship these valuable commodities. Following logging, drainage began for agricultural utilization of the clay plain. By 1900, the chemical industry was well developed.

Most clay lands have been ditched and tiled and are among the most valued agricultural lands in the state. Portions of the sand plain were also ditched for agriculture, but the wettest areas remain, either as swamp forest, wet prairie, or marsh. Diking and pumping has allowed vast expanses of wet prairie and some areas of marsh to be farmed, especially along Saginaw Bay. Organic soils were burned to improve their suitability for agriculture. References to this practice are found in the Bay County (Wonser 1934), and Saginaw County (Moon 1938) soil surveys. One to four percent of the land surface of these counties had burned-over organic soils on clay. Following burning, most of the clay soils required further drainage to be suitable for agriculture. State Game and Wildlife Areas within this district include Gratiot-Saginaw, Crow Island, Tobico Marsh, Quanicassee, and Nayanquing Point. State Forest is located in Midland and Gladwin counties. There is a network of roads and major highways passing throughout the district, and most urban development is concentrated at Saginaw, Bay City, Midland, and Mount Pleasant.

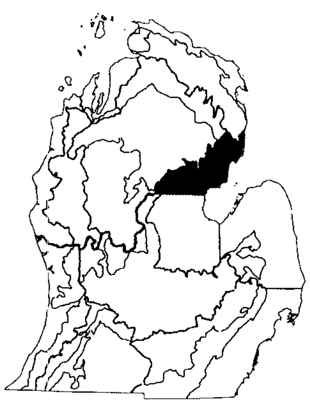
INFLUENCE OF HUMAN LAND USE ON VEGETATION: The majority of both uplands and wetlands within this district have been converted for agriculture. Approximately half of historical wetland acreage has been lost in Bay and Saginaw counties since the 1830s (Comer et al. 1993). Agricultural conversion has been most intensive in the southern half of the district. There, lowland hardwoods occasionally persist where they occupied depressions in the landscape that were difficult to drain. They also persist immediately adjacent to the Saginaw Bay shoreline, where drainage conditions were too poor for conversion to agriculture. Further north, especially in Midland County, there are extensive forested wetlands, most of which are dominated by quaking and bigtooth aspen, and balsam fir. Upland forests are typically dominated by aspen-birch or northern hardwoods.

Much of the Great Lakes marsh persists along the Saginaw Bay shoreline, as it is too poorly drained to be converted to agricultural use. In some of the broadest areas of marsh, near the Quanicassee River, diking and pumping has allowed portions of the marsh to be farmed. A much greater portion of the marsh has been altered, either by diking and ponding for waterfowl management, by boat slip or marina development, or filling for urban industrial development. During surveys of Great Lakes marshes during the summer of 1988 (MNFI 1988), major alteration in the marshes were noted at Coryeon Point, Tobico Marsh, Nayanquing Point, and Pinconning. The majority of the lake plain prairie has been ditched and tiled for agriculture. Some areas of wet prairie require pumping of fields to maintain conditions dry enough for farming. Small areas of prairie persist along the upland edges of Great Lakes marsh, but this accounts for relatively small acreage. Extensive areas of prairie were altered or destroyed along the Saginaw and Quanicassee rivers.

Most of the oak openings that occurred on small beach ridges close to the shoreline have become closed-canopy oak forests due to the suppression of fires. Near the shoreline, and to some degree further inland, the beach ridges that support oak savannas were popular residential sites.

REGION VII: Northern Lower Michigan.

REGIONAL CLIMATE: Most air masses cross the Great Lakes before entering this region, resulting in reduced continentality. Compared to areas of equivalent latitude in Wisconsin, the region is warmer in winter and cooler in summer. Lake effect snow and rain characterizes portions of the region within 20-30 miles of the Great Lakes shorelines. The growing season ranges from 70 days inland to 150 days along the shoreline of Lake Michigan (Eichenlaub et al. 1990). Annual precipitation ranges from 28 to 34 inches. Average annual snowfall ranges from 40 inches inland to 140 inches along Lake Michigan (lake-effect snows). Extreme minimum temperatures are -28° F along Lakes Michigan and Huron, and -50° F inland.



DISTRICT 1 Arenac.

CLIMATE: Located along the northwest shore of Saginaw Bay, this district has a growing season length of 120 to 150 days (Eichenlaub et al. 1990), which is significantly shorter than the adjacent Saginaw district to the south. The extreme minimum temperature is -26° F to -42° F. Precipitation is relatively uniform throughout the growing season. Average annual precipitation in this district is 28 to 32 inches and average annual snowfall is 40 to 60 inches.

DISTRICT 1 Arenac.
SUBDISTRICT 1.1. Standish: lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Glacial drift is 100-200 ft. thick. Underlying bedrock consists of Jurassic sandstone, shale, and clay with minor limestone and gypsum, Pennsylvanian sand, silt, clay, shale, limestone, and coal, and Mississippian limestone, gypsum, sandstone, and shale (Milstein 1987, Dorr and Eschman 1984).

The district is a flat clay and sand lake plain, part of the Saginaw lake plain to the south. The northern third of the district is a large glacial delta that has thick, droughty, sand soils. The Au Sable and Rifle rivers have created a deep, steeply eroded gorges through the thick sands (Dorr and Eschman 1984; Burgis 1977). Within the lake plain, there are large, poorly drained embayments several miles in area; most of which are located several miles inland from the present Great lakes shoreline. Within these embayments there are often numerous small, steeply sided, transverse dune ridges.

The soils of the lake plain are very poorly, poorly, and excessively drained sands or well, moderately well, and poorly drained clay loams and clays. The soils on the small areas of ground and end moraine are moderately well drained or well drained loams and clays.

PRESETTLEMENT VEGETATION: The flat clay plain supported forests of hemlock (4226) and American beech, sugar maple, and yellow birch (4111) on well drained sites, with greater amounts of hemlock, and white pine on less well drained sites. On poorly drained sites, there were also extensive tamarack (4233), cedar (4231), black ash (4141), and maple (4143) swamps. Alder-willow swamps (6122) were also found on the clay lake plain.

Sandy lake plain contained a broad range of wetlands, including extensive cedar (4231), tamarack (4233) and black ash-dominated swamps(4141). Cedar swamps were common along lower reaches of the Au Sable River. Hemlock, white pine, and maple dominated swamps were also found on the sand lake plain. Great Lakes marsh (6222) and lake plain prairies (6226) were located along the Saginaw Bay shoreline in Arenac County. The large embayments along the shoreline supported bogs (6121) or shrub swamps (6122) with stunted quaking aspen or jack pine. The higher, well drained beach ridges on the lake plain and along the lakeshore were dominated by white pine (4211) and red pine (4212) forests, both of which included red oak. Some of the transverse dune ridges supported open oak-pine (334) barrens. The sandy delta of the proglacial Au Sable River and adjacent sand lake plain in Iosco County supported jack pine forests (4213), open, fire-dependent jack pine barrens (333), or jack pine-red pine forests (4215).

Loam or clay soils on the flat ground or end moraines supported forests of hemlock and white pine (4227), hemlock and beech (4119), and mixed northern hardwoods (4111) with sugar maple, American beech, white pine, and hemlock. The fine-textured end moraine located just west of Tawas supported forests of white pine and hemlock (4227).

NATURAL DISTURBANCE: Windthrow was common in the forests near the Great Lakes shoreline, resulting from a combination of strong winds off Saginaw Bay, flat topography, and poor drainage conditions. Water level fluctuations along the Great Lakes shoreline resulted in cyclical floristic variation within the coastal marshes and extensive mortality within the coastal swamp forests. Fire was commonly noted by surveyors on the jack pine barrens of the Au Sable River delta.

HUMAN LAND USE: At the time of the land surveys, there were early lumber mill sites near the mouth of the Rifle River (Trygg 1964). Surveyors noted a few trails associated with the Saginaw Bay shoreline, and along both sides of the Au Sable River. Native American sugar camps were noted along the shoreline south of Tawas. In 1830, Native American villages were located near the modern towns of Oscoda, Au Gres, and Tawas (Tanner 1987). The Au Sable and Rifle rivers were important corridors for access for logging, prior to the establishment of railroads in the 1860s. Logging began in the 1840s along these rivers, and progressed inland. Extensive logging was followed by agricultural development.

Today, agricultural land use is less intensive on this portion of the lake plain than in subdistricts further south, due to both colder climatic conditions and a prevalence of sandy soils. Artificial drainage has occurred on both the clay lake plain and on flat portions of the medium to fine textured ground and end moraines. In Arenac County, which falls entirely within this subdistrict, 38% of historical wetland acreage had been eliminated by the late 1970s (Comer et.al. 1993). Clay soils on the lake plain are used as pasture, while loamy moraines are used for both row crops and pasture. Sandy soils have been less intensively converted to agriculture than on other portions of lake plain further south. Much of the poorly or excessively drained lake plain is managed for either timber or recreational use. The glacial delta of the Au Sable River is managed largely by the Huron National Forest for timber. Both jack pine and red pine plantations cover much of the delta. This subdistrict is traversed by roads along a square mile grid. A large strip mine is located just north of Huron Heights. Urban development in this subdistrict is most intensive around Tawas, Standish, and Au Gres.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The moraines and clay lake plain have generally been converted to agricultural use and no longer support native forest. Native vegetation remains on much of the droughty or poorly drained sand lake plain, but white pine and red pine regeneration has generally been poor, and either aspen or oak regeneration are now characteristic. The jack pine barrens of the Au Sable River delta have been converted to closed-canopy plantations of jack pine or red pine, or eliminated through succession to closed-canopy forests by fire suppression policies.

Some of the swamps along the Saginaw Bay shoreline have been converted to agriculture, but those which persist appear to have forest composition similar to those recorded by surveyors. Many of the Great Lakes marshes along Saginaw Bay have been manipulated for waterfowl management, with dikes being constructed on many of the marshes for water control. Small areas of marsh remain intact. Surveys of some prairie remnants in 1988, immediately following 1986-87 high lake-water levels, indicated possible prairie flora with less diversity than in lake plain prairies further south on Saginaw Bay. Boat slips and channels have also been constructed along many sections of shoreline, resulting in varying degrees of marsh destruction or degradation.

DISTRICT 1 Arenac.
SUBDISTRICT 1.2: Wiggins Lake: fine-textured end and ground moraine.

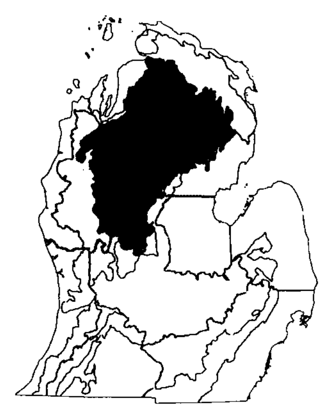
SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: This small subdistrict is the northern end of the loamy ground moraine of subdistrict 4.1, the Lansing subdistrict. It is primarily its cooler, more northern climate that differentiates it from the Lansing subdistrict. The topography consists of rolling to moderately sloping ridges. The soils of the moraines are moderately well to well drained and are used for agriculture. Soil textures are primarily loams to clay loams.

PRESETTLEMENT VEGETATION: Upland forests in this subdistrict were primarily beech and hemlock (4119) with some sugar maple included. Many small wetlands were scattered across the area. Common wetland forest types included cedar (4231), black ash (4141), tamarack (4233), or mixed conifer (423). There were also many small emergent marshes (6221) throughout this subdistrict.

NATURAL DISTURBANCE: No major natural disturbances were recorded by surveyors within this subdistrict.

HUMAN LAND USE: Very little Native American activity was noted by surveyors in this subdistrict. At the time of the surveys, there were already several roads and logging encampments just east of Pratt Lake. The roads connected this early logging activity to the Cedar River (Trygg 1964). After logging, most of the upland soils were farmed, either for row crops or pasture. Today, steeply sloping sites remain forested. The area is traversed with a square-mile grid of roads, but very little urban development exists. Lake Lancer and Wiggins Lake are large artificial lakes in this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The majority of the landscape remains farmed. Upland forests have been mostly eliminated. Nearly all wetlands have been either partially drained, diverted, or dammed.



DISTRICT 2 Highplains.

CLIMATE: Due to its inland location, northern latitude, and relatively high elevations, the district has the most severe climate in Lower Michigan. Growing season length ranges from 70 days in northern lowland areas to 130 days in the south (Eichenlaub et al. 1990). There is a great chance of late spring freezes. The extreme minimum temperatures range from -28° F to -50° F. At the western margin of this high plateau, lake-effect snowfall is considerable, reaching 140 inches. Further east, annual snowfall is as low as 60 inches.

Average annual precipitation is from 28 to 32 inches, and is relatively uniform across the district.

DISTRICT 2 Highplains.
SUBDISTRICT 2.1: Cadillac: coarse-textured end moraine.

CLIMATE: Growing season length is 90-140 days, with longest growing season (120-140) in the Saginaw basin (Eichenlaub et al. 1990). Snowfall is between 50-100 inches, with 50-60 inches in the Saginaw-basin portion of the subdistrict. Annual precipitation is 30-32 inches. Extreme minimum temperature is -28° F to -44° F., with warmest conditions in the Saginaw basin at the south end of the subdistrict.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock is not exposed in this subdistrict, with drift thickness reaching 500-1000 feet, which are some of the thickest in the state (Akers 1938). The subdistrict is underlain primarily by Paleozoic Era bedrock (primarily Pennsylvanian sandstone, shale, coal, and limestone) and Mesozoic Era bedrock (Jurassic "red beds" consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum) (Dorr and Eschman 1984, Milstein 1987).

Large end moraine ridges are typical of the subdistrict. Areas of gently sloping ground moraine and flat outwash are also present. Elevations range from 850 to 1725 ft. The highest point in Lower Michigan (1725 ft.) is near Cadillac. The end moraine hills are large, between 200 and 500 ft. high. The slopes of the ridges are moderate to steep. Slopes of greater than 12% are common on the ridges; the steepest slopes are in the 18-40% slope class. Extensive outwash plains, occur throughout the subdistrict and are typically excessively drained, except near streams. The Muskegon River, which flows through the most extensive outwash deposits, has abundant wetlands along its course. Extensive droughty outwash deposits surround the wetlands. Most of the outwash deposits are flat to gently rolling.

The sandy soils of the moraines are primarily well to excessively drained. Argillic soil horizons are seldom encountered, due to the lack of fine silts and clays in the sandy parent material. Poorly drained soils, found in depressions at the foot of the steep ridges, occupy about 10% of the end moraine landscape. A high percentage of the foot slopes are well drained as a result of the sandy soil texture of both surface soils and the thick underlying parent material.

PRESETTLEMENT VEGETATION: Dominating the sandy end moraine ridges was northern hardwood forest (4111) of beech, sugar maple, red oak, and hop-hornbeam. Large expanses of unbroken northern hardwood forests were found throughout northwest Wexford County, extending east into Missaukee County. Within these forests, hemlocks were present in low numbers, primarily in slightly moister ravines and on northern-aspect slopes. The end moraine ridges from Cadillac Lake extending south to northern Mecosta County were also dominated by northern hardwoods, but were broken by many small lakes and wetlands. These wetlands were predominantly mixed conifer swamp (423), mixed hardwood swamp (414), emergent marsh (6221), and alder-willow shrub swamp (6122). Hemlock, in combination with beech (4119), was found on a number of moraine ridges throughout this subdistrict. White pine was also present in low numbers, scattered among the hardwoods, or in combination with hemlock (4227). White pine, beech, and red maple forests (4219) tended to occur to the east of fire-prone outwash plains. They appear to have been hardwood-dominated forests occasionally effected by catastrophic fire originating from adjacent outwash plains. Oak-pine forests of either red pine and mixed oak (4218), or white pine and white oak (4217) also included red maple and bigtooth aspen. These forest types occupied the excessively drained sandy ridges.

Depending on their relative position on the landscape, some dry outwash channels were fire-prone, and supported pine and oak forests of several different combinations of dominant species. A few of the most frequently burned plains supported open oak-pine barrens (334). The barrens were typically surrounded by forests of white oak and white pine (4217), jack pine (4213), or jack pine with red pine (4215). An example of this mosaic occurred on a small outwash plain in central Clare County. The sand lake plain and outwash channel connecting Cadillac Lake to Lake Missaukee supported forests of red pine and white pine (4216). Other outwash channels, such as in southern Mecosta County, were less fire prone, and supported mixed hardwood-conifer forests such as beech and hemlock (4119) or white pine, beech and red maple (4219). Wetlands on poorly drained portions of outwash were typically mixed conifer swamp (423), mixed hardwood swamp (414), or mixed conifer-hardwood swamp (42).

NATURAL DISTURBANCE: Small windthrows were relatively common in the subdistrict. Several large windthrows (1-3 square miles) were noted by surveyors just east of Big Rapids, at the town of Evart, and several miles west of Lake Mitchell. Surveyors also noted several small fires within this subdistrict.

HUMAN LAND USE: As with the remainder of this district, very few permanent Native American settlements were located within this subdistrict. There were a few trails noted around Cadillac Lake and another trail connected Lake Mecosta to the Muskegon River (Trygg 1964). The only village listed by Tanner (1987) as existing in 1830 was near the present location of Big Rapids.

Logging activity in this area began immediately after the land surveys and were concentrated along the Muskegon and Manistee rivers (Benson 1989). The pines were cut throughout the 1850s-1890s, and where river access was poor, logs were transported via narrow-gauge railroads. Agricultural development has taken place on most lands that could be easily converted. Today, this subdistrict is traversed by roads, with several urban centers, including Big Rapids, Reed City, Cadillac, and Lake City. Several reservoirs have been established within this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The logging era resulted in major changes in forest composition. After cutting the forests became oak and aspen-dominated. Locally, white and red pine remain as understory or sub-dominant trees. On outwash plains, jack pine and northern pin oak continue to occupy the driest areas. Red pine plantations have also been established on these dry sites. Agriculture and urban development have significantly fragmented this subdistrict, which was historically largely forested. Within Osceola County, which falls almost entirely within this subdistrict, total wetland acreage appears to remain similar to historical levels (Comer in prep.).

DISTRICT 2 Highplains.
SUBDISTRICT 2.2: Grayling: outwash.

CLIMATE: Growing season length is 80-130 days, longest in the southeast within the Saginaw basin (Eichenlaub et al. 1990). There is extreme danger of frosts throughout the growing season, especially at the northern and southeastern ends of the subdistrict. Snowfall ranges from 50 to 140 inches, with 50 to 60 inches within the Saginaw basin and 140 inches in the northwestern part of the subdistrict. Annual precipitation is 28-32 inches, and relatively uniform across the subdistrict. Extreme minimum temperatures are -40°F to -48°F, warmest at the southeastern edge of the subdistrict

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: There is no exposed bedrock, with glacial drift from 250-800 ft. thick, which are some of the thickest in the state (Akers 1938). Underlying bedrock is primarily Paleozoic age, including Pennsylvanian and Mississippian sandstone, coal, shale, and limestone (Dorr and Eschman 1984, Milstein 1987). In the south there is also Mesozoic Era bedrock, Jurassic "red beds" consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

The surface of the subdistrict is a high outwash plain. Outwash deposits surround several large ridges of ice-contact material. At the northern edge, a large moraine of ice-contact material has been dissected into several steep ridges by the erosion forces of glacial meltwater streams. The outwash from these streams now forms a flat plain, which separates the blocks of moraine. The elevation of most of the flat outwash plain is between 1050 and 1300 ft. In contrast, most of the moraine blocks have 200-250 ft. relief and maximum elevations between 1450 and 1580 ft. Sand outwash deposits are thick over most of the subdistrict, resulting in excessively drained soils. However, underlying clay deposits are exposed or near the surface in several areas, including from Dead Stream Swamp (Haag 1980) to at least 6 mi. south of Houghton Lake (Albert 1990). Ice-contact deposits, located throughout the subdistrict, typically have well drained to excessively drained sand soils and moderately to steeply sloping topography. Steep-sided ice-block depressions are locally common. Slopes in the 0-2% or 3-6% classes are most common, but slopes as steep as 19-25% occur. Two large lakes, Houghton and Higgins lakes, and several streams are located in the outwash. Large expanses of wetland are located at the margins of the lakes, in the Dead Stream Swamp, and in the headwaters of the Muskegon River. Mean peat depths in the wetlands average between 3-7 ft, with maximum depths reaching 16 ft. (LeMasters and Jones 1984).

The soils are mapped as the same association (Graycalm-Montcalm) as those on the moraines of the Cadillac subdistrict (USDA 1981). Drainage classes ranged from excessively drained to somewhat poorly drained, with excessively drained soils being prevalent. Most of the soils are sand or sands mixed with gravel, but localized deposits of fine-textured till and lacustrine clays may be exposed at the surface.

PRESETTLEMENT VEGETATION: In Michigan, the vegetative mosaic created by wildfire is best exhibited in this subdistrict. The excessively drained outwash plains supported a mosaic of pine and oak forest and barrens. Most frequently burned areas supported open grasslands (31), or open barrens with jack pine (333) and jack pine with northern pin oak (334). Red pine was typically scattered within the barrens. Surrounding these areas, closed forest of jack pine (4213), jack pine and red pine (4215), or red pine and white pine (4216) were common. In the southern and western portions of the subdistrict, white oak and white pine forests (4217) were encountered on these outwash landscapes.

The juxtaposition of landforms played an important role in forming the vegetative mosaic. Given the predominant westerly winds, fires could travel over large distances from west to east where few natural fire breaks existed. A good example of the characteristic vegetative mosaic in this fire-prone landscape was on the extensive outwash plain in southern Crawford County and southeast Kalkaska County. There, a thirty mile stretch of unbroken outwash plain was described as having recently burned. But where outwash channels were oriented from north to south, or where large wetlands or river beds existed, fires did not carry as well and the forests probably did not burn as frequently. In these areas, forests of white pine and hemlock (4227), or even beech and sugar maple (4111) were encountered (Comer 1994).

Large and diverse wetlands were found on poorly drained outwash. Where clay deposits are near the surface, shallow bogs (6121) commonly occupied large areas. Conifer-hardwood swamps (42) contained white pine, jack pine, quaking aspen, paper birch, balsam poplar, and red maple. In the Dead Stream Swamp, where low sand spits separate large, poorly drained flats, mixed conifer swamp (423), bogs (6121) and shrub swamps (6122) were the dominant vegetation. The abiotic conditions and vegetation were very similar to those found on lacustrine deposits in Upper Michigan. Typical tree species on the bog mat were black spruce, tamarack, and jack pine. Low sand ridges within the swamp were dominated by red, white, and jack pines. Swamp forests occupied the margins of most of the major stream courses, and northern white-cedar (4231) was the dominant species. Balsam fir, hemlock, quaking aspen, paper birch, and several other swamp species were also common.

The vegetation on the sandy ice-contact ridges varied, depending upon adjacent landforms and natural fire breaks. Fire frequency, influenced by soil drainage and juxtaposing landforms of both the ice-contact deposits and surrounding outwash deposits, was very important for determining the species composition of the presettlement forests. On some of the largest, deposits, consisting of several large ridges, northern hardwood forests (4111) were dominated by beech and sugar maple, and contain lower numbers of red oak, hemlock, and white pine. In contrast, ridges with extensive outwash deposits to their west commonly supported forests of red and white pine mixed with red oak and aspen (4218), or even pine barrens (333).

At present, the small ice-block depressions on the outwash plains typically contain shrub swamps or sphagnum bogs (6121) with highly depauperate floras. The dominant shrub is usually leatherleaf. It is assumed that the low plant diversity in these wetlands is the result of severe and frequent fires.

NATURAL DISTURBANCE: Fire is the most important factor shaping the forest composition of both the uplands and wetlands of this subdistrict. Surveyors noted that over 3% of the land area was recently burned, with several fires covering thousands of acres (Whitney 1986). Windthrows also occurred, sometimes in combination with burned areas. Some of these forests may have blown down, then caught fire. Out on the large outwash plains, such as in southern Crawford County, blowdowns may have been a result of tremendous winds associated with large fires sweeping over 10-30 square miles. Large frost pockets occur in depressions on the outwash plain, resulting in high tree mortality for deciduous tree species and dominance by jack pine.

HUMAN LAND USE: No Native American settlements were known from this subdistrict in 1830 (Tanner 1987). The area was likely used as a hunting ground, and a portage between the Au Sable and Manistee rivers in western Crawford County made those rivers a short cut across the peninsula. Trygg (1964) noted a trail from Higgins Lake to Grand Traverse Bay at the time of the surveys. In this district, the logging era began along the Au Sable, Manistee, and Muskegon rivers. White and red pine was abundant enough in the Dead Stream Swamp area to justify construction of a railroad, which carried the lumber to the nearby Muskegon River (Meek 1986). Many sandy areas were planted to pines during the 1930s and 1940s. Agriculture has been successfully established in only the best soils, most commonly in the Grand Traverse-Kalkaska County area. Dams and reservoirs were established along the Au Sable and Manistee rivers.

Today, most of the subdistrict remains forested. Much of the area lies within state and national forests. Pulp wood is the major product from aspen and jack pine forests. Recent decades have seen extensive development of oil and gas wells, especially in the northern and western part of the subdistrict. The subdistrict is traversed by an extensive network of roads and highways, and urban development is concentrated at Grayling, Gaylord, Kalkaska, Mio, Roscommon, Lewiston, and around the south shore of Houghton Lake. Recreational use is high throughout the subdistrict, especially for snowmobiling, fishing, and hunting.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Extensive tracts of white pine "stump fields" attest to the destructive logging that took place in this subdistrict. In many places that historically supported white pine, hot slash fires burned organic soils completely off, leaving exposed blow-sand. Since the 1920s, fire suppression and pine plantations have nearly eliminated remnant pine barrens from this landscape. This has probably had significant negative impact on associated plants and insect species. Although much of the area's forests have regenerated, most do not reflect the species composition and structure of native forests. Most notable changes are in the relative loss of conifers such as white pine and hemlock, and relative increases in red oak, red maple, aspen, and paper birch. On the whole wetland acreage within this subdistrict has not declined nearly as much as in subdistricts to the south (Comer 1994). Recent oil and gas development has caused fragmentation of many contiguous forests that had successfully regenerated since the logging era.

DISTRICT 2 Highplains.
SUBDISTRICT 2.3. Vanderbilt: steep end and ground moraine ridges.

CLIMATE: The growing season length is 70 to 120 days, longest near Lakes Michigan and Huron, and shortest in outwash channels near the center of the sub-district (Eichenlaub et al. 1990), where elevations drop rapidly to the north. There is extreme danger of frosts throughout the growing season. Snowfall ranges from 140 inches in the northwest, to 60 inches in the southeast. The heavy snows in the northwest are lake-effect snows off Lake Michigan. Annual precipitation is relatively uniform across the sub-district, from 28 to 32 inches. Extreme minimum temperatures range from -36° F to -50° F, warmest near Lakes Michigan and Huron and coldest in the outwash channels near the northern edge of the subdistrict.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: No exposures of bedrock exist within this subdistrict. Glacial drift thickness ranges from 100-800 ft. and is thickest at the southern edge of the subdistrict (Akers 1938). Underlying bedrock is of Paleozoic age, Devonian and Mississippian sandstone and shale (Dorr and Eschman 1984, Milstein 1987).

The subdistrict is a narrow band of steep end and ground moraine ridges that connect the high plateau of the Grayling subdistrict in the south to the lower terrain of the Grand Traverse subdistrict to the northwest. Elevations decrease from 1300 ft. at the south edge of the subdistrict to 900 ft. at the north edge. Glacial-drift thickness over bedrock ranges from 100 to 800 ft. The drift is thickest at the southern edge of the subdistrict. The topography is some of the steepest in Lower Michigan, with local relief greater than 200 ft. occurs in less than one mile. The steep drop to the north is probably the result of erosion by glacial meltwater channels (Burgis and Eschman 1981). As the glacier retreated, its margins stagnated, forming steep kamic ridges that form the northern part of the subdistrict (Burgis and Eschman 1981). The kamic ridges occupy portions of Alcona, Montmorency, Otsego, Emmet, Charlevoix, and Antrim counties. The steep ridges are dissected by outwash channels with sandy soils. In Emmet County, the steep ridges are separated from the main body of ridges to the south by the Indian River lowland, a low area east of Little Traverse Bay. A segment of steep, sandy end moraine continues farther southwestward to about five miles west of Traverse City. The sandy surface soils of both the outwash channels and the kamic ridges are underlain by till deposited by earlier glacial advances (Burgis and Eschman 1981). The underlying fine-textured till and occasional lacustrine deposits are responsible for the poorly drained conditions of large parts of the outwash.

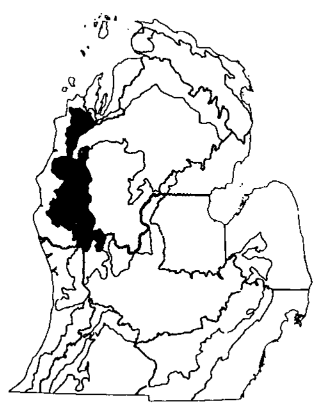
Most of the soils on the moderately to steeply sloping end moraines and kamic deposits are well to excessively drained. The outwash sands range from excessively drained, where the sand deposits are deep, to poorly drained, where underlying finer-textured till or lacustrine deposits are within a few feet of the surface.

PRESETTLEMENT VEGETATION: Northern hardwood forests of American beech, sugar maple, basswood, yellow birch, and hemlock (4111) characterized much of the uplands on end and ground moraine within the subdistrict, while cedar swamps (4231), tamarack swamps (4233), and mixed conifer swamps (423) dominated most of the wetlands between the ridges. Upland portions of the sandy ground moraine in the eastern portion of the subdistrict supported forests of white and red pine (4216), jack pine and red pine (4215), and occasionally pine barrens (333). This vegetative composition likely resulted from a combination of xeric soils and fires sweeping into the area from adjacent outwash plains to the west. Recent field observations in southwestern Alcona County showed a gradual shift from jack pine dominance on flat outwash plain to a mixture of jack pine, red pine, and white pine on lower slopes of morainal ridges, and finally, to northern hardwoods on the morainal ridges further to the east. There were also several large blocks of aspen-birch forests (413) on sandy moraines that probably resulted from both windthrow and fire. The excessively drained sands of the level outwash channels supported forests of jack and red pine (4215), and occasionally red and white pine (4216). Poorly drained outwash supported mixed conifer or hardwood-conifer swamps (41).

NATURAL DISTURBANCE: As mentioned above, both wildfire and windthrow were noted in several areas in this subdistrict. Wildfires were concentrated on the flatter portions of the landscape, but also occurred on the sandy ridges. A particularly large burned area was mentioned just east of Gaylord in what is now Pigeon River State Forest. Beaver floodings were also noted in several areas.

HUMAN LAND USE: At the time of the surveys, trails were noted near the headwaters of the Sturgeon an Black rivers. Tanner (1987) noted no Native American settlements within the area in 1830, but recent archeological work has demonstrated that there was Native American settlement west of Hubbard Lake, including agricultural activity. Logging within this subdistrict occurred first along the upper reaches of the Cheboygan and Au Sable river drainages. The development of railroads in the 1850-60s allowed for this entire subdistrict to be harvested. Today, most of the subdistrict has reforested. Much of the area lies within state and national forests. Pulp wood is the major product from aspen and jack pine forests. Recent decades have seen extensive development of oil and gas wells, especially in Otsego and Montmorency counties. The subdistrict is traversed by an extensive network of roads and highways, and urban development is concentrated at Vanderbilt. The area is a favorite for recreation, including hunting, fishing, and canoeing.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: In many places that historically supported white pine and red pine, hot slash fires burned organic soils completely off, leaving exposed blow-sand. Since the 1920s, fire suppression and pine plantations have nearly eliminated remnant jack pine barrens from this landscape. Although much of the area's forests have regenerated, they often do not reflect the species composition and structure of native forests. Most notable changes are in the relative loss of conifers such as white pine and hemlock, and relative increases in red oak, red maple, aspen, and paper birch. On the whole wetland acreage within this subdistrict has not declined nearly as much as Region VI to the south (Comer in prep). Recent oil and gas development has caused fragmentation of many extensive forests that had successfully regenerated since the logging era.



DISTRICT 3 Newaygo: outwash.

CLIMATE: The climate is intermediate between that of the Manistee district and the Highplains district. The growing season ranges from about 120 to 140 days (Eichenlaub et al. 1990). There is a danger of late spring freezes, as the district forms a cold air drainage from the adjacent high plains. Thermal satellite imagery shows a large frost pocket near Baldwin, a town known for its low temperatures. Extreme minimum temperatures range from -32° F at the northern and southern edges of the district, to -48° F near the center at Baldwin. The average annual precipitation is 32 inches. Average annual lake-effect snows off Lake Michigan ranges from 70 to 140 inches, decreasing rapidly to the east. The growing season of the district is relatively short, averaging 126 days.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Glacial drift is 300 to 600 ft. thick, and there are no bedrock exposures (Akers 1938). Underlying bedrock is primarily Paleozoic age, Pennsylvanian, Mississippian, and Devonian sandstone, coal, shale, and limestone (Dorr and Eschman 1984, Milstein 1987). In the extreme southeast there is also Mesozoic Era bedrock, Jurassic "red beds" consisting mainly of sandstone, shale, and clay, with minor beds of limestone and gypsum.

The surface of the district is an outwash plain about 100 mi. long and 2-25 mi. wide. Elevations range from 700 to 1210 ft. with the elevation gradually increasing from 700 ft in Manistee County at the west edge of the district to 1210 ft. in Lake County to the east. A similar increase in elevation toward the east is evident the entire north-south length of the district. The outwash deposits, all of Wisconsinan age, are the product of more than one glacial advance and subsequent retreat (Farrand and Eschman 1974, Burgis and Eschman 1981). Fragments of end moraine ridges are present throughout the district. Many of the end moraine deposits were either eroded by meltwater channels or partially or completely covered by outwash deposits. Although the remaining fragments of end moraine are relatively small, commonly only 2-3 mi. wide and 10-15 mi. long, they are steeply sloping and typically rise 100-200 ft. above the surrounding flat outwash plain. The topography of the outwash plain is flat; most of the plain has slopes of 0-6%, but localized features, such as ice-block kettles and kames can have slopes as steep as 30%. The district also contains small areas of sandy lacustrine deposits in central Manistee County (Farrand and Bell 1982). Several small beach ridges identify the area as lake plain.

The greater part of the outwash plain has excessively drained sands that contain very little organic material in surface horizons. Soil development is poor. Broad areas of poorly drained sand occur in Lake and Newaygo counties along the numerous rivers of the area, including the Rogue, White, and Big South branch of the Pere Marquette. Organic soils are restricted to channels and ice-block kettles on the outwash. The lacustrine sand deposits contain a high percentage of poorly drained soils, but well and excessively drained soils also occur. The topography is flat with occasional low beach ridges. The soils of the end moraine and ice-contact ridges are sands or gravely sands.

PRESETTLEMENT VEGETATION: The vegetation that dominated outwash and lacustrine deposits at the north end of the this district differed significantly from similar landforms to the south. Outwash plains and sand lake plain in Manistee, Benzie, Leelanau, and Grand Traverse counties were dominated by northern hardwoods (4111), with forests of hemlock and white pine (4227), hemlock and beech (4119), and white pine, beech, and red maple (4219) common near the Interlochen area. Fire frequency was apparently much greater on more southern outwash deposits. In northern Lake County, the outwash plains supported forests of jack pine (4213), jack pine and red pine (4215) and open jack pine barrens (333). In Lake and Mason counties, there was a transition from jack pine-dominated forests to white oak and white pine forest (4217) and oak-pine barrens (334) that were dominant further south. Several large prairies or grasslands (31) were encountered in southern Newaygo County.

Poorly drained outwash and lacustrine deposits throughout the district supported swamps with a mixture of hardwood and conifer species (42, 423 and 414), including white pine, American elm, red and black ash, red maple, hemlock, quaking aspen, and paper birch. Emergent marsh (6221) and intermittent wetlands (6228) were also found in these areas.

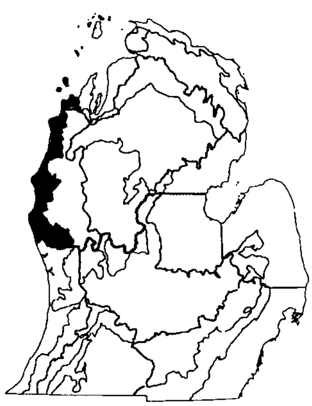
The somewhat excessively drained soils of the end moraine ridges supported forests of white oak and white pine (4217), red and white pine (4216), and white pine, beech, and red maple (4219). Fires probably swept across these forest types, rich in upland conifers, at fairly regular intervals. In contrast, the well drained soils on end moraines that were protected from frequent wildfire supported forests of sugar maple and beech (4111), with scattered white pine and hemlock.

NATURAL DISTURBANCE: Extensive areas of fire were noted by surveyors. Fire was clearly a characteristic disturbance for most of the pine and oak dominated forest types. Comer (1995) calculated historical fire frequency on outwash deposits in Newaygo County using land survey data and found their return intervals to vary from 5-158 years. The most frequent fires being in open prairies. Adjusting for the absence of prairies further north, these estimates were be very similar to those calculated by Whitney (1986) for the jack pine plains of Crawford and Roscommon counties. Windthrow frequency for the same area was calculated to range from 161-322 years.

HUMAN LAND USE: At the time of the surveys, Native American activity was limited two a settlement near Newaygo and trails further north along the Manistee River (Trygg 1964, Tanner 1987). Logging occurred early along all of the major river drainages within the district. Attempts were made to farm immediately after logging, but low soil productivity resulted in abandonment of many lands. Dams and reservoirs were established along most major rivers. Wildfire suppression and pine plantation establishment began in the 1920s and 1930s.

Today, much of the area lies within state and national forests. Pulp wood is the major product from aspen and pine forests. Christmas tree production is also common within this subdistrict. Recent decades have seen extensive development of oil and gas wells, especially in Manistee County. The subdistrict is traversed by an extensive network of roads and highways, and urban development is concentrated at Newaygo, White Cloud, Baldwin, and Thompsonville. Residential development is also concentrated around many lakes within this district. The area is a favorite for recreation, including hunting, fishing, and canoeing.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Attempts to farm dry, sandy outwash soils following logging soon caused severe wind and water erosion (Mick 1951). In many places that historically supported white pine and hemlock, hot slash fires burned organic soils completely off, leaving exposed blow-sand. Since the 1920s, fire suppression and pine plantations have nearly eliminated remnant pine and oak-pine barrens from this landscape, and jack pine-northern pin oak forests expanded in acreage. Although much of the area's forests have regenerated, they often do not reflect the species composition and structure of native forests. In southern portions of the district, there has been a dramatic shift from white oak-white pine forests to black oak and aspen dominance, although white pine remains in the understory in many places. On the more mesic moraines, beech and sugar maple remain the dominants in most of the second growth forests, but white pine is typically absent. Fires following logging have caused bigtooth aspen to become dominant on some mesic sites historically dominated by beech and sugar maple. Reservoirs eliminated significant portions of floodplain forest while disrupting fish migration.



DISTRICT 4 Manistee: end moraine, dune sand, and sand lake plain.

CLIMATE: A strong lake modified climate results in a long growing season of 140 to 150 days (Eichenlaub et al. 1990). Annual average extreme minimum temperature is 16° F. The extreme minimum temperature is -32° F. Retarded spring warming coupled with a long growing season make the climate suitable for commercial fruit production. Lake-effect snowfalls are heavy, averaging 100 to 140 inches. The average annual precipitation is 32 to 34 inches.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock is not exposed in the district, where glacial drift thickness ranges from 400 to 700 ft. The underlying bedrock is Paleozoic Era, Mississippian gypsum, sandstone, and shale, and Devonian sandstone, shale, dolomite, limestone, and evaporates (Dorr and Eschman 1984, Milstein 1987).

The district is characterized by diverse topography, including sand dunes, sand lake plain, ground and end moraines, and outwash. Near Manistee, a broad, flat area of lake plain and ground moraine separates the more steeply sloping moraines into northern and southern parts. Elevations range from 580 ft. on the Lake Michigan shore to 1150 ft. on a large end moraine ridge in Benzie County. The shoreline is noted for large, high sand dunes, including those of the Sleeping Bear Dunes National Lakeshore, Ludington State Park, and the Nordhouse Dunes. These high dunes date from high Lake Nipissing water levels (Kelley 1962). Large Nipissing-age dunes are also found on North and South Manitou islands and on South Fox Island. Most of the high dunes, both on the mainland and on the islands, are perched on underlying till. Many large lakes along the shoreline, including Crystal, Betsie, Hamlin, White, Silver, and Muskegon lakes, are former bays of Lake Michigan or lower reaches of streams, that were separated from Lake Michigan by the development of sandbars across the mouth of the bay or stream (Dorr and Eschman 1984). South of Manistee, end moraines 3-5 mi. wide and 100-300 ft. high are separated by 1-3 mi. wide outwash channels. North of Manistee, the end moraine ridges are much steeper and without broad outwash channels between them. Much of the lake plain between Ludington and Manistee consists of wet depressions and small, droughty beach ridges. Most of the ground moraine in this area is poorly drained.

The dune soils are excessively drained sands containing no fine silts or clays. Most of the soils on the moraines are sands, but there are both medium-textured and fine-textured soils on the moraines. The soils are classified as gently sloping Haplorthods plus Glossoboralfs in the south (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Open dunes (73) occurred along much of the Lake Michigan shoreline, where they were often only 1/8 to 1/4 mile wide. The largest concentrations of open dune were at Sleeping Bear Dunes National Lakeshore, Big Sable Point, and Little Sable Point, the open dunes were noted as extending as much as two miles inland. These broad open dunes were restricted to portions of the Lake Michigan shoreline where there was abundant nearby sand on the lake plain. Dunes were described as "loose sands" and "treeless", but were undoubtedly, in places, vegetated with dune grasses and shrubs. Farther inland, dune formations supported a variety of forests, including hemlock and white pine (4227), white and red pine (4216), and red and jack pine (4215) dominated forests. Northern hardwoods (4111), often with a significant component of hemlock and/or red oak, were also common. Poorly drained interdunal areas, such as those at Point Betsie, often supported cedar (4231) and or hemlock (4237) dominated swamps and alder-willow swamps (6122). Both of the Fox islands supported open dunes (73), northern hardwoods (4111), and cedar swamp (4231). The open dunes on the islands were generally narrow, but blowouts extended 1/2 mile or more in from the shoreline.

Forests of hemlock and beech (4119) and hemlock and white pine (4227) were common on sand lake plain and sandy moraines. These forests were common north of Pentwater, and south of Manistee. Other upland portions of the sandy lake plain included white pine forest (4211), with significant amounts of beech, hemlock, black oak, and white ash. Several large wooded dune and swale complexes (911), supporting a variety of upland/wetland plant communities, are found on the sandy lake plain in and around the Sleeping Bear Dunes National Lakeshore. Poorly drained portions of the sandy lake plain supported black ash (4141), elm (4142), aspen (4146), tamarack (4233), cedar (4231), and hemlock-dominated (4227) swamps. Alder-willow swamp (6122), emergent marsh (6221), and Great Lakes marsh (6222) were also found on the sandy lake plain. As with further south along the Lake Michigan shoreline, Great Lakes marshes were associated with inland lakes which formed at the mouths of major rivers, such as the Manistee and Big Sable. The marshes were protected from storm events on Lake Michigan by coastal barrier dunes, but are influenced by fluctuations in Great Lake's water levels, even several miles inland.

Sandy outwash deposits supported forests of white and red pine (4216) or white pine, beech, and red maple (4219). In the southeast extreme of the district, a mosaic of white oak and white pine forest (4217) with oak-pine barrens (334) was common.

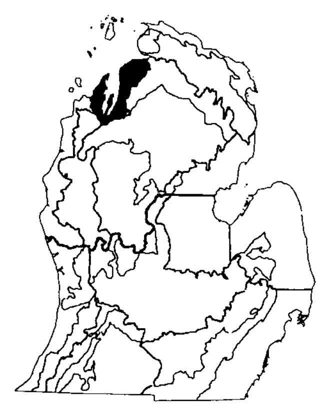
Northern hardwood forest (4111) dominated most of the moraines, regardless of their soil texture. Their dominance result from increased precipitation and reduced transpiration along Lake Michigan (Denton and Barnes 1987, Eichenlaub 1979), allowing beech and sugar maple to dominate sandy soils where oaks and pines would otherwise be expected. The steep, irregular dunes and moraines are also less likely to burn regularly than more level landscape features. For this reason, even the droughty sands of the dunes support moisture demanding species such as beech, sugar maple, and basswood. Poorly drained areas with finer textured soils supported black ash (4141), black spruce (4232), and cedar (4231) swamps.

NATURAL DISTURBANCE: Although many of the Nipissing dunes have been stabilized by forest vegetation, large blowouts are common on the dunes immediately adjacent to Lake Michigan. Some of these blowouts are the product of human disturbance, but many noted by surveyors are probably naturally caused. The blowouts are large features. On South Fox Island, blowouts are in areas where timber was not harvested, probably indicating natural origin. Some of these blowouts continue to move landward, burying and killing northern white-cedar trees that are 100-200 years old. Signs of recent wildfires were noted several times by surveyors on sandy outwash deposits. Occasional, relatively small windthrows were encountered on the moraine ridges of the district.

HUMAN LAND USE: Native American fields and sugar camps were noted south of Stony Lake, and northwest of Bear Lake at the time of the surveys. Tanner (1987) noted Native American settlements at the mouths of the White, Pere Marquette, and Manistee rivers as of 1830. At the time of the surveys, early European settlements, associated with fur trade, logging, and fishing, were already established at Manistee and on both Manitou islands. Logging for white pine had already begun along major river drainages. Hardwood forests near major river mouths were also exploited to fuel Lake Michigan steamships.

Today, many of the end and ground moraines are used for orchards or vineyards. The protection from late spring frosts afforded by Lake Michigan is responsible for the utilization of the district for extensive orchards of apples, cherries, and peaches (Olmsted 1951). State Parks and National Lakeshore encompass many of the major coastal dunes. However, sand mining has occurred elsewhere on the dunes within the district. Oil and gas wells are found in a number of areas. The district is traversed by an extensive network of roads and highways, and urban development has been concentrated along the shoreline, in the town of Manistee, Pentwater, Montague, Whitehall, Ludington, and Frankfort. Further inland there are smaller agricultural towns such as Benzonia and Fremont.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Logging and agriculture have dramatically changed most upland portions of this district. Many wetlands, where they occurred on finer textured soils, were drained for agriculture. Probably due to man-made manipulations and some changes in dune configuration at the Big Sable dunes, the boundaries of Hamlin Lake have changed significantly since the time of the surveys. Areas that were not maintained in agriculture remain as highly fragmented forests. Historically pine-dominated forests, for the most part, include only scattered white and red pine, and more black oak and aspen than the presettlement condition. Northern hardwood forests in this district probably retain much of the species composition of presettlement conditions.



DISTRICT 5 Leelanau.

CLIMATE: The climate is strongly influenced by Lake Michigan. Spring and early summer are cooler than the Highplains district to the east. The growing season is 110 days at the inland edge of the district, and as long as 150 days along the shoreline of Lake Michigan (Eichenlaub et al. 1990). The lake-effect snowfall is heavy, averaging 100 to 140 inches annually. Average annual precipitation is 30 to 34 inches. Extreme minimum temperatures are -32° F along Lake Michigan and -40° F inland.

DISTRICT 5 Leelanau.
SUBDISTRICT 5.1. Williamsburg: coarse-textured end moraine

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Mississippian and Devonian marine and near-shore sedimentary bedrock underlie the entire district (Milstein 1987, Dorr and Eschman 1984). The subdistrict is a narrow band of steep end and ground moraine ridges that connect the high plateau of the Grayling subdistrict in the southeast to the lower terrain of the Grand Traverse subdistrict to the northwest. Elevations decrease from 1300 ft. at the south edge of the subdistrict to 900 ft. at the north edge. Glacial drift thickness over bedrock ranges from 100 to 800 ft. The drift is thickest at the southern edge of the subdistrict. The topography is some of the steepest in Lower Michigan, with local relief sometimes greater than 200 ft./mile. The steep drop to the north is probably the result of erosion by glacial meltwater channels (Burgis and Eschman 1981). Most of the soils on the moderately to steeply sloping end moraines are well to excessively drained.

PRESETTLEMENT VEGETATION: Northern hardwood forests (4111) of beech, sugar maple, basswood, yellow birch, and hemlock characterized the uplands of the district. Forests of red and white pine with red oak (4218) and white pine, beech, and red maple (4219) were located just southeast of Traverse City. Most wetlands in the subdistrict were either cedar swamp (4231), or mixed conifer-hardwood swamp (42).

NATURAL DISTURBANCE: No mention of disturbances was made by the surveyors within this subdistrict.

HUMAN LAND USE: At the time of the surveys, Native American activities within the subdistrict were limited to trails that connected Grand Traverse Bay to settlements further south, and an individual hut at Bass Lake. There was already a small logging camp established along the Boardman River, which was the primary access for early logging activity (Trygg 1964). A combination of early date of last freeze in spring, cool spring temperatures, and reduced thunderstorm severity allowed the area to develop commercial fruit production, primarily apples, cherries, and grapes. Sandy soils at the east end of the subdistrict fall primarily on State Forest, and are managed for timber, wildlife, and recreation. A network of roads exists throughout the entire subdistrict, but urban development is limited to the western outskirts of Traverse City.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Agriculture has replaced much of the upland forests which characterized the western portion of the subdistrict. Most of the wetlands which occupied the poorly drained soils remain, but are often completely surrounded by intensive agriculture. Urban development around Traverse City has eliminated some northern hardwood forest. Logging history and intensive forest management in the eastern end of the subdistrict has favored aspen, birch, and red oak over white pine and hemlock as components of those forests.

DISTRICT 5 Leelanau.
SUBDISTRICT 5.2. Traverse City: coarse-textured drumlin fields on ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: This subdistrict is located around Grand Traverse Bay and Lake Michigan. Bays of the lake and several long, narrow inland lakes divide the subdistrict into narrow peninsulas. Two of the long, narrow lakes of the district, Torch and Elk lakes, were bays of Lake Michigan until they were cut off by sand deposition during Nipissing time (Dorr and Eschman 1984). Elevation ranges from 580 ft. along the Lake Michigan shoreline to 1095 ft. inland. Underlying limestone bedrock is exposed in several places, and the glacial drift is less than 50 ft. thick over much of the district (Akers 1938). The thickest drift, approximately 350 ft., is located just east of Lake Charlevoix. The glacial drift contains abundant limestone fragments derived from nearby bedrock.

Most of the district is occupied by drumlin fields. The drumlins are long, narrow ridges, usually about 1/4 mile wide, one mile long, and less than 100 ft. high. Slopes are moderate to steep, and the soils are gravely sand and gravely sandy loam, mostly well drained. Swamps and small lakes were found in depressions between many of the drumlins, but some depressions are well drained. In western Charlevoix County, where the drumlin ridges are closely spaced, narrow deposits of thick organic soils, less than 1000 ft. wide, separate adjacent drumlins. A narrow band of sandy lake plain occurs along most large inland lake margins, and along Grand Traverse Bay at the northeast end of the Leelanau Peninsula and at the south extreme of the bay. Coarse-textured end moraine and outwash deposits lie along the south end of the district.

Throughout the district, most of the poorly drained soils were shallow or deep organic deposits rather than poorly drained mineral soils. Narrow, somewhat low sand dunes border the western shorelines of the Leelanau Peninsula, Mission Peninsula, and of Charlevoix and Antrim counties. This dune border is typically less than a mile wide, accounting for a only a small percentage of the district's surface area.

PRESETTLEMENT VEGETATION: Northern hardwood forest (4111) of American beech, sugar maple, basswood, yellow birch, and hemlock characterized the upland portions of the drumlin fields, while northern white-cedar (4231) dominated most of the wetlands between the drumlins. A small area of medium textured ground moraine located northwest of Elk Lake supported black ash swamp (4141).

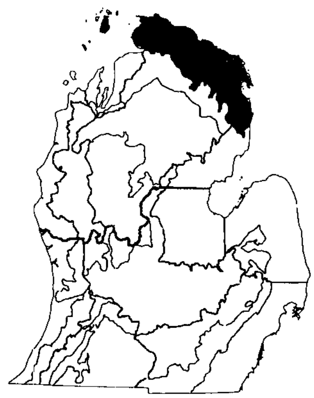
Northern white-cedar was common in the wetlands due to the calcareous soils. Cedar was dominant also on the sandy lake plain bordering many inland lakes and Grand Traverse Bay. Small wooded dune and swale complexes (911) are located on sandy lake plain at the south end of the east arm of Grand Traverse Bay, and on the west side of the Mission Peninsula at Bowers Harbor. Shrub swamps (6122) were also found on the sandy lake plain. Other wetland species present include balsam fir, hemlock, white pine, white spruce, red maple, American elm, and quaking aspen. On most dunes, northern hardwoods forests (4111) of beech, sugar maple, red maple, red oak, hemlock, white pine, and hop-hornbeam were found. Narrow open dunes (73) were found at the tip of the Leelanau Peninsula.

NATURAL DISTURBANCE: Windthrows were noted in several of the black ash and cedar-hemlock dominated swamps close to the shoreline. Surveyors noted recent fires near the shore along the eastern Leelanau Peninsula, and behind sand dunes along the east shore of Grand Traverse Bay.

HUMAN LAND USE: At the time of the surveys, Native American settlements and trails were known from the north end of the Leelanau Peninsula, the Mission Peninsula, Traverse City, and in several locations around Elk and Torch lakes (Trygg 1964). Most of the area was logged early on and converted to agriculture.

Today, the subdistrict contains numerous orchards and vineyards. The lake-moderated climate and the rich, calcareous soils both add to the district's agricultural value. The steeper drumlins are used for pasture. Urban development in this district is most concentrated around Traverse City, Charlevoix, Petoskey, Boyne City, and Elk Rapids. A number of smaller towns, roads, highways, and shoreline development also characterize land use in this area. The open dunes at the tip of the Leelanau Peninsula are included within Leelanau State Park.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Agriculture has replaced much of the upland forests which characterized this subdistrict. Most of the wetlands which occupied the poorly drained soils between drumlin and morainic ridges have been altered; often for use as pasture. Others are completely surrounded by intensive agriculture. Urban development around Traverse City has eliminated most of the pine and oak forests that once occupied the sand lake plain there.



DISTRICT 6 Presque Isle.

CLIMATE: The climate of much of the district is moderated by Lake Michigan and Lake Huron. The growing season is 140 days long near the Lake Huron shoreline, but at the inland margin of the district (Atlanta, a town near the inland border) the growing season is only 110 days (Eichenlaub et al. 1990). There is a greater chance of late spring and early fall freezes farther inland. Snowfall is high throughout the district, ranging from 70 to 140 inches, but lake-effect snowfall is greatest in the west, near Lake Michigan. Average annual precipitation is 28 to 32 inches. Extreme minimum temperatures are as cold as -40° F inland, but only -28° F along the Great Lakes shorelines.

DISTRICT 6 Presque Isle.
SUBDISTRICT 6.1. Onaway: drumlin fields on coarse-textured ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Glacial drift is as thick as 500 ft. at the inland margin of the subdistrict, and discontinuous within 30 miles of the shorelines of Lake Michigan and Lake Huron. The underlying bedrock consists of Mississippian and Devonian marine and near-shore sedimentary deposits (Milstein 1987, Dorr and Eschman 1984). Limestone, dolomite, and gypsum are locally exposed and mined. Devonian bedrock in the subdistrict is a source for salt, brine, and major petroleum reservoirs (Dorr and Eschman 1984).

The subdistrict has rolling to moderately sloping ground moraine topography. Drumlins are common on the ground moraine of the eastern three-quarters of the subdistrict. In the drumlin fields, individual ridges are typically separated by poorly drained outwash. The western quarter of the subdistrict contains several large lakes and large areas of lake plain interspersed with small ground moraine deposits. The lacustrine deposits are from early Algonquin time, when the small ground moraine deposits remained as "islands" above the level of glacial Lake Algonquin (Burgis and Eschman 1981, Dorr and Eschman 1984). The elevation of the entire district ranges from 595 to 975 ft. Elevations are generally lower to the northeast near Lake Huron and higher to the southwest along the boundary with the Vanderbilt subdistrict. The rolling hills and drumlins of the eastern section of ground moraine, characterized by slopes in the 0-12% slope class, have highly variable drainage and soil texture. The gravel and angular rock fragments are predominantly limestone, derived from bedrock at the northern edge of the drumlin fields (Burgis and Eschman 1981). The glacial deposits within the drumlin fields are primarily brown, sandy tills, but locally these are overlain by red, sandy till or lacustrine deposits. Readvancing glaciers sculpted the southeastward-trending drumlin fields. Most of the drumlins are less than 60 ft. high, 1/8-1/4 mi. wide, and about 1 mi. long. Karst topography is also present on the ground moraine of the subdistrict. The ground moraine is also broken by a broad outwash channel west of the town of Hawks. The outwash contains several kettle lakes. Extensive ice-contact topography dominated eastern Alcona County, with a cluster of kamic ridges southeast of Hubbard Lake, and more gently sloping hills further east.

Soils of the outwash channels vary from sand to gravel and drainage conditions vary from excessively well drained to very poorly drained. Gravely sandy loams are common on drumlins and ice-contact topography in the eastern portion of the subdistrict. Moderately well to well drained sands and sandy loams typify the drumlins elsewhere. The depressions between the drumlins, that are generally poorly drained, constitute a greater portion of the landscape than the drumlin ridges.

PRESETTLEMENT VEGETATION: Most of the drumlins of the subdistrict supported northern hardwood forest (4111), dominated by sugar maple, beech, basswood, hop-hornbeam, white ash, and hemlock. Some of the smaller, low drumlin ridges were dominated by hemlock (4226), a mix of hemlock and white pine (4227), or hemlock and cedar (4222). Some sandy drumlins adjacent to droughty outwash supported red and white pine forest (4216), with red oak and bigtooth aspen. Fires from the outwash probably burned onto the sandy drumlins, resulting in upland forests of fire-dependant conifers.

More extensive outwash deposits in Presque Isle, Alpena, and Alcona counties supported forests of red and white pine (4216), and jack and red pine (4215). These pine-dominated forests were also found on ground moraine in southwestern Presque Isle County. Here too, fires probably originated on adjacent outwash plains to the southwest. Ice-contact topography in Alcona County supported forests of white pine, beech, and red maple (4219) and beech and hemlock (4119).

The poorly drained outwash and ground moraine typically supported swamps of northern white-cedar (4231). Cedar was commonly the dominant at the upland margins, but increasing amounts of tamarack and black spruce occurred in the center of larger wetlands. Tamarack swamp (4233) was most abundant in what became the Fletcher Pond flooding. Other species observed in these forested wetlands included quaking aspen, balsam poplar, paper birch, black ash, white pine, hemlock, willow, and speckled alder.

The sand lake plain at the western end of the subdistrict supported cedar swamps (4231) in most poorly drained portions. In the uplands, forests of northern hardwoods (4111), beech and hemlock (4119), hemlock and white pine (4227), white pine, beech, and red maple (4219), red and white pine (4216), and red and jack pine (4215) were found. Pine-dominated types were most abundant on droughty soils between Burt Lake and Mullett Lake.

NATURAL DISTURBANCE: Windthrows were noted along the boundary with subdistrict 6.3, mostly on the lake plain, and not on the moraines of this subdistrict. There were extensive wildfires associated with Long Swamp in Alpena County, and the jack pine plains to the west in Montmorency County. Beaver activity was mentioned by surveyors throughout this subdistrict.

HUMAN LAND USE: Trygg (1964) noted a concentration of Native American activities surrounding Burt Lake, Mullett Lake, and Black Lake. These lakes were important for transportation between Lakes Huron and Michigan and were known as the inland waterway. They also moderated the climate and allowed Native Americans to successfully farm easily-worked sandy soils alongs the lakeshores. Early logging activity took place along the Cheboygan and Thunder Bay river drainages (Benson 1989). Most of the drumlin ridges and well drained ground moraine were cleared for agriculture, primarily for pasture, but also for some row crops and potatoes. The soils are very rocky, and the rocks form huge mounds on the landscape. Some of the wetlands have also been drained for pasture, but most remain intact. Small portions of this subdistrict fall under state and federal ownership. A network of roads and highways extends throughout the subdistrict, but urban development is concentrated only in Pellston and Indian River.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The northern hardwood forests have been extensively cleared for agriculture, and have caused heavy fragmentation in forest cover. Other uplands have been converted to aspen-birch forests, especially in the eastern 2/3 of the subdistrict. Most of the cedar and mixed conifer swamps have been logged, but typically remain as forest lands, with relatively more hardwoods intermixed.

DISTRICT 6 Presque Isle.
SUBDISTRICT 6.2. Stutsmanville: steep sand ridges.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: This subdistrict includes central portions of Emmet County, along with Beaver and High islands. Glacial drift is several hundred feet thick over the underlying Devonian shale, sandstone, limestone, dolomite, and evaporates (Dorr and Eschman 1984, Milstein 1987). The surface of this small subdistrict is characterized by large, broad ridges of sandy ground moraines, some nearly 500 ft. high. The soils are primarily well drained sands and sandy loams. The moderate to steep slopes of the subdistrict account for the well drained soils. The narrow, often steep valleys between the ridges are poorly or very poorly drained, but they account for only a small part of the subdistrict's surface area. Beaver and High islands are predominantly sand lake plain and dune formations.

PRESETTLEMENT VEGETATION: The predominant vegetation of the subdistrict is northern hardwood forest (4111) dominated by beech, sugar maple, hemlock, basswood, hop-hornbeam, and yellow birch. Lowlands, restricted to relatively narrow valleys between the ridges, are dominated by northern white-cedar (4231), or occasionally tamarack (4233) or mixed conifers (423). Pleasant View Swamp, by far the largest wetland in the subdistrict, was dominated by northern white-cedar and balsam fir.

Beaver Island had mostly northern hardwoods (4111) in the uplands and mixed hardwood and conifer swamp (42) in poorly drained areas. Mixed conifer swamps of cedar, tamarack, and hemlock were also common. High islands supported northern hardwoods (4111), spruce-fir-cedar forest (4223), and white pine forest (4211) in the uplands, with cedar swamps most common in poorly drained areas. There were also open dunes (73) noted along the west side of the island.

NATURAL DISTURBANCE: No natural disturbances were noted by surveyors in this subdistrict.

HUMAN LAND USE: Several Native American fields were noted within one to two miles of the shoreline on the sloping ridges of this subdistrict. There were also Native American settlements at Cross Village and Indian Point on Beaver Island (Trygg 1964). At the time of the surveys, early European fishing activities were evident on the islands as well. Following European settlement, nearly all of the forests were logged, but little agricultural development has occurred on the large, steep ridges. Larks Lake was apparently formed artificially. Today, roads traverse the subdistrict, but little concentrated urban development has taken place. Downhill ski slopes have been developed at Boyne Highlands. A portion of State Forest is within this subdistrict, and is managed for timber, wildlife research, and recreation. High Island is wholely state owned.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Most of the wetlands persist, although all have undoubtedly been logged. The upland forests have become fragmented, and probably contain less white pine and hemlock today than the presettlement condition. Dispersed homesite development along the shoreline has certainly impacted native plant communities.

DISTRICT 6 Presque Isle.
SUBDISTRICT 6.3. Cheboygan: lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The subdistrict forms a narrow band of sandy lake plain, 2-10 mi. wide, along the shoreline of Lake Huron in northeastern Lower Michigan. The elevation ranges from 580 ft. along Lake Huron to 750 ft. inland. Glacial drift is discontinuous near the shorelines of Lake Michigan and Lake Huron. The underlying bedrock consists of Mississippian and Devonian marine and near-shore sedimentary deposits (Milstein 1987, Dorr and Eschman 1984). Limestone, dolomite, and gypsum are locally exposed and mined. Devonian bedrock in the district is a source for salt, brine, and major petroleum reservoirs (Dorr and Eschman 1984). Although a veneer of sand covers a large part of the subdistrict's surface, limestone bedrock is near the surface of almost the entire subdistrict, and exposed bedrock and cobble beaches are common. Exposed limestone bedrock and thick deposits of cobbles are common southeast of Rogers City.

Similar to other sand lake plains in the state, much of the topography is a series of beach ridges and adjacent wet depressions, locally extending several miles inland. These dune and swale complexes (911) are well developed in Sturgeon Bay of Lake Michigan and east of Cheboygan and along Hammond Bay of Lake Huron. Sand dunes, low foredunes, sand spits, and beach ridges line much of the shoreline. Large Nipissing age dunes are located near Sturgeon Bay, on Lake Michigan (Dorr and Eschman 1984). Most of the dunes on Lake Huron are much smaller; the largest of these are 30-40 ft. high near 40 Mile Beach. Inland from the beach ridges and depressions are extensive flat, featureless areas of sand lake plain that are usually poorly drained. Within these broad tracts occur low sandy rises with slightly better drainage. Karst depressions occur locally around Long Lake. Long, Grand, and Grass lakes have long and linear basins formed by glacial erosion of the underlying bedrock. The orientation of these lakes is similar to that of the drumlins in adjacent Subdistrict 6.1. Hog and Garden islands are sand lake plain with dune features throughout.

West of Rogers City, the surface soil is primarily sand. Sand depth and the surface features are quite variable. The Ocqueoc River, in northwestern Presque Isle County, cuts through thick sand deposits that extend landward for greater than a mile. These deposits are relatively flat, and their origin is unclear. Organic soils covered the cobbles in many places, but fire, which was widespread throughout this portion of the lake plain at the time of the surveys, destroyed much of the organic cover, leaving bare cobbles.

PRESETTLEMENT VEGETATION: Large areas of flat, poorly drained sand lake plain were dominated by mixed conifer swamp (423). The conifer species most common dominant on the lake plain was northern white-cedar (4231). Cedar dominated in areas where there was some lateral water movement and formed dense stands at the seepy, calcareous margins of the adjacent subdistrict (6.1). Tamarack (4233) was also a common dominant, and often was found growing with cedar. It was more common where drainage conditions were more impeded. Numerous other species were common in the extensive wetlands of the subdistrict, including balsam fir, black spruce, eastern hemlock, white pine, balsam poplar, quaking aspen, paper birch, speckled alder, and shrub willows.

White and red pine (4216), or red and jack pine (4215) were common co-dominants on the well drained, low sandy ridges of the lake plain, especially near the Lake Michigan and Lake Huron shorelines. Hemlock and white pine (4227) were also common co-dominants, often where the drainage conditions were slightly poorer than where white pine and red pine grew together. Aspen-birch forest (413) and aspen swamp (4146) also occurred locally on flat to rolling portions of the sand lake plain. Near the Ocqueoc River, where droughty outwash sands extended for several miles inland from the shore, there were extensive stands of jack pine (4213) and red pine-jack pine (4215). These stands also contained red oak and some white pine.

The areas of wooded dune and swale complex (911) near Sturgeon Bay and Cheboygan contained ridges of white pine and red pine and swales dominated by either northern white-cedar and other conifers, or if they were flooded, by emergent marsh. The complex at Hammond Bay was drier. The ridges were dominated by white pine and red pine near the shoreline, with jack pine and northern pin oak becoming more common further inland. The swales were typically narrow. The drier ones supported balsam fir, aspen, and other upland species, and the wetter swales supported cedar, tamarack, and other lowland conifers or hardwoods. Other complexes dominate the shoreline from Thunder Bay south to Harrisville. Along the shoreline, Great Lakes marsh (6222) occurred within the wooded dune and swale complexes. Calcareous ponds (52) also occurred near the shoreline and sometimes included emergent marsh (6221) or small diameter tamarack, cedar, and occasional black spruce.

Although northern hardwoods (4111) were not generally extensive in the subdistrict, some large tracts were located on better drained soils around Long and Grand Lakes, along the Cheboygan and Black Rivers, and locally along the Lake Michigan and Lake Huron shorelines. Northern hardwoods also dominated well drained uplands on Garden and Hog islands. These islands also included mixed conifer swamps (423) and Great Lakes marsh (6222). Upland forests of cedar, white spruce, and balsam fir (4223) were common in this subdistrict along the shoreline, and further inland, where bedrock is exposed at the surface.

NATURAL DISTURBANCE: At the time of the surveys several windthrows were noted, with the largest being less than two square miles in area. The windthrows were concentrated near the boundary of the lake plain with the drumlins of subdistrict 6.1. Windthrows were also recorded on Garden, and High islands. There were also several large areas of burned timber. These burns were not noted in the first survey (of the township lines), and may have been the result of early logging operations near Cheboygan, where log mills were already noted in the first survey. Several square miles of timber were burned near Cheboygan and several more large fires were noted near Thompson's Harbor and Grand Lake. Wildfires were also noted on Garden and Hog islands.

HUMAN LAND USE: Tanner (1987) noted Native American settlements concentrated at Cheboygan and Alpena in 1830. Trygg (1964) noted Native American activity around Grand Lake, and on Garden, Hog, Squaw, and Whiskey islands. On Hog Island, the Native American fields have regenerated to white-pine and red-oak dominated forest. Early European activity centered around Fort Michilimackinac and the town of Cheboygan. Both existed at the time of the surveys, and there were already a number of roads connected to the Black and Cheboygan rivers. Logging within this subdistrict took place early along major river drainages and the Great Lakes shoreline. Limestone in this subdistrict has been quarried at several locations, including near Alpena, Grand Lake, Adams Point, and Rogers City. A network of roads and highways exists throughout the subdistrict, and residential development is concentrated in Alpena, Rogers City, Cheboygan, Mackinaw City. State Parks and State Forest lands are found in the subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Logging has greatly altered the forest composition of many upland and wetland forest types, especially those dominated by white pine, red pine, hemlock, or cedar. Many of these areas have been converted to aspen-birch forest and hardwood-conifer swamp and managed intensively to maintain these forest types, both for pulp harvest and wildlife management. Quarrys have completely altered large landscapes near Rogers City, Presque Isle, and Alpena.

REGION VIII. Eastern Upper Michigan.

REGIONAL CLIMATE: Due to northern latitude and the close proximity of Lake Michigan, Lake Superior, and Lake Huron, the region has a cool, lacustrine climate. Most air masses cross the Great Lakes before entering this region, resulting in reduced continentality. Compared to areas of equivalent latitude in Wisconsin and Minnesota, the region is warmer in winter and cooler in summer. The lakes also reduce the severity of thunderstorms. Lake effect snow and rain characterizes portions of the region near the Great Lakes shorelines. Much more snowfall occurs in the northeastern part of the region than in the southwestern parts. Much of the region is relatively low in elevation, and most physiographic features do not appreciably influence climate.

The growing season length is less than 100 days inland and up to 150 days along the Great Lakes shorelines (Eichenlaub et al. 1990). Annual precipitation ranges from 30 to 34 inches. Annual snowfall ranges from 180 inches of lake-effect snow along Lake Superior to 60 inches along Lake Michigan. Extreme minimum temperatures range from -28° F along the Great Lakes to -46° F inland.

DISTRICT 1 Mackinac.

CLIMATE: The district is moderated by the Great Lakes, and as a result, is the warmest district in Northern Michigan. The growing season for the district as a whole is 125 days (Eichenlaub et al. 1990). Extreme minimum temperatures is -29° F. Lake-effect snowfall occurs throughout the district, most commonly in the Rudyard subdistrict. The St. Ignace and Escanaba subdistricts are also warmer than the Rudyard subdistrict. Average annual precipitation ranges from 30 to 34 inches.

DISTRICT 1 Mackinac.
SUBDISTRICT 1.1. St. Ignace: limestone bedrock and sand lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The entire district is underlain by Silurian and Ordovician age sedimentary bedrock, principally The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which is locally exposed as cliffs and limestone pavement (alvar) along the Lake Michigan shoreline from the Stonington Peninsula in the west to Drummond Island at the far eastern edge of the Upper Peninsula of Michigan, and eastward to Cockburn Island, Manitoulan Island, and the Bruce Peninsula of Ontario. The underlying bedrock is typically less than 50 ft below the surface of the glacial drift (Vanlier and Deutsch 1958; Sinclair 1959, 1960; Vanlier 1963).

A wide variety of landforms of glacial lacustrine origin characterize the subdistrict; including flat lake bed, deltaic deposits of sand, parabolic dune fields, and shallow embayments containing transverse dunes. Large areas consist of lacustrine sand deposits that have flat to gently undulating surfaces. On this topography, only a few inches of elevation change can greatly alter drainage conditions. Drainage conditions also depend on depth to underlying bedrock or fine-textured substrate. Ground moraine is locally present. Exposed limestone and dolomite bedrock form flat, pavement-like areas and breccia chimneys are locally exposed.

Soils within the district are diverse. Lacustrine soils are primarily sands, but there are small, local areas of lacustrine clays. The clays are primarily poorly drained. The sands are generally either excessively drained or poorly drained. Excessively drained sands are on beach ridges or dunes. Poorly drained sands are more common, occupying much of the flat lake plain or depressions between dunes and beach ridges. Within the district the soils of the ground moraine range from loamy sands to loams, and are often stony. Where bedrock is near the surface, soils are often calcareous and poorly drained. The most common soil orders within the subdistrict are Alfisols (Boralfs), Histosols, and Entisols (Aquepts), with some Orthods and Aquods (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: At the eastern edge of the subdistrict, Drummond Island, for the most part described by surveyors as "rolling and stony," was dominated by forests of white spruce, northern white-cedar and balsam fir (4223) mixed with aspen-paper birch forests (413) on thin soils over bedrock. On central portions of the island, where soils were deeper, there were northern hardwoods (4111) intermixed with spruce-fir- and birch- dominated forests. The southwest of the island had experienced many windthrows from storms off Lake Huron. This part of the island was described as predominantly aspen-birch thicket (413). Great Lakes marsh (6222) was noted by surveyors along the shoreline of Drummond Island in small, protected coves and embayments. Organic soils in shallow depressions on the eastern and southern side of the island supported conifer- hardwood swamps (42) dominated by cedar, spruce, tamarack, black ash, and aspen.

Some of the more resistant dolomites and shales, when they occur as a pavement at or near the surface, experience spring floods and summer drought, thus limiting forest establishment. The resulting shrub and grassland communities are called alvar (741). Good examples of alvar are found today on the northern Maxton Plains of Drummond Island. A dense mat of roots and rhizomes form on the surface of the bedrock, especially in cracks were there is increased moisture availability. Small wet depressions and lower slopes support herbs and shrubs tolerant of saturated soil. Thin organic soils develop over the bedrock, but they are subject to destruction by fire in drought years. Quaking aspen forms stunted clones on both the droughty uplands and in moist depressions.

Between Drummond Island and St. Ignace, much of the coastal area along northern Lake Huron, where thin soils overlay bedrock, was dominated by balsam fir-spruce-cedar forests (4223) and northern hardwoods (4111). Thin soils over bedrock also characterize Mackinac Island and the area around St. Ignace. These soils supported several forest types, including northern hardwoods (4111) on better drained sites, and both balsam spruce-fir-cedar (4223), and aspen-birch (413) on poorly drained sites. Limestone ledges (744) were encountered by surveyors throughout the inland forests north of St. Martins Bay.

Several wooded dune and swale complexes (911) occur along the Lake Huron shoreline. At St. Vital Bay, just west of De Tour Village, a large wooded dune and swale complex supported balsam fir, white pine and red oak on the ridges, with shrub swamps (6122) and emergent marshes (6221) in the open swales. Just east of Ponchartrain Shores, the dune and swale complex supported cedar swamp (4231) and those west of St. Martin Bay and in Horseshoe Bay, supported cedar, spruce, and paper birch. Marly pools (6231) were mentioned by the surveyors at Horseshoe Bay. Stunted cedar, tamarack, and white pine grew along the edges of these pools. Vast areas of organic soils located on lacustrine deposits just north of St. Ignace supported cedar (4231) and tamarack swamps (4233), with scattered dune ridges.

Sandy lake plain along northern Lake Huron supported Great Lakes marsh (6222) in a number of protected coves in and around the Les Cheneaux Islands. In many places, the surface sands were very thin, and the underlying substrate was clay or marl (MNFI 1988). Further west on St. Martins Bay, Great Lakes marsh (6222) was found on the protected west side of the bay.

The sandy lake plain portions of Bois Blanc Island supported extensive cedar swamps (4231), tamarack swamps (4233) and spruce-fir-cedar upland (4223). Hemlock (4226) and northern hardwood (4111) forests also dominated better drained portions of sandy lake plain and bedrock on Bois Blanc Island.

The Les Cheneaux Islands are predominantly sandy ground moraine, and supported fir-spruce-cedar (4223), and aspen-birch forests (413). North of the Les Cheneaux Islands and the town of Hessel, small areas of sandy ground moraine and thin soils over bedrock supported northern hardwood forests.

West of St. Ignace, the subdistrict consists largely of sand lake plain. Large dune and swale complexes were common. The vast dune/swale complex at Point Aux Chenes supported tamarack, aspen, birch, and spruce in the narrower swales, with emergent marsh (6221) and alder-willow shrub swamps (6122) in the wider swales. Pines dominated the dune ridges. From Epoufette to the western end of the subdistrict, the shoreline was dominated by a chain of wooded dune and swale complexes (911). Within the complexes, the ridges were dominated by forests of white pine, red pine, white spruce, balsam fir, and hardwoods; the wetter swales were dominated by grasses, sedges, and other aquatic plants; the drier swales supported northern white-cedar swamps and, occasionally, upland forest.

From Pointe Aux Chenes to Brevoort there are areas of low parabolic dunes along the sandy lake plain of Lake Michigan. Near the Lake Michigan shoreline, the moist air, higher precipitation, resulted in most dunes being dominated by northern hardwood forest (4111) of sugar maple, beech, hemlock, red oak, yellow birch, paper birch, and basswood. In contrast, similar dunes located near Round Lake, several miles inland from Lake Michigan, supported forests dominated by red and jack pine (4215), possibly indicating the lack of local micro-climatic influence bringing moisture from Lake Michigan.

The small, protected embayments of Epoufette and Kenyon bays supported Great Lakes marsh (6222). Inland from these marshes were swamps of cedar, tamarack and spruce.

Sand and clay lake plain extend as far as fourteen miles inland in this subdistrict. These extensive tracts of inland lacustrine deposits, which include some areas of deep organic soils, supported vast swamps dominated by cedar, spruce, and tamarack (423).

Exposures of dolomite bedrock were less extensive at the west end of the subdistrict than at the eastern edge. Just west of East Lake, in north-central Mackinac County, was another concentration of exposed dolomite and limestone. In contrast to Drummond Island, where the exposed bedrock is typically within a mosaic with fir-spruce-cedar and aspen-birch forests, these bedrock exposures were surrounded by northern hardwoods. High bedrock ridges west of the straits area, and lower morainal ridges northeast of Brevoort Lake supported northern hardwood forests (4111). Adjacent ground moraine ridges were dominated by northern hardwoods (4111), hemlock-beech (4119), and hemlock-white pine (4227) forests.

NATURAL DISTURBANCE: The surveyors recorded numerous occurrences of fire in upland and swamp forests on both sand and bedrock. A fire approximately six square miles in size was noted several miles northeast of Epoufette Bay and beach ridges near the Crow River mouth were burnt off at the time of the surveys. Windthrows were noted just west of Little Manistique Lake. There were both wildfires and windthrows on Little St. Martin Island. Beach ridges near the Crow River mouth were burnt off at the time of the surveys. Many windthrows were noted by surveyors in the cedar and tamarack-dominated swamps north of Hughes Point.

HUMAN LAND USE: European settlements were well established at Mackinac Island, St. Ignace, Bois Blanc Island, and at Gros Cap at the time of the surveys in the 1840s. The 1829 survey of Mackinac Island showed only small second growth timber over the entire island, probably the result of firewood cutting. A British military outpost was established at the southwest end of Drummond Island. Fishing establishments were based at various locations along the shoreline from Epoufette west to Seul Choix Point. Native American settlements were also located on Bois Blanc Island and St. Martins Island. Their sugar camps were located throughout the area where northern hardwoods dominated.

Limestone has been quarried at a number of locations within this subdistrict including Drummond Island, inland areas northeast of Hessel, Milacokia Lake, and at Seul Choix Bay. St. Ignace was a major mill town in the 1870s (Karamanski 1989). Upland areas dominated by pines and northern hardwood were cut, and often burned, by the early 20th century.

IMPACT OF HUMAN LAND USE ON VEGETATION: Limestone quarries have had obvious permanent impacts on several locations within this subdistrict. Roads and highways have probably had the most enduring negative impact on coastal wetlands, by disrupting wetland hydrology and facilitating shoreline development. A number of Great Lakes marshes (6222) along northern Lake Huron were effected by the construction of M-134 along that shoreline. Urban development is increasing around St. Ignace. Residential development is quite dense on many of the Les Cheneaux Islands which have been connected to the mainland by bridges. Most of the white pine and hemlock-dominated forests of this subdistrict were utilized early in the logging-era, and converted to other species. Many of the northern hardwood forests located on ground moraine in this subdistrict have been cleared for agriculture and pasturage. This is especially the case from Millecoquins Lake extending west to the western border of the subdistrict. The wooded dune and swale complexes west of Naubenway remain, for the most part, similar to their native character, with changes limited to a few upland forest dominants.

DISTRICT 1 Mackinac.
SUBDISTRICT 1.2. Rudyard: clay lake plain.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The entire district is underlain by Silurian and Ordovician age sedimentary bedrock, principally limestone and dolomite. The bedrock is typically less than 50 ft. below the surface of the glacial drift, but drift 100-200 ft. thick may be found where preglacial valleys dissected the bedrock surface. Such valleys underlie the present valleys of the Pine and Carp rivers (Vanlier and Deutsch 1958; Sinclair 1959, 1960; Vanlier 1963).

Almost the entire subdistrict is a broad clay lake plain. On a small area of sand lake plain near Kinross at the center of the subdistrict, there is a series of ancient beach ridges and swales, many miles from the present Great Lakes shoreline. Sandy ground moraine is encountered on Sugar and Neebish islands, and on the mainland at the north end of Munuscong Bay.

Soils are generally well drained on the ground moraine. The clay soils are somewhat poorly drained to poorly drained. The localized sands near Kinross are either excessively drained or poorly drained.

PRESETTLEMENT VEGETATION: The poorly drained clay plain, common within 3-4 miles of the Great Lakes shoreline in much of the subdistrict, supported conifer-hardwood swamps (42) with balsam fir, balsam poplar, hemlock, northern white-cedar, tamarack, quaking aspen, white pine, black spruce, and white spruce. Lowland conifer swamps (423) were also found on the clay plain. These were similar in composition but lacking a significant hardwood component. Much of the clay lake plain was not poorly drained, but somewhat poorly drained. None the less, these lands were also dominated largely by the above mentioned conifers, along with balsam poplar, quaking aspen, and paper birch. The poorly drained shores of the St. Marys River, at the east edge of the subdistrict, today support some of the most extensive Great Lakes marsh (6222) in Michigan. These marshes, for the most part, were described by the surveyors as being narrower than they are today, however, they likely described only those portions of the marsh which we recognize as the wet meadow zone, stopping at the water line. The emergent marsh zone, which occupies water up to four or five feet deep, can be a mile wide, and the wet meadow zone along the shoreline is often another quarter to half mile wide (MNFI 1987, 1989).

On the sandy lacustrine deposits in this subdistrict, balsam fir-spruce-cedar forests (4223) were found along many of the rivers, including the North Pine River and the West Branch of the Waiska River. The sandy lake plain along Waiska Bay supported cedar swamp (4231) and hemlock swamp (4237). Large peatlands on sand lake plain supported "open swamp" dominated by spruce, cedar, and tamarack (423 or 6125) east of Izaak Walton Bay, and hemlock forests (4226) dominated sand beach ridges along that shoreline. Peatlands to the northwest and south of Munuscong Bay, also on sand lake plain, were dominated by several conifer forest types, including cedar (4231), spruce (4232), and tamarack (4233). A large balsam fir-dominated swamp was located on localized, poorly drained sand lake plain at the south end of Neebish Island.

On the well drained ground moraine of Sugar and Neebish islands, hemlock-sugar maple forests (4228) containing American elm, basswood, and yellow birch, and aspen-birch forests (413), were locally common. Hemlock-sugar maple (4228) and hemlock-white pine (4227) forests were also found on the well drained ground moraine in the central part of the subdistrict, southeast of Kinross. Poorly drained portions of these ground moraines supported alder-willow swamps (6122).

NATURAL DISTURBANCE: Poor drainage conditions result in widespread windthrow. Several large windthrows, totaling several square miles in area were noted by surveyors south and west of Sault St. Marie, primarily on lacustrine clays. There was also a large windthrow on clay lake plain on the southeastern shoreline of Sugar Island. Areas of windfall and burned timber were noted by the surveyors on the mainland, especially in the vicinity of Kinross and Dafter.

HUMAN LAND USE: European settlement at Sault St. Marie began with a mission established by Father Marquette in 1668, so there had been many years of European activity prior to the land survey conducted in 1845. Forests had been cleared for several miles around the settlement. Native American settlements and trails were also noted in the Sault St. Marie area by the surveyors. Numerous trails and roads were also noted by the surveyors near Rudyard, mostly associated with a major trail connecting Sault St. Marie to St. Ignace.

Subsequent development of this subdistrict has seen extensive forest clearing and swamp drainage for agricultural production. Swamps near the Great Lakes shoreline have been less modified than those elsewhere in the subdistrict. Nonetheless, many Great Lakes marshes were partially drained by shallow ditching of the marshes, thus allowing for the harvest of marsh hay. All of these ditches are now abandoned. Railroads and highways extend south from the urban development around Sault St. Marie. Kincheloe Air Force Base is located at Kinross.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Much of the clay plain has been converted to pasture or other agricultural use, following widespread construction of ditches. However, drainage remains a limiting factor. Where pasture land is abandoned, it quickly returns to shrub willows, speckled alder, tamarack, black ash, and other species indicative of poor drainage.

The wakes produced by large ships passing through the St. Marys River have degraded portions of many Great Lakes marshes. Many of the lowland conifer swamps along Izaak Walton Bay and on organic deposits further inland, remain relatively intact; however most are dissected by roadways and railroad tracks.

On Sugar and Neebish islands and in rural areas throughout the subdistrict, the majority of upland hemlock-sugar maple, aspen-birch, and balsam fir-spruce forests remain in some form, although degraded by past logging. Several large alder-willow swamps on Sugar and Neebish islands remain relatively intact. Most of the large peatlands northwest and south of Munuscong Lake also remain relatively intact. The Gogomain Swamp, south of Munuscong Lake, covers roughly 20 square miles. It is the largest remaining swamp in the subdistrict.

DISTRICT 1 Mackinac.
SUBDISTRICT 1.3. Escanaba: limestone bedrock and sand lake plain.

CLIMATE: Climatic differences are used to separate subdistrict 1.3 from subdistrict 1.1. The climate of this subdistrict (1.3) is milder (Albert et al. 1986). This subdistrict also receives less snowfall than most of subdistrict 1.1 and average precipitation is slightly lower.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The soils, glacial landforms, and bedrock geology of this subdistrict are similar to those of subdistrict 1.1. The primary difference between the two subdistricts is a milder climate in this subdistrict, which results in a greater presence of more southern tree species.

The entire subdistrict is underlain by Silurian and Ordovician-age sedimentary bedrock, principally limestone and dolomite, but also including less resistant shale and gypsum (Dorr and Eschman 1984). The resistant Niagaran series dolomite and limestone of Silurian age form the Niagaran Escarpment, which is locally exposed as cliffs and/or flat limestone pavement along the Lake Michigan shoreline of the Stonington and Garden peninsulas, and adjacent islands. Little Bay de Noc and Big Bay de Noc occupy depressions where soft gypsum and shales were eroded, probably both by glacial and lacustrine processes (Sinclair 1960). Devonian limestone, dolomite, and breccia are locally exposed at the southern edge of the district. The underlying bedrock is typically less than 50 ft. below the surface of the glacial drift (Vanlier and Deutsch 1958; Sinclair 1959, 1960; Vanlier 1963).

A wide variety of landforms of glacial lacustrine origin characterize the subdistrict, including flat lake bed, deltaic deposits of sand, parabolic dune fields, and shallow embayments containing transverse dunes. Beach-ridge and swale topography, made up of dozens of low, linear beach ridges alternating with shallow depressions (swales), commonly forms a narrow 1-2 miles wide band along the shorelines of protected embayments of Lake Michigan. Large areas consist of lacustrine sand deposits with flat to gently undulating surfaces. Regional slope is typically only 8 to 10 ft./mile. On this topography, only a few inches of elevational change can greatly alter drainage conditions. Drainage conditions also depend on depth to underlying bedrock or fine-textured substrate. Ground moraine is locally present south of Escanaba and north of the Garden Peninsula. Outwash deposits are located near the Lake Michigan shore north of Escanaba near Rapid River. Small barchan dunes (crescent shaped) are scattered over the surface of this outwash plain.

Soils within the subdistrict are diverse. Lacustrine soils are primarily sands which are often underlain by lake clays or bedrock within only a few feet of the surface. The sands are generally either excessively drained or poorly drained. Excessively drained sands may be found on beach ridges or dunes. Poorly drained sands are more common, occupying much of the flat lake plain or depressions between dunes and beach ridges. The soils of the ground moraine within the district range from loamy sands to loams, and are often stony. Where bedrock is near the surface, soils are often calcareous and poorly drained. The most common soil orders within the subdistrict are Alfisols (Boralfs), Histosols, and Entisols (Aquepts), with some Orthods and Aquods (SCS 1967).

PRESETTLEMENT VEGETATION: Extensive cedar swamps (4231) grew on the poorly drained soils of the lake plain, extending inland several miles from the present shoreline. Although cedar was the tree species most commonly noted by the surveyors, other common wetland species included tamarack, balsam fir, (red) maple, (paper) birch, black ash, (black) spruce, hemlock, (quaking) aspen, and balsam poplar. Depressions within the extensive wetlands of the lake plain were often dominated by low productivity tamarack swamps (4233) or black spruce swamps (4232). These swamps were often traversed by low, narrow beach ridges. The smaller ridges often supported upland conifer forests of hemlock (4226), white pine (4211), or a mixture of the two (4227).

Along embayments of Lake Michigan there were extensive wooded dune and swale complexes (911). Within the dune and swale complexes, the drier ridges were dominated by forests of white pine or red pine, along with white spruce, balsam fir, and hardwoods. Lower ridges were often dominated by northern white-cedar (4231), as were some of the drier swales. The wetter swales supported emergent marsh (6221). Great Lakes marsh (6222) also occurred in many of the embayments, but they were generally narrow due to severe wave action. The only extensive marshes within the subdistrict were near Escanaba, at Portage Bay, and in Little Bay de Noc, at the mouth of the White River.

Extensive floodplain occurred along the lower reaches of the Sturgeon River, where it is a broad, meandering stream with many oxbow lakes as it flows across sand lake plain. Its wide floodplain forest is dominated by silver maple (4143), and also contained butternut, both species rare in Northern Michigan.

Low broad upland areas of lacustrine sands supported upland conifer forests with the same species as the surrounding wetlands, or occasionally, northern hardwoods forest (4111) dominated by American beech and sugar maple. In areas where lacustrine sands are quite thin over bedrock, such as on the Stonington and Garden peninsulas, spruce-fir-cedar forests (4223) were common. Areas of open grasslands (alvar) probably occurred within these conifer forests on the southern half of the Garden Peninsula. Recent ecological surveys have discovered small areas of alvar, but these are small enough that they might not have been encountered by surveyors.

Pine barrens (333) occurred on the outwash sands near Rapid River. Large portions of the pine barrens were noted as burned over at the time of the surveys. Jack pine was the predominant species on the pine barrens, but red pine was also common.

NATURAL DISTURBANCE: The most common type of disturbance noted by the surveyors within the subdistrict was windthrow. In the stretch of Lake Michigan shoreline between Menominee and Escanaba, 18 windthrows, mostly under a square mile in area, were noted within one or two miles of the shore. Winds off Lake Michigan were responsible for most of these windthrow areas. Occasionally the windthrows burned later, as noted by the surveyors. Windthrows were found in both upland and wetland forests.

Fires were also noted by the surveyors, primarily on pine plains. These pine plains were near Native American settlements, but it was not clear from the surveyor's notes whether Native Americans were responsible for the fires. Such fires were noted near Menominee, Escanaba, and Rapid River.

HUMAN LAND USE: The surveyors noted Native American settlements near Menominee, Escanaba, Rapid River, Manistique Lake, and on both the Stonington and Garden peninsulas. Both sugar bushes and gardens were noted near most of these sites. A lime kiln was mentioned just east of Manistique Lake. Trails were commonly noted, especially along major rivers and the Lake Michigan shoreline. There was an established trail between Manistique Lake and Big Bay de Noc, and also across the Stonington Peninsula. A trail extended from Rapid River up to the trading post at Munising.

In 1831, prior to the land surveys, a sawmill had already been established near the mouth of the Menominee River. Following European settlement, logging began, first for white and red pines, then for northern white-cedar and hemlock, and finally for hardwoods and pulp. Logging mills were located along many of the rivers near the Lake Michigan shoreline (Karamanski 1989). Railroads dissect wetlands throughout this subdistrict. Agricultural land use within the subdistrict has been limited to pasturing of the ground moraine and small areas of sand lake plain. Few of the wetlands have been greatly altered for agricultural purposes. Major highways are located along much of this shoreline. Urban development is also concentrated along the Lake Michigan shoreline at Menominee, Escanaba, Gladstone, Rapid River, and Manistique.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Some northern hardwood forest on both sand lake plain and ground moraine has been cut and converted to pasture. Most areas of original hemlock, white pine, or red pine forest persist as forest. However, the forest composition has generally changed since regeneration of these species has been poor. The remaining forest is characterized by quaking aspen, balsam fir, paper birch, and other early successional species. Most of the pine barrens persist, or have succeeded to closed-canopy forest with jack pine remaining dominant.

Almost all lowland conifer swamps persist in some form, although deer browse has resulted in the conversion of large areas to hardwood swamp. Tamarack, and to a lesser extent, black spruce remain common dominants. Alder-willow swamp was historically limited to narrow bands along streams, where it typically persists.

Emergent marsh was limited to the margins of a couple of lakes, where it still persists. All of the Great Lakes marsh within this subdistrict have been degraded. At Portage Bay, manipulation of the marsh has resulted in the introduction of Eurasian water milfoil, which forms dense submergent beds of little utility to wildlife. Along the Whitefish River mouth, docks have greatly altered portions of the marsh.

DISTRICT 2 Luce.
SUBDISTRICT 2.1. Seney: poorly drained sand lake plain.

CLIMATE: The climate is dominated by lacustrine influences. The growing season ranges from 110 in the north to 130 days in the south (Eichenlaub et al. 1990). The growing season heat sum is one of the lowest in the state and winters are cold. Some of the coldest minimum temperatures in the state are recorded within the district, ranging from -40° F to -46° F. Average annual precipitation, similar to that of the entire eastern Upper Peninsula, ranges from 32 to 34 inches. Annual snowfall is between 80 and 120 inches (Eichenlaub et al. 1990), much less than in the Grand Marais district to the north.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock is typically covered by 100-200 ft. of glacial drift, but is near the surface along the western edge of the subdistrict. Ordovician and Silurian-age limestone, dolomite, and other sedimentary rocks of marine or near-shore environments underlie the entire district (Sinclair 1959, 1960).

This subdistrict of sand lake plain contains the largest expanses of wetland in the state. Landforms of lacustrine origin typify the subdistrict. These include broad, poorly drained embayments of Glacial Lake Algonquin (10,000 years before present) that contain beach ridges and depressions (swales), sand spits, transverse sand dunes, and sand bars. Deltaic deposits occur along the northern margins of the embayments, where glacial meltwater streams carried massive amounts of sand into the shallow waters.

Many rivers originate in the wetlands of the subdistrict. All of these rivers meander, creating broad oxbows on the flat lacustrine landscape. Most of the rivers, including the Manistique, Fox, Driggs, Creighton and Sturgeon, flow to the southeast, perpendicular to the regional bedrock slope.

Organic soils characterize most of the subdistrict, but there are also extensive areas of poorly drained sand, and both beach ridges and sand dunes have excessively drained sand soil. It was only during the moister, cooler climatic conditions of the last 3000-4000 years that peat began to accumulate in the large embayments of Glacial Lake Algonquin. As a result, the peat in most of the district is relatively shallow, less than three or four feet deep. The soils are classified as Histosols and Entisols (Aquepts), with some Orthods and Aquods (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: On the very poorly drained lacustrine embayments of the western half of this subdistrict, and locally in the northeast, muskeg (6125) and patterned peatlands (6124) were the predominant vegetation types. This vegetation was variously described by the surveyors as "marshy with sand knobs and drifts", "open marsh with groves of trees", "swamp with a thick growth of grass" and "open swamp". The tamarack and spruce commonly scattered throughout these peatlands were of small diameter; ranging from 3-7 inches. Since the surveyor's descriptions for these two types were very similar, they were differentiated with the aid of information taken from 1938 aerial photography. The sand knobs and ridges were timbered with various combinations of red pine, jack pine, white pine and (white) spruce. Mixed conifer swamp (423), composed of northern white-cedar, tamarack, hemlock, (black) spruce, balsam fir and white pine), tamarack swamp (4233), bogs (6121) and emergent marsh (6221) were also found on these poorly drained lacustrine sands. Alder swamp (6122) was fairly extensive along the streams flowing through this area.

The poorly drained lacustrine deposits on the eastern end of this subdistrict supported vast peatlands, dominated by black spruce (4232), cedar (4231), tamarack (4233) and mixed conifer swamps (423) composed of black spruce, jack pine, red pine, white pine, balsam fir, northern white-cedar and tamarack were common throughout poorly drained portions of the lake plain. Several of these areas, mapped by Farrand and Bell (1982) as organic deposits were spruce and tamarack swamps (423) which included narrow beach ridges dominated by white and red pine (4216). Several square miles of "wet marsh" (6221) and a large area described by the surveyors as "open tamarack and spruce swamp" (6125) were also found on these organic deposits. Intermittent wetlands (6228) were described by the surveyors as "dry marsh." Spruce, fir, and cedar forest (4223) occurred on the drier lands along the rivers.

Well drained lacustrine deposits were relatively limited in this subdistrict and generally supported various combinations of jack pine, red pine and white pine (4215 and 4216), pine "openings" (333) and beech-white pine forests (4219).

On the rolling uplands in this subdistrict, which were somewhat limited in extent, the well drained glacial outwash was dominated by northern hardwoods (4111), hemlock-sugar maple (4228) and hemlock-white pine forests (4227). Aspen-white birch (413), white pine-beech-red maple (4219) and hemlock forests (4226) were also common. Some areas of jack pine-red pine (4215), white pine-red pine (4216) and jack pine and/or red pine-dominated "openings" (333) were also noted by the surveyors.

Poorly drained areas on the glacial outwash supported mixed conifer swamp (423) and cedar swamp (4231). Emergent marsh (6221) was common along the shores of many of the numerous small lakes in the subdistrict. Alder swamp (6122) was found along many of the streams.

NATURAL DISTURBANCE: The surveyors made mention of both fire and windthrow throughout the subdistrict. Combined windthrow and fire were most extensive in central Luce County, just northeast of Newberry, where the disturbances covered several square miles. This was in an area of large peatlands. Another large windthrow was noted just north of Seney. Beaver flooding was noted along streams throughout the subdistrict.

HUMAN LAND USE: Many of the large swamps were logged for white pine, then later, tamarack and spruce (Karamanski 1989). In many cases they also burned as a result of slash fires spreading from adjacent uplands. Wildlife management at Seney National Wildlife Refuge includes damming streams, constructing diversion ditches and flooding rather extensive areas which supported muskeg during the time of the surveys. Railroads and roadways dissect the area. Newberry is the primary center of urban development in this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Logging and associated activities have resulted in a decline in pines, cedar, and hemlock, and the conversion of conifer-dominated swamps to mixed hardwood-conifer swamps. In upland forests, there has also been a relative decline of pines and hemlock in favor of aspen, birch, and red maple. Wildlife habitat projects have converted several muskeg and patterned peatlands to open water habitats.

DISTRICT 2 Luce.
SUBDISTRICT 2.2. Grand Marais: sandy end moraine, shoreline, and outwash plains.

CLIMATE: The climate of the entire district is strongly influenced by Lakes Superior and Michigan, but these influences are greater at the northern edge of the district in subdistrict 2.2, the Grand Marais subdistrict, than in subdistrict 2.1, the Seney subdistrict. The growing season ranges from less than 100 days in the interior of the district, to 140 days along Lake Superior. The extreme minimum temperature ranges from -30° F along Lake Superior, to -46° F further inland in subdistrict 2.1. Average annual precipitation ranges from 32 to 34 inches. Annual snowfall is as high as 180 inches near the Lake Superior shoreline, while further inland, average snowfall is 80 to 100 inches.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: An east-west trending sandstone escarpment of Cambrian age is exposed in several waterfalls, including Tahquamenon Falls, Au Train Falls, Miner's Falls, and Laughing Whitefish Falls, and along the Lake Superior shoreline at Pictured Rock National Lakeshore and Grand Island (Dorr and Eschman 1984). Farther inland, Ordovician sandstone and dolomite are the underlying bedrock (Reed and Daniels 1987).

Sandy ridges of end moraine and pitted outwash are characteristic of the northern edge of the subdistrict. There are locally numerous kettle lakes in the pitted outwash. Recent geomorphological interpretation suggests that many of the end moraines (as originally interpreted by Leverett 1929) are actually heads of outwash and related stagnation landforms (Blewett and Rieck 1987). Lacustrine deposits of glacial and postglacial origin are also located along the northeastern edge of the district. Lacustrine deposits within the district consist primarily of droughty sand dunes and beach ridge deposits, but also include some poorly and very poorly drained glacial lacustrine deposits. An extensive complex of sand-spits at Whitefish Point, in northwestern Chippewa County, consists of hundreds of alternating swales and sand-spits. Most of the beach ridge and swale complexes along Lake Superior are unique in that they are excessively drained, unlike ridge and swale complexes along most shorelines of the Great Lakes. The Grand Sable Dunes, west of the town of Grand Marais, are large, steep dunes perched on till. Outwash plains are concentrated along the southern edge of the district. There is also a relatively small area of poorly drained outwash at the extreme west edge of the district. Along the shoreline, outwash is restricted to areas west of Munising, west of Grand Marais, west of Nodoway Point and south of Vermilion.

Most of the moraine ridges and pitted outwash have well drained, sandy soils. Kettles within the pitted outwash and moraines contains bogs with thick deposits of sphagnum peat. At the far western edge of the district, where sandstone bedrock is only thinly covered by till, soils are moderately well drained. Along the Lake Superior shoreline, sand dunes, sand spits, and beach ridges form a broad zone characterized by vast expanses of excessively drained sands. The soils are classified as Histosols and Entisols (Aquepts), with some Orthods and Aquods (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Sandy lake plain in this subdistrict supported a number of wetland and upland communities. Emergent marsh (6221), bogs (6121), and alder-willow swamps (6122) were common in the swales associated with the shoreline and small lakes immediately inland. Wooded dune and swale complexes (911) also occurred on the sandy lake plain. Most examples were excessively drained and supported jack pine-red pine (4215), red pine (4212), and red pine-white pine (4216) forests. At Whitefish Point the dunes also supported aspen-white birch forests (413). However, the complex at Tahquamenon Bay primarily supported spruce and tamarack-dominated swamp (423). And the swales at Au Train and Whitefish Point supported tamarack (4233) and shrub swamps (6122). Great Lakes marsh (6222) was noted near the mouth of the Au Train River and in Morrow Bay, at the southeast end of Grand Island. The Au Train marsh is best described as a fresh water estuary or drowned river mouth created when barrier dunes restricted the river's flow into Lake Superior.

Upland portions of the lake plain that were better protected from wildfires were extensive along the shoreline. These areas supported forests dominated by hemlock (4226), northern hardwoods (4111), and hemlock-white pine (4227). In contrast, excessively drained, fire-prone forests were dominated by jack pine (4213) and red pine-jack pine forests (4215). These pine-dominated forests were extensive along the shoreline between Grand Marais and Whitefish Point.

Clay lake plain at Taquamenon Bay supported spruce, tamarack, and cedar-dominated swamps (423). Narrow strips of clay lake plain along the shore of Lake Superior in Luce County supported hemlock-white pine forests (4227).

Coarse textured moraines are common south of Tahquamenon Bay, Pendills Bay, and Vermilion as well as along the southern edge of the district. These areas supported northern hardwoods (4111), often with significant amounts of hemlock. They also supported hemlock-sugar maple (4228) and hemlock-yellow birch (4229) forests. Small cedar, tamarack, and spruce-dominated swamps (423) were also found on these moraines. On somewhat poorly drained tills, where bedrock is near the surface, hemlock and white pine were dominant species. Small cedar and tamarack-dominated swamps also occurred on the end moraines east of Munising.

The excessively drained sand soils of broad outwash plains supported red pine-white pine forests (4216) and jack pine forests (4213). An area described by the surveyor as a jack pine thicket was located on what is now Raco Field. A pine "opening" (333) two to five miles wide and approximately 13 miles long was also found on the coarse-textured deposits south of Pendills Bay. This area was described as being "nearly destitute of timber" and as "containing much fallen timber." It was dominated by red and white pine.

Poorly drained outwash was uncommon in this subdistrict. Where it did occur, just west of Munising, there was cedar dominated swamp (4231), "alder bottoms" (6122), and wet meadow (6224). Upland outwash supported hemlock forests (4226), dense jack pine forests (4213), and barrens (333) of jack pine, red pine, and occasionally, white pine. Pitted outwash and end moraines supported northern hardwoods (4111).

The Grand Sable dunes were active, and were described as "barren sandhills" by the surveyors. At their protected east end they supported a small area of northern hardwood forest (4111) and a few, small pockets of jack pine (4213) persisted within the dunes. Sandstone cliffs (745) were noted by surveyors at Pictured Rocks National Lakeshore and west of Pendills Bay.

NATURAL DISTURBANCE: Surveyors recorded that forests at the mouth of the Tahquamenon River had been burned. There were also several mentions of fire in pineries on the sand ridges along Lake Superior, between Whitefish Point and Grand Marais. A large windthrow was noted in the cedar-tamarack swamps east of Beaver Lake within Pictured Rocks National Lakeshore. A windthrow noted on the north half of Grand Island was estimated as having blown down 1/3 of the timber in the area. Other concentrations of windthrow and fire were mentioned near Bass lake and Long Lake in Luce County. A windthrow approximately six square miles in size was noted on the large outwash plain north of Seney. The surveyors also noted beaver flooding along the creeks around present day Melstrand.

HUMAN LAND USE: Surveyors noted several Native American trails, fields, and sugar camps west of Tahquamenon Bay, and near Munising. Early European settlements were established on Grand Island and west of Munising at the time of the surveys. At the time of the surveys, James Pendill's sawmill was already established at the mouth of what is now Pendills Creek (Karamanski 1989). A trading post had been established at Munising.

The dominant use of this subdistrict has been commercial timber production and recreation. There are numerous roadways and railroad tracks throughout. Urban development has been mainly limited to the Munising area.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Although most of the wetlands in this region persist, they were probably altered by logging and post-logging fires. Roads and small dams have had the most significant impact on wetland hydrology in this subdistrict.

The upland forests have also been greatly altered by logging-era activities. On the droughty Raco Plains, jack pine dominance expanded, whereas areas of white and red pine have regenerated poorly. The Kingston Plains were dominated by forests of red pine, white pine, hemlock, and northern hardwoods. In the most severely burned areas, the only existing vegetation 90-100 years after logging consists of lichens, sedges, and scattered small (1-3 inches in diameter) black cherry and juneberry. Subsequently, portions of both plains have been planted to red pine or jack pine.

DISTRICT 3. Dickinson.

CLIMATE: The temperature is somewhat moderated by Lake Michigan. At the center of the district, the growing season is under 100 days, but farther both to the south along Lake Michigan and to the north along Lake Superior, the growing season is much longer, 140 days (Eichenlaub et al. 1990). The extreme minimum temperatures recorded for the district range from -32° F near Lake Michigan and Lake Superior, to -40° F at the inland edge of the district. At the northern end of the district, in the Gwinn and Deerton Subdistricts, lake-effect snowfall off Lake Superior averages 100-140 inches. Influence of the Great Lakes on snowfall is less at the southern end of the region, where snowfall is a relatively light, 60-80 inches annually (Eichenlaub et al. 1990).

DISTRICT 3 Dickinson.
SUBDISTRICT 3.1. Hermansville: drumlins and ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The bedrock in the northern third of the subdistrict is Cambrian sandstone, whereas bedrock in the remainder is Ordovician limestone, dolomite, and sandstone, and Silurian dolomite (Dorr and Eschman 1984, Reed and Daniels 1987). Paleozoic limestone and dolomite bedrock is generally within 40 feet of the surface, accounting for the rocky nature of the glacial drift and also the nutrient-rich, sandy loam soils (Vanlier 1963, Sinclair 1960). It is probably also responsible for the extensive areas of poorly-drained soils in the subdistrict.

The topography of the greater part of the subdistrict consists of drumlin ridges trending northeast-southwest on relatively flat ground moraine. Surface deposits of glacial drift reflect the local bedrock from which the till was derived. Drumlin ridges are typically 1/8-1/4 mile wide, less than a mile long, and 20-60 ft. high (Albert et al. 1986). The highest drumlins are less than 100 ft high. The northern end of the subdistrict includes large expanses of rolling ground moraine, some of which is well drained.

Rocky, podzolized, pink sandy loams are common in the subdistrict. Soils on the drumlins are generally well to moderately-well drained, but some of the smaller, more gently sloping drumlins can have poorly drained soils (Albert 1990). Peat and muck soils are common. Soils are classified as Alfisols, primarily Udalfs with Aquolls in the south, and as Spodosols, primarily Orthods, in the north (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: On the larger, loamy drumlins, northern hardwoods of beech and sugar maple (4111), beech and hemlock (4119), or sugar maple and hemlock (4228) were dominant. Forests of sugar maple, in combination with yellow birch and balsam fir (4115), or with basswood (4117), were found among the rolling ground moraine at the western end of the subdistrict in Dickinson County. On the smaller ridges, conifer-dominated forest of hemlock (4226), white pine (4211), or a combination of hemlock and white pine (4227) were common. Also, in lower, less well drained areas, hemlock was commonly in combination with yellow birch (4229) or with cedar (4222). Throughout the drumlin fields, small pockets of aspen and birch forests (413) were associated with windthrows of variable size. Portions of the well drained ground moraine at the north end of the subdistrict were dominated by sugar maple and hemlock (4228), with some portions dominated by beech and sugar maple (4111).

Wetlands covered all but the drumlin ridges, accounting for large percentages of the land surface. A cross-section of the flat plain between the drumlins had swamp of northern white-cedar (4231), often with tamarack, at the margins of the drumlins (on poorly drained mineral soil or shallow organic soils), with swamps of tamarack (4233) or black spruce (4232) at the center of the plain (on very poorly drained peats or mucks). Black ash swamps (4141) were noted in a few places in Menominee County, at the base of drumlin ridges. There was often a band of emergent marsh (6221) or alder-willow thicket (6122) along streams within the swamps. Several bogs (6121) and large "open swamps," or muskegs (6125) of tamarack and spruce were noted in larger depressions between drumlin ridges.

NATURAL DISTURBANCE: Large areas of windthrow were common both on the uplands and in the lowlands. Uplands were windthrow-prone because the upland forests stood above the surrounding wetlands, exposed to strong winds off Lake Michigan. Poor drainage in the wetlands caused shallow rooting that increased the chances of windthrow. Several very large windthrown and burned areas, each encompassing 10-15 square miles were associated with the Escanaba River. One area extended from the river northeast to the town of Rock (NW Delta County). Two other large areas were noted northwest of Gladstone. It is possible that these fires were associated with early logging activities. Smaller clusters of windthrows were mentioned near the town of Nadeau and near the Cedar River, a few miles to the east.

HUMAN LAND USE: Logging began early in this subdistrict, primarily for the white pine. Logging for northern white-cedar and hemlock followed. Although many large areas of upland hemlock remained until quite recently, these have been cut and some have been planted to red pine plantation.

The loamy drumlin ridges were extensively cleared for agriculture. Most of the uplands were cleared for pasture, but corn is also planted. Some of the lowland forests were also cleared and used for pasture.

Very little urban development exists within this subdistrict. Much of the northern end of the subdistrict lies within state forest lands.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Much of the northern hardwood and mixed hardwood-conifer forest located on larger drumlin ridges have been cleared for pasture. There are, however, isolated ridges within extensive swamps that remain forested. Most of the cedar and mixed conifer, or hardwood-conifer swamps remain in this subdistrict, although many have been crossed by roads. Past logging and deer browse have favored hardwood regeneration in many swamps. Some cedar swamps have been converted to pasture. Ash swamps, often localized along the margins of drumlin ridges, remain forested, though some have been partially converted to pasture. Most of the tamarack and spruce-dominated swamps occupy highly unproductive, very poorly drained basins. They remain dominated by tamarack or a mixture of tamarack and black spruce. Most bogs have undergone no management. Alder thickets persist along the margins of most small streams.

DISTRICT 3 Dickinson.
SUBDISTRICT 3.2. Gwinn. poorly drained sandy outwash.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The bedrock in this subdistrict is Cambrian sandstone. The surface of most of the subdistrict is a large outwash plain In the north, the outwash is locally quite thin over bedrock. Near Gwinn, there are numerous kettle lakes and depressions, some containing ponds and bog vegetation. Farther to the south, the outwash slopes gradually to the southeast. The southern portion of the subdistrict has thick, acid, organic soils over sand or sandy loam. The northern portion has excessively drained sand soils. The Escanaba River flows through the wetland at the southeast end of the subdistrict. Bedrock is exposed at the margins of the outwash plain in the west.

PRESETTLEMENT VEGETATION: The extensive conifer swamps (423) contained northern white-cedar at the upland margins, with increased amounts of black spruce and tamarack dominant in the wetland interior. a large spruce and tamarack-dominated muskeg (6125) was noted along the Escanaba River west of Cyr Swamp. Swamp hardwoods include balsam poplar, red maple, paper birch, and black ash.

The excessively drained outwash supports jack pine forest (4213) and, in a few places, open jack pine barrens (333). Wetlands within the outwash plain were either shallow emergent marsh (6221) or tamarack swamp (4233). Forests of white pine and red pine (4216), or white pine and hemlock (4227) were common at the southern and western margins of the outwash plain, where there were numerous kettle lakes. White pine and hemlock stands are locally dominant on the margins of these kettle lakes. Hemlock, in combination with yellow birch (4229) was noted at the western end of the subdistrict in moderately well drained uplands.

NATURAL DISTURBANCE: Very few windthrows were mentioned by surveyor's in this subdistrict, but portions of the outwash plain were described as recently burned and shrubby thickets of jack pine were also noted.

HUMAN LAND USE: Several logging roads had been established in the early 1850s when this area was surveyed. The logging roads probably were based on existing Native American trails that connected the Escanaba River with the Lake Superior shoreline near the Chocolay River mouth. Most of the valuable timber from this subdistrict was removed during the logging era. Today, the towns of Gwinn, New Swanzy, Little Lake, and the K.I. Sawyer Air Force Base dominate upland portions of this subdistrict. The swamps, for the most part, remain.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Wetlands in this subdistrict remain dominated by conifers, although logging probably shifted relative composition toward hardwoods. Jack pine remains the dominant vegetation on the droughty outwash. The pine barrens, if not eliminated by urban development, were likely eliminated by the suppression of fire, which is necessary to maintain open conditions. Locally white pine and hemlock remain among the kettle lakes, but many of these stands were logged and replaced by quaking aspen and paper birch. Forests of white pine and red pine also persist near the Escanaba River west of Gwinn.

DISTRICT 3 Dickinson.
SUBDISTRICT 3.3. Deerton: sandstone bedrock and high, sandy ridges.

CLIMATE: Minimum temperatures are moderated along Lake Superior, ranging from -28° F to -32° F, but are -38° F at the inland edge of this small subdistrict. The growing season ranges from 140 days along Lake Superior to less than 100 days along the inland margin of the subdistrict. Average precipitation is 32 to 34 days and annual snowfall ranges from 120 to 140 inches.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Large, rounded, sandstone knobs typically covered with a mantle of sandy glacial drift may be found on the eastern portion of the subdistrict. The western portion has irregular, steep sand ridges. Elevations range from 602-1300 ft.

The bedrock knobs, 100-200 ft. high, have steep sides and relatively flat tops. Exposed at the surface or underlying the glacial drift are Cambrian age Munising and Jacobsville sandstones (Dorr and Eschman 1984, Hamblin 1958). Most of the bedrock is covered with a veneer of sand or rocky till. However, bedrock is occasionally exposed in roadcuts, or more dramatically, in steep ravines, such as the one at Laughing Whitefish Falls. The surveyors mentioned bedrock exposures in several places. Where glacial drift is thick, soils are well drained. Where drift is thin, drainage is poor, and large swampy areas occur. The drift is very rocky. West of Munising, large boulders, several feet in diameter, are common on the surface.

The high sand ridges (100-200 ft.) in the west have been deeply eroded by postglacial streams. Steep valleys, only 300-400 ft. wide, are up to 150 ft. deep. The soils are well drained sands.

PRESETTLEMENT VEGETATION: Cedar, spruce, and hemlock dominated many of the small swamps (423) associated with thin soils over bedrock. Hemlock (4226) was especially common on many of the poorly drained bedrock ridgetops and in the steeper ravines. The large, rounded bedrock knobs were occupied by northern hardwood forests (4111). Sugar maple, hemlock, yellow birch, and white pine forests (4228) and hemlock-white pine forests (4227) were found on the side slopes and lower topographic positions in this area. Beech was generally absent from the steep ridges found on the western portion of this subdistrict. Southeast of Sands, a large aspen-birch forest (413) was noted along the slopes east of the large outwash plain in adjacent subdistrict 3.2. This stand likely resulted from a fire originating on the adjacent, droughty plain. The northwestern extreme of this subdistrict includes an outwash plain that supported both red pine and white pine (4216) and hemlock and white pine (4227) forests.

The long, narrow wooded dune and swale complexes (911) just east of Marquette along Lake Superior, were dominated by red pine-jack pine forest (4215) and jack pine forest (4213) on the dunes and mixed lowland conifer swamp (423), marsh (6221), and bog (6121) in the swales. Inland from these complexes, still on sand lake plain, there were extensive mixed conifer- hardwood swamps (42) composed of northern white-cedar, hemlock and birch, as well as alder swamps (6122) and cedar swamps (4231) along the Chocolay River. A narrow strip of Great Lake marsh (6222) stretched east from the mouth of the Chocolay River for approximately 3.5 miles.

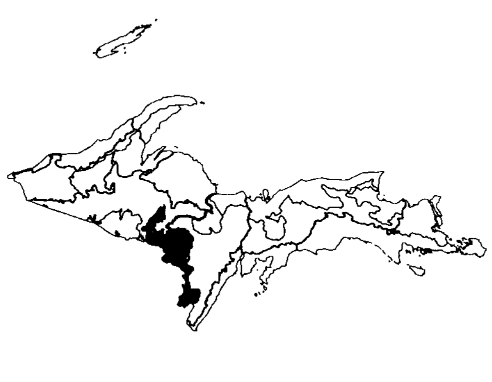
NATURAL DISTURBANCE: No major natural disturbances were recorded by surveyors in this subdistrict.

HUMAN LAND USE: The dominant land use in this subdistrict has included logging and, more recently, recreation and intensive residential development, especially along the shoreline.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The influence of logging-era activities decreased the relative composition of hemlock and white pine in upland forests. A number of small rivers were dammed, altering wetland drainage. Urban development and road construction along the shoreline has significantly altered upland and wetland vegetation.

REGION IX. Western Upper Michigan.

REGIONAL CLIMATE: The region has a strongly continental climate, with only moderate influence from Lake Superior. Temperatures are extremely cold in the winter. Snowfall and rainfall are high adjacent to Lake Superior as a result of moisture laden air from the lake being forced to rise rapidly over the bedrock uplands at the northern edge of the region (Eichenlaub et al. 1990, Eichenlaub 1979, Albert et al. 1986). The growing season ranges from less than 75 days inland to 150 days along portions of the Lake Superior shoreline (Eichenlaub et al. 1990). Annual precipitation ranges from 32 to 36 inches. Annual snowfall ranges from 46 inches inland to 200 inches of lake-effect snow south of Lake Superior. Extreme minimum temperatures range from -28° F along Lake Superior to -50° F inland.



DISTRICT 1 Norway: till plain, outwash, sandstone bedrock, and granitic bedrock.

CLIMATE: The temperature is moderated by Lake Michigan. The growing season can be shorter than 100 days (Eichenlaub et al. 1990). Extreme minimum temperatures are about -40° F. At the southern edge of the district, snowfall is a relatively light, 70-80 inches annually (Eichenlaub et al. 1990). Average annual precipitation is relatively uniform, ranging from 30-34 inches.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: While much of the district is blanketed with outwash sands and till, there are numerous exposed bedrock knobs of Precambrian bedrock. The bedrock is primarily granite and quartzite, including iron bearing rocks of the Vulcan Formation of the Menominee Range (Dorr and Eschman 1970). Iron ore was mentioned as being at the surface in several locations within this district. The elevation of the ridges reaches 1530 ft. in the south end of the district. Many of the ridges are sand capped, but both the shape of the ridges and localized bedrock outcrops indicate that all of the ridges have bedrock cores.

Surrounded the bedrock knobs are extensive outwash plains, especially along the Menominee River. Some of the outwash plains are pitted, containing many ice-block depressions, which frequently contain wetlands and kettle lakes. Large rivers flowing across the outwash include the Paint, Michigamme, and Menominee. Steep end moraine ridges are also common along the Menominee River, and there are inclusions of sandy ground moraine and end moraine.

Droughty outwash sands, thin sandy soils on bedrock, sandy loams and loamy sands on ground moraine and end moraine characterize the soils of the district. The greater portion of the plains is excessively drained. Depressions in the outwash contain peat deposits.

PRESETTLEMENT VEGETATION: Bedrock knobs with thin, sandy soils, most concentrated in south-central Dickinson County, supported forests of sugar maple and hemlock (4228), hemlock and white pine (4227), red and white pine (4216), aspen and paper birch (413), and white spruce with balsam fir (4223). A similar mix of forest types was found on the end and ground moraine in western Menominee County, with sugar maple and hemlock covering the greater portion of the landscape. Northern hardwoods with a significant component of beech (4111) reach their western extreme near the Menominee River, at the eastern edge of this district. Other tree species reaching the northern edge of their distribution in Michigan along this portion of the Menominee River include pig-nut hickory and butternut. White pine, beech, and red maple (4219) were also common on end moraine further south, east of the Menominee River, adjacent to fire-prone outwash deposits. This forest may be a fire-successional variant of northern hardwood forests in the region. Wetlands among these landforms were predominantly mixed conifer swamps (423) with black spruce, tamarack, balsam fir, and hemlock, or alder and willow shrub swamps (6122).

The greater portion of the outwash plains, which are concentrated in southern Iron County along the Michigamme River, and in southern Dickinson County and southwestern Menominee County along the Menominee River, are excessively drained and supported jack pine (4213) red and jack pine (4215), red and white pine (4216). In the most frequently burned areas, such as at Shakey Lakes, Menominee County, pine barrens (333) and oak-pine barrens (334) were dominant. Outwash deposits around Iron Mountain were dominated by extensive areas of aspen and paper birch (413), as was nearby sandy ground-moraine ridges. The northern end of the district in Iron County, well drained portions of the outwash supported hardwood and conifer-hardwood forests of sugar maple, yellow birch, and balsam fir (4115) or sugar maple and hemlock (4228). Small depressions in the outwash contained either depauperate bog-like wetlands (6121) or wet meadows (6224). Several large swamps dominated by black spruce (4232) or a mixture of spruce and tamarack (6125) were mentioned on outwash deposits between the Paint and Michigamme rivers. Floodplains dominated by hardwood and/or conifer swamp (41, 42, 414, and 423) were common along major rivers within the district.

NATURAL DISTURBANCE: Fires and windthrows were quite extensive on outwash deposits east of the Menominee River, especially at Iron Mountain, near Nathan, and further south around Shakey Lakes. A cluster of small windthrows was recorded near Channing. Beaver dams were mentioned by surveyors throughout this subdistrict.

HUMAN LAND USE: At the time of the surveys in the 1840-50s, Native American trails and settlements were noted in several places along the Menominee River. The area with the most extensive activity was around Iron Mountain (Trygg 1964). Mining for iron occurred within the district, and the pineries were logged at the turn of the century. There are extensive State Forest lands within the district, managed for timber, wildlife, and recreation. Several highways and many two track roads cross the district. Michigamme Reservoir and Peavy Pond are two large reservoirs in the district. Urban development is concentrated at Iron Mountain, Kingsford, Quinnesec, and Norway.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Following intensive iron mining in the late 18th and early 19th centuries, no mines remain active within the district. Aspen and paper birch presently dominate many of the lands once dominated by either northern hardwoods or mixed red and white pine, and are presently harvested for pulp. As a result of past land use, jack pine has increased in relative abundance on the outwash plains, while both red pine and white pine have declined. Fire suppression during this century has allowed once-open pine barrens to succeed to closed-canopy oak and oak-pine forest.

DISTRICT 2. Michigamme: granite bedrock.

CLIMATE: The climate is continental, with lake effect limited to a narrow zone along Lake Superior. The growing season is short, ranging from 75 in the interior to 100 days along the Lake Superior coast; most of the variation occurs within 10-15 miles of the coast (Albert et al. 1986). Extreme minimum temperature varies from -28° F along the coast to -46° F inland (Eichenlaub et al. 1990). Snowfall is heaviest inland, averaging 200 inches, and lightest along the coast, averaging 120-140 inches. The average annual precipitation is 32 to 36 inches, with the most precipitation at high elevations inland.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Precambrian age bedrock consists of diverse types of metamorphic, igneous, and sedimentary bedrock, including sandstone and shale, gneiss, amphibole, slate, metagraywacke, quartzite, mafic volcanic rocks, and iron formation (Morey et al. 1982). The iron formations were once heavily mined in the Michigamme Range. Exposed bedrock knobs characterize large parts of the district. Elevations rise rapidly from Lake Superior at 602 ft. to a maximum of 1980 ft. at Mount Curwood, the highest point in the state (Albert et al. 1986).

Although bedrock generally controls topography, the character of the topography is variable. In some areas the terrain is a mosaic of low rocky ridges less than 50 ft. high, with many small lakes and swamps (Albert et al. 1986). In other areas, like the Huron Mountains, large, exposed ridges of granite or sandstone can be 300-500 ft. high. There are large areas of sandy ground moraine. The Yellow Dog and the Mulligan plains, two large outwash plains, separated by only a few miles, occur within the district.

The soils are generally sands. Local silt caps of aeolian origin covers some of the rock knobs (Pregitzer and Barnes 1984). The tops of the bedrock knobs have little or no soil. All of the soils are very acid. The soils on the two outwash plains are excessively drained sands. Soils of the entire district are classified as Spodosols, primarily Orthods (Soil Conservation Service 1967).

PRESETTLEMENT VEGETATION: Sugar maple and hemlock were co-dominants (4228) in the uplands of this district within 10-15 miles of Lake Superior. White pine and hemlock (4227) were common in many steep-sided ravines. Hemlock and yellow birch (4229) were common on less well drained ground moraine. American beech was only infrequently mentioned in this district. It only occurred within 1-2 miles of the Lake Superior shoreline, where the severe, low winter temperatures are moderated. Further inland, sugar maple was often co-dominant with yellow birch (4115). These forests typically included a significant component of balsam fir and some northern white-cedar, but very little hemlock. White spruce and balsam fir (4223) were also found in this area where soils were quite thin over bedrock. Sugar maple and basswood were co-dominant (4117) on a small portion of ground moraine at the western and southern end of the district. Exposed bedrock was most prominent around the Huron Mountains. Scattered white pine, red pine, and red oak were the dominant trees on exposed ridges.

Jack pine (4213), red pine and jack pine (4215) dominated the extensive outwash sands of the Yellow Dog Plains, along with some aspen-birch (413) and red pine and white pine (4216) forests. Red and white pine forests (4216) dominated other excessively drained sands on smaller outwash and sand lake plains along Lake Superior. Aspen-birch forest was especially common near Marquette.

Some of the largest wetlands for this district were along the Lake Superior shoreline on sandy lake plain. Great Lakes marsh (6222) was noted along the Iron River near its mouth. Wooded dune and swale complexes (911) are located at Little Presque Isle, Big Bay, Iron River, the mouth of the Salmon Trout River, and at the Pine River mouth. The complex at Little Presque Isle, which is mostly upland was dominated by red pine forest (4212). The complexes at the Iron and Pine rivers were also mostly upland, with jack pine and red pine (4215) most common. The complex at Big Bay was mostly bog (6121) and tamarack swamp (4233). The complex at the Salmon Trout River was dominated by cedar and white pine (423) and bog (6121) inland, and alder-willow swamps (6122) closer to the shoreline. Farther inland, large mixed conifer swamp (423) was found on ground moraine near the headwaters of the Salmon Trout River. The many small streams with steep-sided ravines in west-central Marquette County and adjacent Baraga County often supported mixed conifer swamp (423) and shrub swamp (6122) along their margins. These wetlands were narrow, typically less than an 1/8th of a mile wide. Small wetland depressions with the bedrock and thin-soiled landscape were often less than 40 acres in area and were typically dominated by mixed conifer swamp (423). More extensive swamps of similar composition were found on the southern end of the district. These swamps typically contained balsam fir, tamarack, and black spruce.

NATURAL DISTURBANCE: Extensive burned forests were reported by surveyors around Marquette. No major windthrow areas were recorded by surveyors in this district. Recent studies within the Huron Mountains have shown that windthrown trees are common on the rocky, thin soils (Simpson et al. 1990), but that these windthrows were probably too small to have been recorded by the surveyors. A large (3-5 square mile) windthrow was noted at the west end of the Yellow Dog Plain. Beaver dams were mentioned by surveyors throughout this subdistrict.

HUMAN LAND USE: Native American encampments and trails were noted by surveyors at Marquette, Big Bay. Trails extended south from the Carp River mouth to the Escanaba River, and west toward Lake Michigamme (Trygg 1964). By 1846, when this area was surveyed, iron mining activities by European companies had already begun. Furnaces and forges were already established in and around Marquette. Roads were established leading west and southwest of the village, and some rivers had already been diverted for use in mining activities. Logging and mining have represented a major portion of land use activities in the subdistrict. Urban development is concentrated around Marquette and recreational use occurs throughout. Roads and highways are most concentrated along Lake Superior and on the southern boundary of the district. Though there are extensive two-track roads, this district includes significant roadless areas. There are some state and federal lands within the district, and the Huron Mountain Club maintains an 8,000 acre old growth forest preserve. These forests are discussed in detail in Simpson et al. (1990).

INFLUENCE OF HUMAN LAND USE ON VEGETATION: The diversion of creeks and rivers have undoubtedly altered associated lakes, streams, and wetlands; either by flooding or removal of water sources. Several large impoundments are highly polluted by mine tailings and chemical products of mining. Roads leading out of Marquette have also altered some wetlands. Logging, as elsewhere in the region, has changed the relative composition of white pine and hemlock in uplands and favored aspen-birch forest.

DISTRICT 3: Iron

CLIMATE: Lacustrine moderation is less here than in any other district in Michigan. The growing season is a short 87 days. The chance of late spring frosts is greater in this district than any other in Michigan. Winters are cold; extreme minimum temperatures range from -45°_F to -50°_F (Eichenlaub et al. 1990). Annual snowfall ranges from 40 to 140 inches (Eichenlaub et al. 1990), with the greatest amounts in the northern part of the district, nearer to Lake Superior. Severe winds associated with squall lines and thunderstorms may have a strong influence on forests.

SUBDISTRICT 3.1. Iron River. drumlinized ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Glacial drift covers bedrock, which is only locally exposed. The predominant bedrock types are

Precambrian basaltic to rhyolitic metavolcanic rock with some metasedimentary rock (Morey et al. 1982). The western part of the Menominee Iron Range is within the subdistrict.

The subdistrict is characterized by drumlin ridges and adjacent swampy depressions that are oriented northeast-southwest. The ridges are typically 1/3-1/2 mi. wide, one mile long, and 80-140 ft. high. Glacio-fluvial deposits of sand and gravel surround many of the drumlins, but these are often covered with a thin silt cap, resulting in vegetation dominated by northern hardwoods. The majority of large lakes within the subdistrict are linear, with the same general trend as the adjacent drumlins. The lake basins were eroded by glacial ice. Among the larger lakes are Smoky Lake, Brule Lake, Golden, Chicagon, Stanley, Ottawa, and James lakes. Smaller kettle lakes are also scattered throughout. Small creeks and rivers are abundant, draining the numerous linear wetlands between the drumlins.

The soils are generally well drained, derived from rocky, red, sandy loam till or gravely, loamy sand outwash. Often the soils have a thin silt cap of loess. At the northern edge of the subdistrict, the loess is localized. Often one side of an outwash channel will have a thin loess cap, while the other will not. Fragipans are common, often resulting in poor drainage conditions on flat ridge tops. The soils are reddish in color from the abundance of iron in the local bedrock.

PRESETTLEMENT VEGETATION: Northern Hardwoods with sugar maple and yellow birch co-dominant (4115) were common in this subdistrict. These forests had greater amounts of white ash, American elm, and basswood on silt-capped soils than on sandy loam soils. On deeper, well drained soils, hemlock was more abundant (4228), while on more poorly drained, sandy soils, hemlock was co-dominant with yellow birch (4229). White spruce-balsam fir forests (4223) were also found on these soils as well, especially where they occur along rivers.

Tamarack and black spruce dominated mixed conifer swamps (423) in most depressions between the drumlin-like ridges, and the centers of some of these depressions supported bog (6121) and wet meadows (6224). Tamarack was typically dominant along the edges of these depressions and was gradually replaced by black spruce toward the center. Northern white-cedar was occasionally present at the edges of depressions, but the ground and end moraines generally contain little of this species. Black ash, yellow birch, and American elm dominated mixed hardwood swamp (414) and hardwood-conifer swamp (41) on better drained depressions.

NATURAL DISTURBANCE: Windthrows were large and relatively common on broad ridges, based both on the survey notes and field studies (Albert 1990). Based on field observations, the surface of the drumlins is in most cases almost completely covered with windthrow mounds. Beaver dams were mentioned by surveyors throughout this subdistrict.

HUMAN LAND USE: At the time of the surveys, Native American trails passed through this subdistrict, primarily connecting settlements, sugar camps, and rivers in the south to those further north. Iron mining was once important near the city of Iron River, on the Menominee Iron Range. The logging-era reached its peak in this part of the state at the turn of the century. Today, much of the western half of this subdistrict falls within the Ottawa National Forest. The uplands are managed for timber, wildlife, and recreation, but locally the broad ridges are pastured. Several highways and many forest roads traverse the subdistrict, and urban development is centered around Iron River.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Today, northern hardwoods are dominant on both sandy loam and silt loam soils. American elm, basswood, white ash, and yellow birch are much more common on silt loams than on the sandy loams (Albert 1983). Where the linear depressions between the drumlinized ridges are drained by streams, American elm and balsam fir are common.

SUBDISTRICT 3.2. Crystal Falls. kettle-kame topography, outwash, and sandy ground moraine.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The Archean-age metamorphic and igneous rocks include granite, metavolcanics (including wacke, conglomerate, and iron formation) and metamorphosed mafic-intermediate volcanic rock (including greenstone, gneiss, and amphibolite) (Morey et al. 1982). In most of the subdistrict, glacial drift is generally thick, 200-300 ft. over the Precambrian bedrock.

The most common landforms include ice stagnation features (kettle lakes within a landscape of steep ridges), end moraines, ground moraine, and outwash. Irregular lobes of end moraine, in which kettles and steep ridges comprise the majority of the landscape. The subdistrict has a poorly developed drainage system due to the irregular topography. In large areas there are almost no streams; instead ground water flow is important for water movement. Kettle lakes are quite common. The water of the kettle lakes is acid and low in nutrients.

The glacial drift of the entire subdistrict is acid, rocky, red sandy loam or loamy sand, derived from the iron-rich, local Precambrian bedrock. Soils are podzolized sandy loams and loamy sands. Fragipans are common throughout the subdistrict (Albert 1983). Most of the soils are classified as Fragiorthods and Haplorthods.

PRESETTLEMENT VEGETATION: On the ground moraine in the eastern part of the subdistrict, northern hardwood forests of sugar maple, yellow birch, and balsam fir dominated much of the well drained soils. White spruce and balsam fir forest (4223) was also common, especially in low-lying areas adjacent to swamps. Large mixed conifer swamps (423) of tamarack and black spruce, more "open swamp," or muskeg (6125), and bogs (6121) were found in poorly drained portions of ground moraine.

Further west, sugar maple with hemlock (4228) dominated uplands within the end moraine and ice-contact topography. The end moraine and ice-contact topography contains many kettle depressions, some of which are occupied by small lakes. In the Sylvania Recreation (Wilderness) Area, close to fifty percent of the landscape is occupied by kettle lakes. Hemlock and white pine (4227) occupied the more fire-prone lake margins on steep south and west aspect slopes.

Many of the smaller kettles are completely occupied by bogs (6121) and low productivity black spruce and tamarack swamps (423), which range in size from a few acres to 100s of acres. In parts of the ice-contact landscape, these wetlands cover more than half the land surface. Between Winslow Lake and Perch Lake, in northern Iron County, there are several large areas of aspen-birch forest (413) on somewhat poorly drained end moraine. Although the area is mapped as end moraine, the relief is low and bedrock appears to be close to the surface, which would account for the extensive areas of wetland. Upland forests of balsam fir, spruce, and northern white-cedar (4223) were also common in the same general area.

The Baraga Plains, the most extensive outwash deposits within this subdistrict, supported a mosaic of open jack pine barrens (333) and pine forests similar to those described in he northern Lower Peninsula. Pine barrens dominated central portions of the outwash plain where wildfires were most frequent. Surrounding the open barrens were forests of jack pine and northern pin oak (4213), red and jack pine (4215), and red and white pine (4216). Surveyors also described dense thickets of young jack pine (97) on the plain. Shallow wetlands on the outwash plain were described as emergent marsh (6221) and jack pine-dominated swamp (4236). Along the upper reaches of the Sturgeon River, a variety of forests included hemlock-white pine (4227), hemlock cedar (4222), sugar maple-hemlock (4228), and aspen-birch (413) were common.

NATURAL DISTURBANCE: Windthrow was common in the subdistrict, but typically did not exceed 100 acres in area. The size of individual windthrows was small on the stagnation moraine due to the irregularity of the landscape and the small size of the ridge tops. Several large fires were noted by surveyors near the Dickinson-Marquette County line. Extensive fires, in combination with small windthrows, were also reported on the Baraga Plains.

HUMAN LAND USE: In the 1850s, Native American trails within this subdistrict connected rivers and settlements further south with Keweenaw Bay. One trail was specifically noted as connecting Worm Lake to the Sturgeon River. Since the logging-era, land uses have been dominated by timber, wildlife, and recreational activities. This subdistrict contains large areas of state and federal forest land. The forested ecosystems of the Sylvania Recreation (Wilderness) Area is a large tract of virgin forest, located along the Michigan-Wisconsin border.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Following logging, the upland forests are dominated by hardwoods, primarily sugar maple and red maple, with very little hemlock or white pine present, although stumps and the soils characteristic of these conifers remain. Deer browse is considered by many to be the reason for poor conifer regeneration. Aspen-birch forests are also much more abundant now than they were historically. Wildfire suppression during this century has allowed much of the open pine barren on the Baraga Plains to succeed to closed-canopy, jack pine forest.

DISTRICT 5 Lac Vieux Desert: outwash plain.

CLIMATE: This district lies primarily in northern Wisconsin, and includes only two small portions that extend into Northern Michigan along the southern edge of Iron and Gogebic counties. The climate is continental, with cold winters and warm summers. The extreme low temperatures are between -45° F to -50° F. Annual precipitation averages 30-34 inches, and average annual snowfall is 50-90 inches. Growing season varies from approximately 100 days in the north to over 120 days in the south.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Precambrian bedrock is covered by 100-300 ft. of glacial drift. Underlying bedrock consists of quartzose sedimentary rock predominates, including mafic metavolcanic rocks and small bodies of granite and pegmatite. Locally there is gneiss, amphibolite, and foliated granite.

The surface of the district is largely pitted outwash plain, but it also includes coarse-textured end moraines and ice-contact sands and gravels. Kettle lakes are abundant throughout, especially on the pitted outwash. Many streams originate in extensive wetlands found on this flat outwash plain.

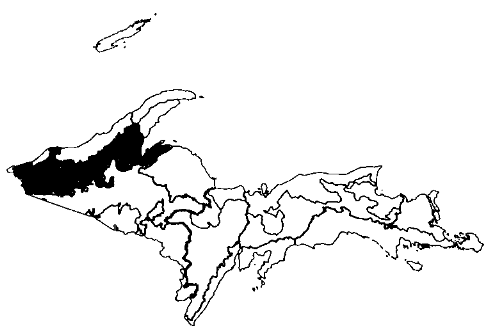
Soils are acid sands over large areas, often tens of feet thick (Hole 1976). Soil productivity is generally low because of low moisture-holding capacity and loss of soil humus through burning. Throughout the barrens, Omega loamy sand (Spodic Udipsamments) are common on upper slopes, while Vilas loamy sands (Entic Haplorthods) are common in depressions (Germain and Hole 1992). Spodosols will develop where there is stable vegetation (Hole 1976).

PRESETTLEMENT VEGETATION: White pine and red pine forests (4216) dominated the majority of the pitted outwash plain in adjacent Wisconsin. These forests were also found within Michigan west of Lac Vieux Desert. Elsewhere in the uplands, northern hardwoods with sugar maple and yellow birch (4115), white spruce-balsam fir (4223), and aspen-paper birch forests (413) were dominant. Conifer-hardwood swamp (42) were common in poorly drained areas.

NATURAL DISTURBANCE: Fire was mentioned by surveyors within this district west of Lac Vieux Desert.

HUMAN LAND USE: In the 1840-50s, there were Native American trails and sugar camps within this district. A Native American settlement was located at Lac Vieux Desert in 1830 (Tanner 1987). At the turn of the century, white pine and red pine were heavily logged. Today, the district is important for recreation, forest products (pulp), and wildlife management (grouse and other upland game birds). There are several roads within the Michigan portion of this district.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Past land use resulted in conversion of most upland forests to either paper birch and aspen or jack pine.



DISTRICT 6. Bergland.

CLIMATE: The growing season ranges from 110 to 130 days, and is longest near Lake Superior (Eichenlaub et al. 1990). It has a relatively cool growing season. Extreme minimum temperatures range from -40° F to -48° F. Average annual precipitation ranges from 30 to 36 inches. Heavy lake-effect snowfalls, ranging from 160 to 200 inches, characterize the district.

DISTRICT 6. Bergland.
SUBDISTRICT 6.1: Gogebic Iron Range.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The landforms of the district are the basis for further dividing the district into three subdistricts. The western portion of the district is noted for steep ridges of Keweenawan (late Precambrian) basaltic lavas and conglomerates, which rise several hundred feet above the adjacent lake and till plains. The ridges extend from northern Wisconsin to the north end of the subdistrict and on to the tip of the Keweenaw Peninsula and are part of the Lake Superior Syncline. Erosion-resistant conglomerates form the steep ridges, between which veins of highly eroded lavas form lakes and wetlands. Beginning at the south of the Keweenaw Peninsula, the volcanic bedrock ridges form a narrow, 1-2 mi. wide, 200-400 ft. high linear rock ridge, from Houghton in the northeast to Bergland in the southwest. This ridge is broken in several places by streams that have eroded through the bedrock. The channels of the East Sleeping, Firesteel, and Ontonagon rivers all occupy major breaks in the ridge. Broad breaks or depressions in the ridge are interpreted to be preglacial valleys (Leverett 1929). The Porcupine Mountains are a three or four miles wide and 10 mile long band of Keweenawan basalt and conglomerate ridges.

South of Bergland, the Keweenawan bedrock ridge is partially or completely covered with either fine- or coarse-textured till. Also included within this subdistrict is the iron-rich Penokee-Gogebic Range, a narrow band of Huronian age (middle Precambrian) bedrock.

Rocky, acid, red sandy loams and silt loams (Spodosols and Inceptisols) characterize the bedrock controlled topography at the western edge of the district. Poor drainage conditions characterize some parts of the bedrock-controlled plain.

PRESETTLEMENT VEGETATION: Northern hardwood forests dominated by sugar maple and hemlock (4228) were common throughout the well drained part of the ground moraine at the southwest end of the subdistrict. There are a number of plateaus at the tops of steep-sloping ridges extending from the Porcupine mountains to the east and northwest, nearly all of which were dominated by northern hardwoods of sugar maple and basswood (4117) with lesser amounts of sugar maple with yellow birch and balsam fir (4115). A narrow, broken band of basaltic bedrock ridges runs from the southwestern to the northeastern end of the subdistrict. Northern hardwood forests of sugar maple and basswood were the most common vegetation on these steep ridges, with scattered white pine, red pine, and red oak located on the bare rock or thin soils of the summit. Other forest types found on thin soils include aspen-birch forest (413) and white spruce-balsam fir forest (4223).

Wetlands within this subdistrict were typically mixed conifer swamp (423) dominated by black spruce and tamarack, or alder-willow shrub swamp (6122) which was common along river drainages. Emergent marsh (6221) and alder-willow swamp (6122) were located around the Lake of the Clouds in the Porcupine Mountains. The level ground moraine on either side of Lake Gogebic was a complex landscape of mixed conifer swamps (423) among upland forest of hemlock and cedar (4222), balsam fir, white spruce, and northern white-cedar (4223), hemlock and sugar maple (4228), and hemlock and yellow birch (4229).

NATURAL DISTURBANCE: A large windthrow, one mile wide and 15 miles long, was recorded by surveyors extending northeast from Ironwood. Other smaller windthrows were recorded further east in the subdistrict. Beaver ponds were also mentioned throughout the subdistrict.

HUMAN LAND USE: Tanner (1987) noted no Native American settlement within this subdistrict as of 1830. At the time of the surveys in the late 1840s, a number of mines and access roads were already established along the bedrock ridges. This activity was centered along the Ontonagon River, but was not limited to that area. Mining of the iron range continued for many years within this subdistrict. Nearly all of the area was logged beginning with mine development and continuing through the turn of the century. Today, portions of the subdistrict fall within the Ottawa National Forest and are managed for timber, wildlife and recreation. Porcupine Mountains State Park includes some of the largest remaining tracts of un-cut forest in Michigan. Roads and highways are found at variable densities throughout the subdistrict, and urban development is clustered around Ironwood, Bessemer, Bergland, Rockland, Greenland, and Houghton.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: As noted elsewhere in this region, logging era activities probably have changed the relative composition of white pine and hemlock in forests of this subdistrict. Many rivers and streams were diverted for use in mining and logging activities, resulting in alterations to associated wetlands. Roads have also altered wetland hydrology in places. For the most part, the wetlands of this subdistrict persist in some form.

DISTRICT 6 Bergland.
SUBDISTRICT 6.2: Ewen.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Bedrock within the subdistrict consists of Precambrian sedimentary rock of Keweenawan-age that is primarily sandstone, shale, and conglomerates. The shales are locally copper-rich. Bedrock is exposed in only a few places along streams within the subdistrict.

This subdistrict lies southeast of the bedrock ridges of the Gogebic Iron Range, where there is a relatively small area of older glacial lake plain created by Glacial Lake Ontonagon (Leverett 1929) that extends about 25 miles further inland than the lake plain of district 8. This lake bed is deeply dissected by several rivers and is separated from district 8 by a narrow band of steep volcanic bedrock ridges (described above). At the east edge of the lake plain there are some small areas of sand dunes, distinct from the rest of the clay lake plain. Also at the southeast is an area of flat, poorly drained lake plain.

The lake plain has clay soils. Where the lake plain is flat and on lower slopes, these clays are poorly drained. On the upper slopes of the dissected clay plain, soils are well drained. There are droughty sand soils at the eastern edge of the lake plain.

PRESETTLEMENT VEGETATION: While clay soils characterize almost all of this subdistrict, differences in slope are extreme. On the best drained, broad ridges of the clay plain, forests of hemlock and white pine (4227) and hemlock and sugar maple (4228) were common. The flatter, more poorly drained headwater areas supported extensive forests of hemlock and northern white-cedar (4222), and balsam fir, white spruce, and cedar (4223), with a diversity of other hardwoods and conifers. Almost pure stands of hemlock (4226), or hemlock and white pine (4227) were also found in the flat headwaters of streams. Aspen-birch forest (413) was associated with extensive windthrow along the Ontonagon River, both on lacustrine clays and sands. Although quaking aspen and paper birch were most common, these forests were diverse, containing northern white-cedar, white pine, balsam fir, white spruce, and sugar maple.

A relatively small area of droughty, sand lake plain, located at the eastern edge of the subdistrict, supported forests of white pine and red pine (4216), as well as smaller areas of aspen-birch forest (413). These pines also extended south onto a small area of droughty outwash. There was also a large wetland dominated by scattered black spruce and tamarack (6125) on the extreme western edge of the sand lake plain.

Coastal sand dunes were dominated by forests of white and red pine (4216) and hemlock and white pine (4227). The poorly drained lake plain was dominated by mixed conifer swamp (423) with black spruce and tamarack. Alder-willow shrub swamp (6122) formed dense, streamside thickets.

NATURAL DISTURBANCE: Extensive windthrows were noted by surveyors along the Ontonagon River. There was also an area of burned over pine plain (white pine-red pine (4216)) on the sand lake plain near Kenyon.

HUMAN LAND USE: At the time of the surveys, Native American trails passed through this subdistrict, connecting branches of the Ontonagon River to settlements further south. White pine was harvested throughout the subdistrict for mining timbers. A number of well drained ridge-tops have been grazed. Several highways, and many logging roads dissect the area. Urban development is limited, centered around Ewen. Portions of the this subdistrict fall within the Ottawa National Forest.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Today, most of the subdistrict is forested, with aspen-birch forest dominating both uplands and wetlands.

DISTRICT 6 Bergland.
SUBDISTRICT 6.3. Baraga: broad ridges of coarse-textured rocky till.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Most of the subdistrict is underlain by Precambrian sedimentary bedrock ranging from Jacobsville feldspathic to quartzose sandstone and shale.

The predominant landforms are large, broad end moraine ridges 150-500 ft. high. Gullying is severe on steep slopes of the moraines, especially on the broad ridges near Lake Superior. Both sand and clay lake plain occurs close to Lake Superior; most of which is poorly drained. The Sturgeon River flows across both outwash and lake plain. On the inland edge of the subdistrict, the river has eroded a steep gorge. Closer to the lake, the river meanders over the sand lake plain. There are many small creeks throughout this area, and small lakes are concentrated in the western end of the subdistrict.

The soils are typically acid, well-drained sands and sandy loams, derived from local sandstone and shale. Rock fragments are common. Poorly drained soils are restricted to stream margins and depressions between large moraine ridges.

PRESETTLEMENT VEGETATION: The large, sandy and loamy moraines east of L'Anse and north of Baraga, for the most part, supported hemlock and sugar maple (4228) or hemlock and yellow birch (4229) forests. The latter forest was most common on the Abbaye Peninsula. An isolated occurence of American beech was also noted among northern hardwoods northeast of L'Anse along the Lake Superior shoreline.

Most wetlands on the moraines were located along river drainages, with cedar, tamarack, spruce (423), and/or alder (6122) as dominants. There were also several small emergent marshes (6221) in small depressions on the ground moraine. A Great Lakes marsh (6222), apparently quite boggy in character ("covered with cranberry vines"), was located at the north end of Huron Bay; this marsh is located in an area mapped as ground moraine by Farrand and Bell (1982), but it likely occupied a localized deposit of lacustrine sands.

A large part of the sand lake plain, both that located along Lake Superior and isolated inland deposits west and southwest of Keweenaw Bay, were poorly drained, and supported wetlands. Large mixed conifer swamps (423) dominated by cedar, black spruce, and tamarack were located just north of Baraga, and southwest of Keweenaw Bay. A Great Lakes marsh was also located on a tombolo that connected an island to the Abbaye Peninsula at Sand Bay. Field surveys, both in Wisconsin and Michigan showed that the coastal marshes along Lake Superior generally had vegetation more characteristic of bogs or poor fens than the Great Lakes marshes further south in the state (MNFI 1987). Tamarack (4233), cedar (4231), and alder-dominated (6122) swamps were located south of Otter Lake. There were some upland forests on sand lake plain. A red pine forest (4212) was noted immediately east of L'Anse, and southwest of Baraga, and some hemlock and white pine forest was also mentioned (4227).

Clay lake plain, localized in a township-sized area west of L'Anse, was dominated by a forest of northern white-cedar and hemlock (4222). These forests also included balsam fir, and spruce (white or possible, black). Swamps on the clay lake plain, which was restricted to west of Baraga and L'Anse, were dominated by black ash (4141) and cedar (4231), and mixed tamarack and black spruce muskeg (6125).

NATURAL DISTURBANCE: A small windthrow was noted at the southern end of Huron Bay, and just south of L'Anse. No major wildfires were noted by surveyors in this area.

HUMAN LAND USE: Tanner (1987) noted Native American encampments on Portage Lake in 1830. Many roads, and several sawmills and missions, were already established in this area at the time of the surveys in 1845. Land use since that time as involved mining, logging, urban development, and recreation. Portions of state and federal forest lands fall within this subdistrict. There are a number of highways and logging roads that found throughout this subdistrict, and urban development is concentrated in Baraga and L'Anse.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: As noted elsewhere in this region, logging era activities probably have changed the relative composition of white pine and hemlock in forests of this subdistrict. Aspen and paper birch are much more common throughout his subdistrict than they were in the 1850s. Roads have altered wetland hydrology in places.

DISTRICT 7 Keweenaw.

CLIMATE: Climate is dominated by lacustrine influences. Except for air flows from the southwest, all air passes over Lake Superior before reaching this district. Due to combination of lake and orographic effects, snowfalls are heavy, from 140 to 200 inches/year (Eichenlaub et al. 1990). Average annual precipitation ranges from 32 to 34 inches. Growing season is relatively long, over 130 days, but cool. Winters are moderated by Lake Superior.

DISTRICT 7 Keweenaw.
SUBDISTRICT 7.1. Gay: coarse-textured broad ridges and swamps.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The subdistrict, located along the eastern side of the Keweenaw Peninsula, consists of broad ground moraine ridges, up to 550 ft. high, with gentle to moderate slopes. Sand lake plain dominates the Lake Superior shoreline from Little Traverse Bay north to Lac La Belle. Jacobsville sandstone of Precambrian age is found in outcrops along the shoreline around Little Traverse Bay. There are few lakes, but several extensive wetlands occupy depressions between the ridges and the shoreline near Keweenaw Bay, at the northeastern end of the subdistrict. Soils are derived largely from the underlying sandstone and shale. Soils of the moraines are typically well drained, acid, loamy sands and sandy loams derived largely from the underlying Cambrian sandstone.

PRESETTLEMENT VEGETATION: On the sandy ground moraine of the eastern Keweenaw Peninsula, sugar maple, yellow birch, and balsam fir (4115) were most common. Hemlock was more common on ground moraine along the shorelines at the south end of the subdistrict, either in combination with sugar maple (4228), or with yellow birch (4229). White spruce, balsam fir, and cedar (4223) were common on sand lake plain within two to three miles of the Lake Superior shoreline. Poorly drained portions of the subdistrict were dominated by mixed conifer swamp (423), which included cedar, balsam fir, black spruce, and tamarack. Alder swamp (6122) occupied both narrow stream valleys and large wetland depressions. While cedar occurs regularly within the subdistrict, only a few cedar swamps (4231) were noted by the surveyors. On the sand lake plain along Keweenaw Bay, wooded dune and swale complexes (911) were found with wide swales dominated by tamarack and black spruce scattered across the bog mat. A Great Lakes marsh (6222) and wooded dune and swale complex (911) were noted at Lac La Belle. Conifer-hardwood swamps (42) were also found on rocky, poorly drained beach terraces far above the present lake level.

NATURAL DISTURBANCE: Many windthrows were noted by surveyors throughout the poorly drained soils of this subdistrict.

HUMAN LAND USE: Native American encampments were noted by surveyors around Little Traverse Bay in 1845. Logging, mining, and pasture have been the historically dominant land uses in this subdistrict. The deposition of mine tailings along the shoreline is most evident at Gay. A number of areas, both wetland and upland, throughout the subdistrict, have been targeted historically for depositing mine tailings. There is almost no public land within the subdistrict, and roads exist along the shoreline and are scattered throughout it's interior. More recently, recreational/cottage development along the shoreline and along inland lakes has intensified.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Logging and mining activities altered wetlands associated with rivers in this subdistrict. Road construction and the deposition of mine tailings has also altered some wetlands. Upland forests probably retain less hemlock and white pine, and include more aspen and paper birch than they did in the 1850s.

DISTRICT 7 Keweenaw.
SUBDISTRICT 7.2. Calumet: high igneous and sedimentary bedrock ridges and knobs.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: Erosion-resistant conglomerates form the steep ridges of the subdistrict, between which veins of highly eroded lavas are the sites for lakes and wetlands. The Lake Superior shoreline consists of rugged volcanic bedrock. Copper-rich lava flows, common on the Keweenaw Peninsula, were extensively mined. Precambrian bedrock is primarily Keweenawan basalts and conglomerates, but also include iron-rich marine sandstone and dolomites of Huronian age (the Gogebic Range), and Archean bedrock.

The subdistrict is noted for steep ridges of Keweenawan basaltic lavas and conglomerates, which rise several hundred feet above the adjacent lake and till plains. The bedrock ridges of the Keweenaw Peninsula and of Isle Royale are both part of the Lake Superior Syncline, which extends from northern Wisconsin to the tip of the Keweenaw Peninsula of Michigan.

Soils formed on the volcanic and conglomerate ridges are rocky, acid, red sandy loams and silt loams (Podsols and Inceptisols). Soils tend to be rockier at the northern end of the subdistrict.

PRESETTLEMENT VEGETATION: Volcanic bedrock is near or at the surface from the Lake Superior shoreline to the exposed bedrock summits, which are one to two miles inland. This steep landscape has thin soils and is dominated by forests of white spruce-balsam fir (4223) and aspen-birch (413); balsam poplar was common in both forest types. White spruce and balsam fir forests were common on some of the high ridges, and dominated Manitou Island, located off the eastern tip of the Keweenaw Peninsula. Balds, areas of exposed bedrock, supported scattered red oak, white pine, red pine, and paper birch. The balds were subject to strong winds, heavy snows, and ice storms, which resulted in dwarfed, misshapen trees, especially red oak, called Krummholz.

Farther inland, well drained uplands on thin soils were dominated by sugar maple, yellow birch, and balsam fir (4115); this is by far the most common forest type in the subdistrict. Southwest of Calumet, hemlock was co-dominant with sugar maple (4228). Red pine alone (4212), or in combination with white pine (4216) were common on the low dunes of the sand lake plain along Five Mile Point, Great Sand Bay, and the east side of Agate Harbor.

Throughout this subdistrict, mixed conifer swamp (423) included much black spruce, tamarack, and cedar. Cedar-dominated swamp (4231) was most common near the tip of the Keweenaw Peninsula. Extensive mixed conifer swamp (423), bog (6121), and alder-willow swamp (6122) dominated wet swales among the dune ridges at Great Sand Bay.

NATURAL DISTURBANCE: Windthrows were noted in swamps along the northern shoreline.

HUMAN LAND USE: European settlements, including Fort William (Fort Wilkins), and a number of mines and roads were already established in this subdistrict by 1845 when the area was surveyed (Trygg 1964). Dominant land uses in this subdistrict have included mining, logging, and more recently, recreational/cottage development along the shoreline and inland lakes. Roads are most densely concentrated at the southern end of the subdistrict. Roads extend along most of the shoreline. Urban development is concentrated at Hancock, Calumet, Laurium, Eagle Harbor, and Copper Harbor. Several small parcels of State Forest and two small State Parks are located within this subdistrict.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: As with elsewhere in this district, rivers were altered by historical mining and logging activities. The deposition of mine tailings has altered coastal wetlands in several places. The large swamp/marsh complex at the north end of Portage Lake was nearly eliminated in the construction of the shipping channel linking that inland lake to Lake Superior. Upland forests probably include less white pine and hemlock than they did prior to the logging era.

DISTRICT 7 Keweenaw.
SUBDISTRICT 7.3. Isle Royale: island of igneous bedrock ridges and swamps.

CLIMATE: Isle Royale is treated as a separate subdistrict, distinct from the Calumet subdistrict, because of its climate, which is strongly influenced by surrounding Lake Superior.

SOILS, GLACIAL LANDFORMS, AND BEDROCK GEOLOGY: The subdistrict is noted for steep ridges of Keweenawan (late Precambrian) basaltic lavas and conglomerates, which rise several hundred feet above the adjacent lake and till plains. The bedrock ridges of Isle Royale are part of the Lake Superior Syncline. Isle Royale is located at the northern end of the syncline. It has similar bedrock, physiography, and flora to the Calumet subdistrict.

PRESETTLEMENT VEGETATION: Much of the upland portions of the island were dominated by boreal forest of white spruce, balsam fir, and northern white-cedar (4223) included much quaking aspen. Aspen and paper birch forests (413) were common along the shoreline where windthrows were frequent. In the southwest interior of the island, thicker soils included northern hardwoods of sugar maple, yellow birch, and balsam fir (4115). A small area of jack pine forest (4213) was noted just south of Conglomerate Bay. The mixed conifer swamps (423) of Isle Royale were dominated by black spruce, balsam fir, tamarack, and cedar. There were also several bogs (6121) noted in large undrained depressions within the island interior.

NATURAL DISTURBANCE: Extensive windthrow was recorded along the southern shoreline of the island.

HUMAN LAND USE: Native Americans used the island for fishing and hunting, and there were several encampments noted by surveyors in 1855 (Trygg 1964). Several outposts of the American Fur Company also existed at the time. There had been extensive mining activity by that time. Given the frequency of heavy winds, it is unlikely that Isle Royale ever had significant sawtimber resources, but the island was logged for fuelwood and mining timbers. Today, the entire island is a National Park. Scientific research and semi-primitive recreational activities are most common on the island.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: Mining alterations on Isle Royale were not as extensive as those on the Keweenaw Peninsula. Logging activity favored the expansion of aspen-birch forest over other native forests.

DISTRICT 8 Lake Superior. Ontonagon. clay lake plain.

CLIMATE: The growing season ranges from 110-140 days growing season, with the shortest growing season at the western edge of the district (Eichenlaub et al. 1990). Annual snowfall is heavy and lake-effect snows ranges from 120 to 160 inches. Total annual precipitation is 30 to 34 inches. Extreme minimum temperatures range from -30° F to -40° F.

BEDROCK GEOLOGY AND SOILS: Bedrock is not exposed at surface except in localized outcrops along streams and at selected portions of the shoreline. Bedrock consists of Precambrian (Middle Proterozoic) sedimentary bedrock, primarily feldspathic to quartzose sandstone and shale, and including lithic sandstone and siltstone (Morey et al. 1982). The shale is locally copper-rich (Dorr and Eschman 1984).

Lake plain from glacial Lake Duluth covers almost all of the district in a band ranging from one - 24 miles wide. A narrow exposed ridge of volcanic bedrock occurs at the southern edge (Farrand and Bell 1982). The soils are classified as Aquepts and Boralfs (Soil Conservation Service 1967). Portions of this glacial lake bed are relatively flat, as east of the Porcupine Mountains. In these stretches the lake plain is dissected by numerous small rivers with straight, shallow valleys. Between the Porcupine Mountains and the Wisconsin border, the subdistrict is narrow and steeply sloping, with deeply eroded streams, often with waterfalls.

Soils consist of leached, calcareous red clays and pink sands that are podsolized; peatlands are not extensive. The soils are moderately well drained loam and clay, derived from local, iron-rich volcanic bedrock. Most of the soils are red in color.

PRESETTLEMENT VEGETATION: Well drained or moderately well drained clay soils characterize large parts of the lake plain. These soils were dominated by hemlock and sugar maple forest (4228). Hemlock was much more common than its associates, which include sugar maple, yellow birch, red maple, black ash, balsam fir, and northern white-cedar. Close to the lakeshore, forests of hemlock (4226), hemlock and yellow birch (4229), and hemlock and cedar (4222) were most concentrated.

Narrow wooded dune and swale complexes (911) were located along Misery Bay, Sleeping Bay, and west of the Flintsteel River mouth. A diversity of conifers, including hemlock, cedar, spruce, fir, and alder dominated wet swales in these complexes. The complex at the Flint Steel River , the only large area of sand lake plain within the subdistrict, included shrub swamp (6122) and bog (6121). Cedar swamp (4231) was common on a small area of sandy lake plain bordering the Salmon Trout River, along the eastern edge of the subdistrict. Mixed conifer swamps (423) dominated by cedar, spruce, fir, hemlock, and red maple were located upstream in the Graveraet River drainage.

NATURAL DISTURBANCE: No major windthrows or wildfires were noted by surveyors in this subdistrict.

HUMAN LAND USE: Tanner (1987) noted a Native American settlement at Ontonagon circa 1830. Trygg (1964) noted a Native American graveyard at the mouth of the Iron

River at the time of the surveys. Logging-era activities were intensive within the subdistrict, providing fuel and timbers for the mining industry and lumber for local construction. Many rivers were diverted for mining or logging purposes. Large tailings ponds are located in both Gogebic and Ontonagon counties. Today, the majority of the subdistrict is forested, and a small percent of the land remains used for pasture. A small amount of National Forest land falls within this subdistrict. Several highways, and many logging roads, traverse this subdistrict, and urban development is concentrated at Ontonagon.

INFLUENCE OF HUMAN LAND USE ON VEGETATION: River diversions have undoubtedly altered associated wetlands. Roads have also altered wetland hydrology in places throughout the subdistrict. Most of the land remains forested. Species composition in forests have changed since the logging era, with white pine and hemlock becoming much less abundant. Aspen-birch forests are now far more abundant that they were in the 1850s, especially around Ontonagon. Urban development around Ontonagon and along the shoreline have eliminated or altered some coastal wetlands.

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Appendix A: Sample layout of digital map from Summerfield Township, Monroe County.