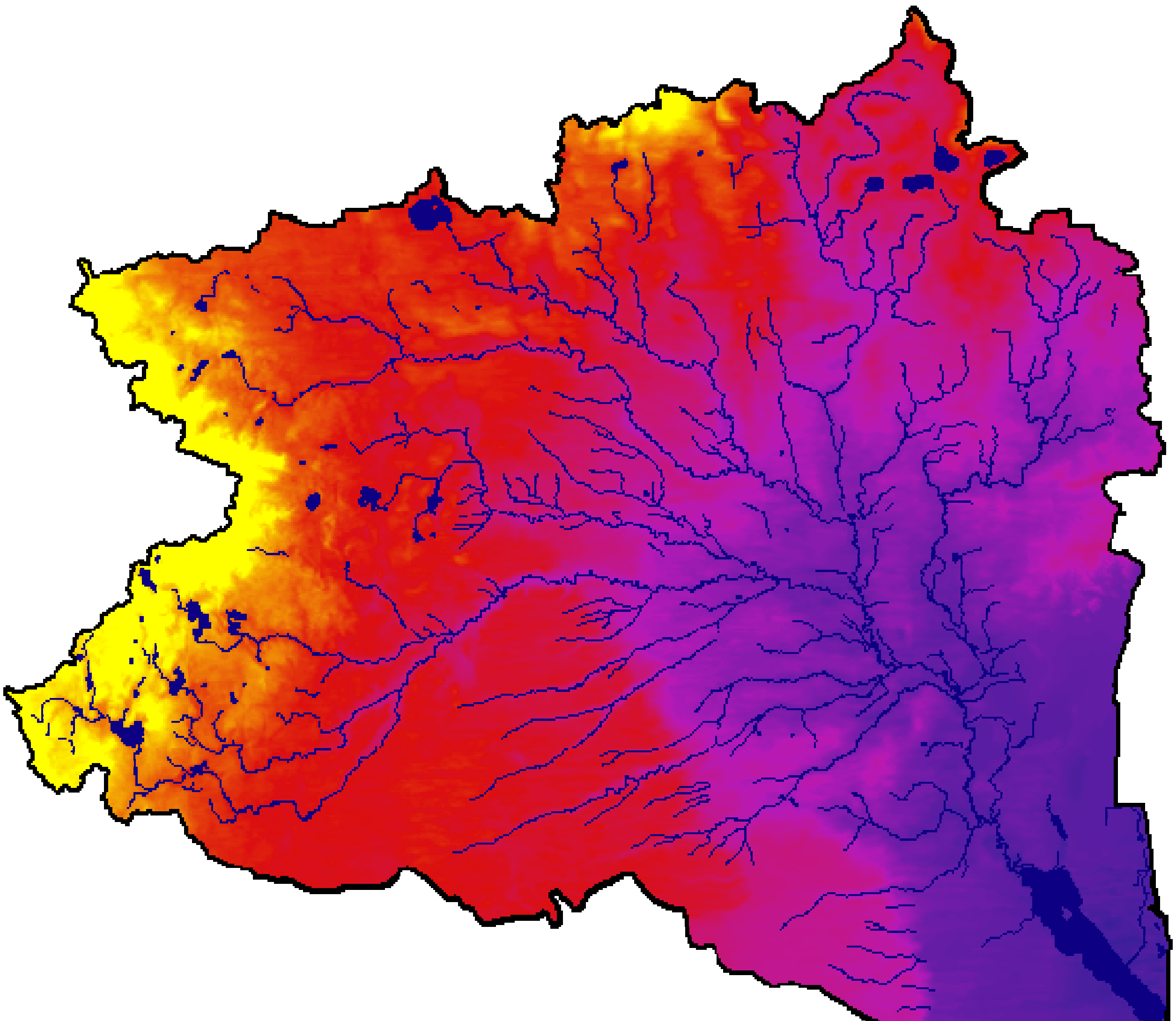
Pine River/Van Etten Lake Watershed Hydrologic Study



Dave Fongers
Hydrologic Studies Unit
Land and Water Management Division
Michigan Department of Environmental Quality
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DEQ
Michigan's Nonpoint Source Program

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This Nonpoint Source (NPS) Pollution Control project has been funded wholly by the United States Environmental Protection Agency (EPA) through a Part 319 grant to the Michigan Department of Environmental Quality. This study is in support of NPS grant 2006-0119 to the Huron Pines Resource Conservation and Development Council. The contents of the document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use. For more information, go to www.michigan.gov/deqnps.

The cover depicts the drains, streams, lakes, and rivers and ground elevations of the Pine River/Van Etten Lake Watershed. Lighter colors are higher elevations.

For comments or questions relating to this document, contact Dave Fongers at:

MDEQ, LWMD, P.O. Box 30458, Lansing, MI 48909
fongersd@michigan.gov
517-373-0210

Summary

This hydrologic study of the Pine River/Van Etten Lake watershed was conducted by the Hydrologic Studies Unit (HSU) of the Michigan Department of Environmental Quality (MDEQ). The study is in support of an MDEQ Nonpoint Source (NPS) grant for the Pine River/Van Etten Lake watershed to update the watershed management plan. Hydrologic characteristics of the watershed were evaluated to provide a basis for stormwater management to protect streams from increased erosion and flooding and to help determine the watershed management plan's critical areas. Local governments within the watershed could use the information to help develop stormwater ordinances. Watershed stakeholders may combine this information with other determinants, such as open space preservation, to decide which locations are the most appropriate for wetland restoration, stormwater infiltration or detention, in-stream Best Management Practices (BMPs), or upland BMPs.

The watershed study has two scenarios corresponding to land cover in 1800 and 1978. The loss of wetland and the establishment of agricultural and urban land uses are the most noticeable land use transitions during this period. Agricultural land uses are generally located in or near the Van Etten Creek watershed. The largest area of urban land use is the former Wurtsmith Air Force Base, located along Van Etten Lake near the downstream end of the watershed. Most of the watershed land uses remain natural, however, and protected from land use change, or are agricultural, but with little apparent development pressure. Most of the watershed's streams are designated trout streams, with the notable exception of Van Etten Creek and its tributaries.

Hydrologic studies conducted by this office for the NPS program typically model runoff volumes and peak flows from the 4 percent chance (25-year), 24-hour storm to represent flood flows and the 50 percent chance (2-year), 24-hour storm to represent channel-forming flows. Increases in 4 percent chance storm flows would indicate aggravated flooding. Increases in 50 percent chance storm flows would increase channel-forming flows, which can cause the stream channel to become unstable. Stream instability is indicated by excessive erosion at many locations throughout a stream reach. In this hydrologic study, hydrologic modeling was only used to quantify changes in stormwater runoff volumes from 1800 to 1978 for the 4 percent chance (25-year), 24-hour storm because the model does not predict enough runoff from the 50 percent chance storm to be valid. These 4 percent chance results identify the Van Etten Creek subbasin as the subbasin with the largest increase in runoff volume over this period. The other two subbasins with notable increases are the East Branch of the Pine River and Wallace Creek. The runoff increases are due to changes in land use in these subbasins.

Large-scale stream channel instability, erosion, and flooding are not likely major problems in this watershed because the runoff volumes are low and because the runoff volume increases since 1800 are nonexistent or minor in comparison to other Michigan watersheds. If such problems exist, they would likely be limited to smaller sites or tributary streams, which are beyond the scope of this study, with correspondingly local causes.

Based on runoff analysis and trout stream information, the Van Etten Creek, Wallace Creek, and East Branch of the Pine River subbasins are the subbasins that have the most impact on the watershed's waterbodies. Comparatively little of the land within these subbasins is protected as conservation or recreation land.

Project Goals

The Pine River/Van Etten Lake hydrologic study was initiated in support of the Huron Pines Resource Conservation and Development Council, which is updating a watershed management plan for the Pine River/Van Etten Lake watershed. This Pine River/Van Etten Lake hydrologic study is funded by a United States Environmental Protection Agency (EPA) Part 319 grant administered by the MDEQ. The goals of this Pine River/Van Etten Lake study are:

- To better understand the watershed's hydrologic characteristics and the impact of land use changes in the Pine River/Van Etten Lake watershed on storm flows
- To provide a basis for stormwater management to protect stream morphology
- To help determine the watershed management plan's critical areas – the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody

One portion of this study compares hydrologic characteristics of Pine River/Van Etten Lake watershed subbasins. The hydrologic analysis models 1800 and 1978 land use. The 1800 scenario is included to show the impact of land use change, but it is not intended as BMP design criteria or as a goal for watershed managers. Runoff from each subbasin for a standard 24-hour storm is calculated for both scenarios. This highlights subbasins that generate a higher proportion of runoff due to soils and land use. Runoff volume per area can be used to help select critical areas. Higher values can identify areas that may benefit from rehabilitation BMPs. Lower values can identify sensitive areas to be protected.

To provide a basis for stormwater management practices and ordinances to protect channel morphology, the Center for Watershed Protection's recommendation of 24-hour extended detention of the one-year 24-hour storm event will be considered.

Watershed Description

Overview

The 282-square mile Pine River/Van Etten Lake watershed, Figures 1 and 2, outlets to the Au Sable River, Figure 3, near Oscoda and is located in Alcona and Iosco Counties.

Figure 1: Pine River/Van Etten Lake Watershed Location

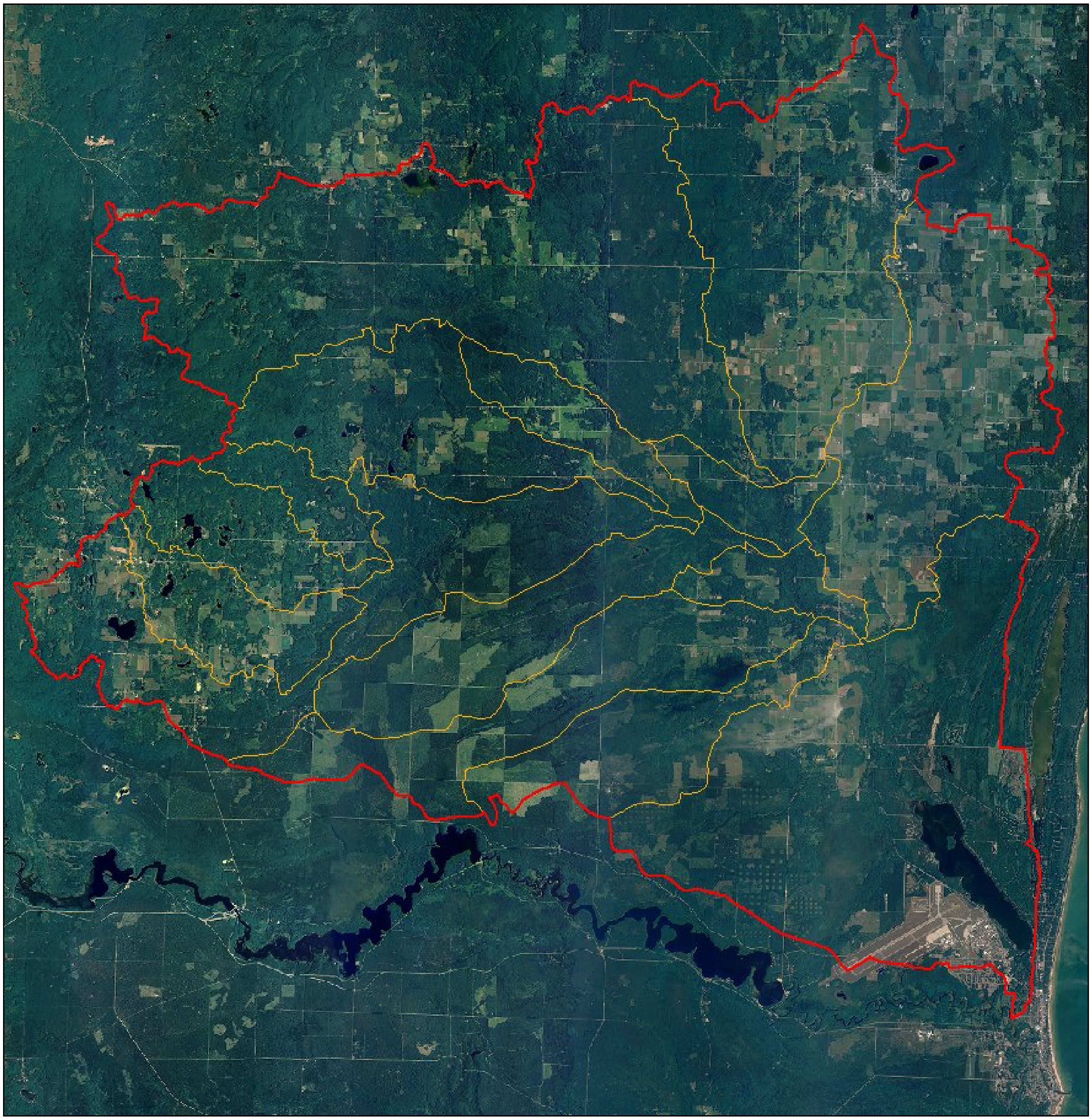

Figure 2: 2005 Aerial Photo of the Pine River/Van Etten Lake Watershed

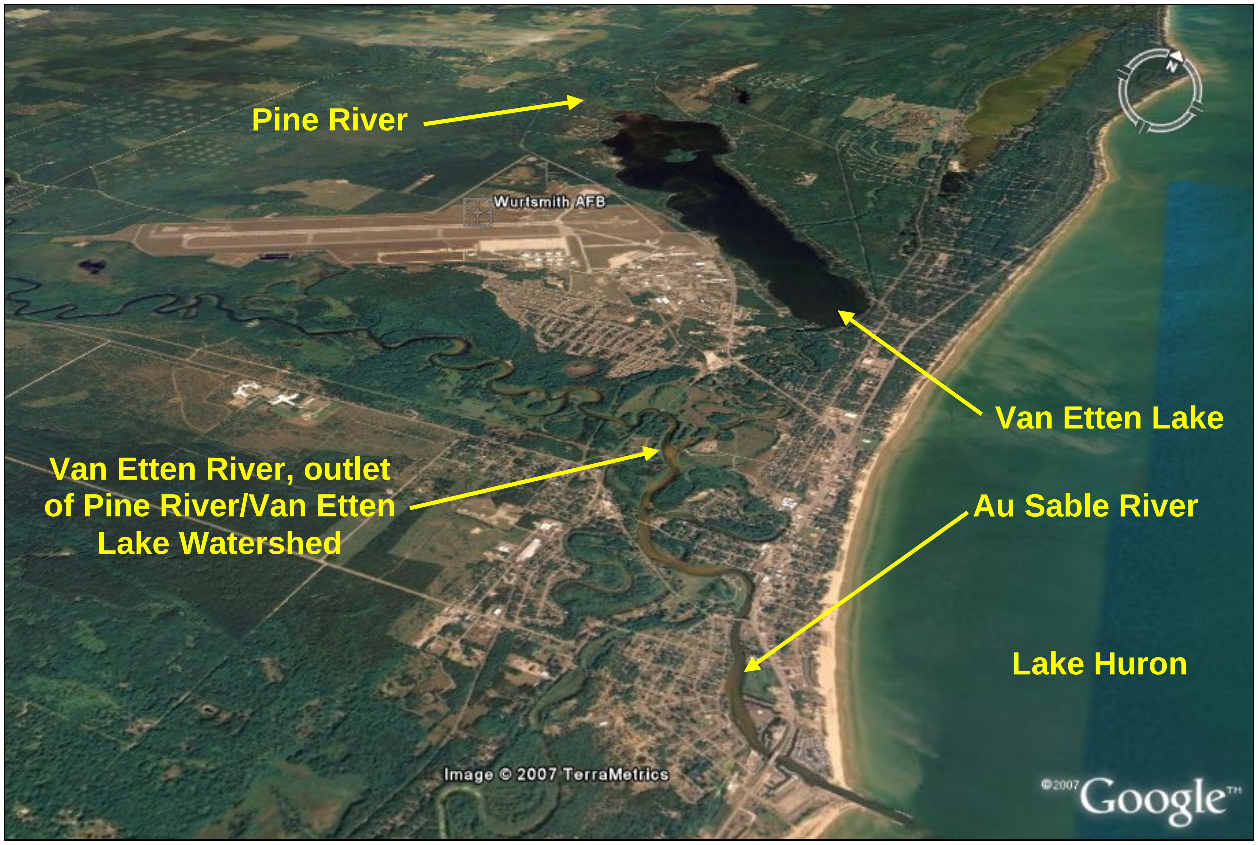

Figure 3: Aerial Photo of the Pine River/Van Etten Lake Watershed and Au Sable River Watershed Outlets

Trout Streams

Significant portions of the Pine River and its tributaries are designated trout streams, as shown in Figure 4. One lake is a designated trout lake. Trout streams and lakes are associated with high quality waters and a good supply of groundwater-fed baseflow, which helps keep the stream flows and temperatures steady.

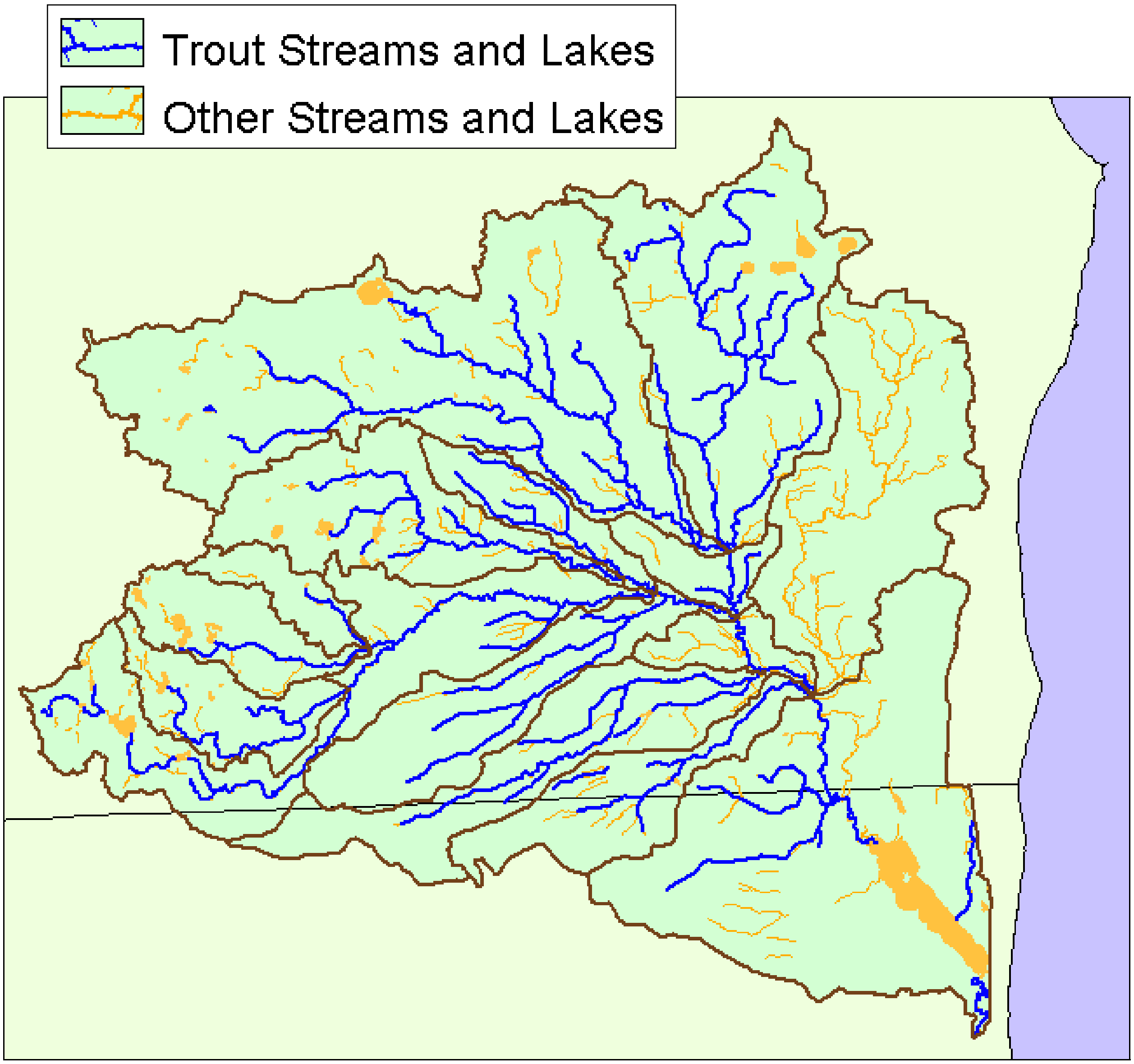

Figure 4: Trout Stream and Lake Locations

Stream Profile

A stream's ability to move sediment, both size and quantity, is directly related the stream's slope and flow. Thus steeper reaches generally move larger material, such as stones and pebbles, and the flatter reaches tend to accumulate sediment. According to Rosgen, 1996, "generally, channel gradient decreases in a downstream direction with commensurate increases in streamflow and a corresponding decrease in sediment size." A typical river profile is steeper in the headwaters and flatter toward the mouth. The streams of the Pine River/Van Etten Lake watershed, Figure 5, exemplify this profile. The result is that sediment transported through the Pine River and its tributaries will tend to accumulate in the lower reaches of the Pine River and in Van Etten Lake, Figure 6.

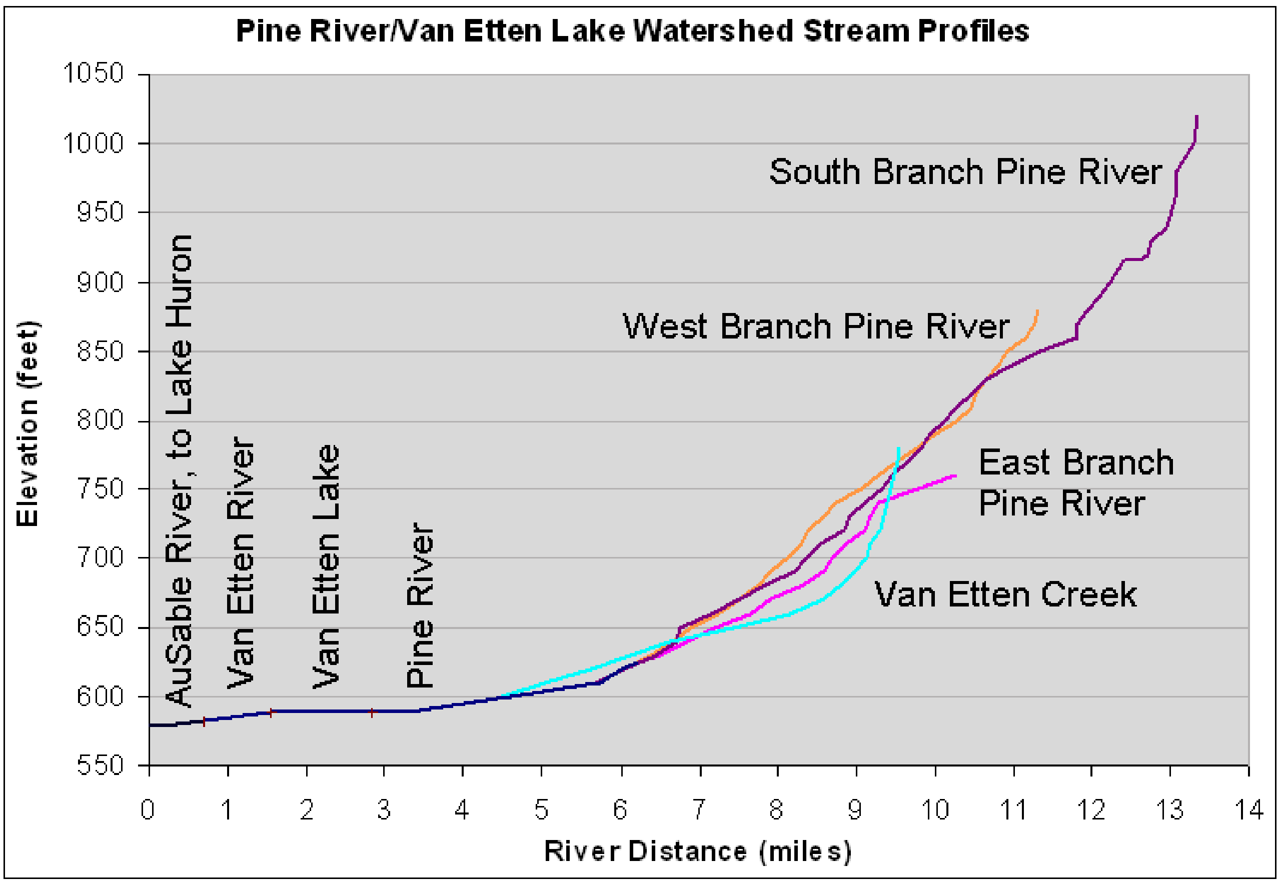

Figure 5: Stream Profiles

Figure 6: 2005 Aerial Photo, Pine River outlet to Van Etten Lake

Stream Order

Stream order is a numbering sequence which starts when two first order, or headwater, streams join, forming a second order stream, and so on. Two second order streams converging form a third order. Streams of lower order joining a higher order stream do not change the order of the higher, as shown in Figure 7. Stream order provides a comparison of the size and potential power of streams.

The Michigan Department of Natural Resources (MDNR) Institute for Fisheries Research and the United States Geological Survey (USGS) Great Lakes Gap have nearly completed a three-year EPA-funded study that provides Geographic Information Systems (GIS) stream order data for Michigan's streams using the 1:100,000 National Hydrography Dataset (NHD). The Pine River/Van Etten Lake results are shown in Figure 8.

The stream orders shown are not absolute. If larger scale maps are used or actual channels are found through field reconnaissance, the stream orders designated in Figure 8 may increase, because smaller channels are likely to be included. A more detailed analysis, based on 1:24,000 NHD layer, is also being developed.

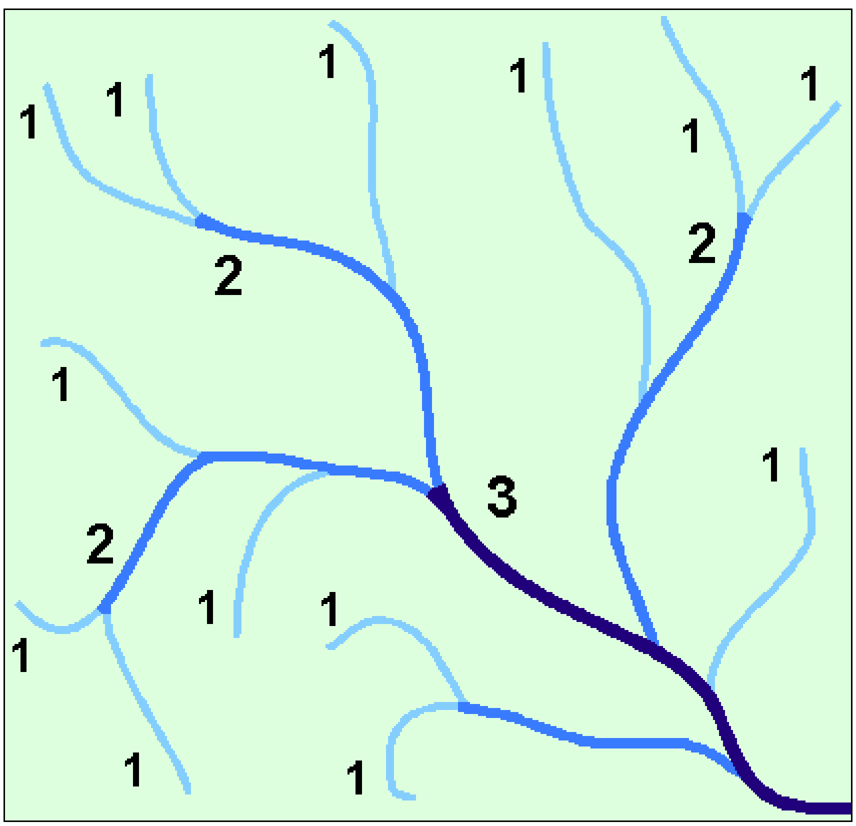

Figure 7: Stream Ordering Procedure

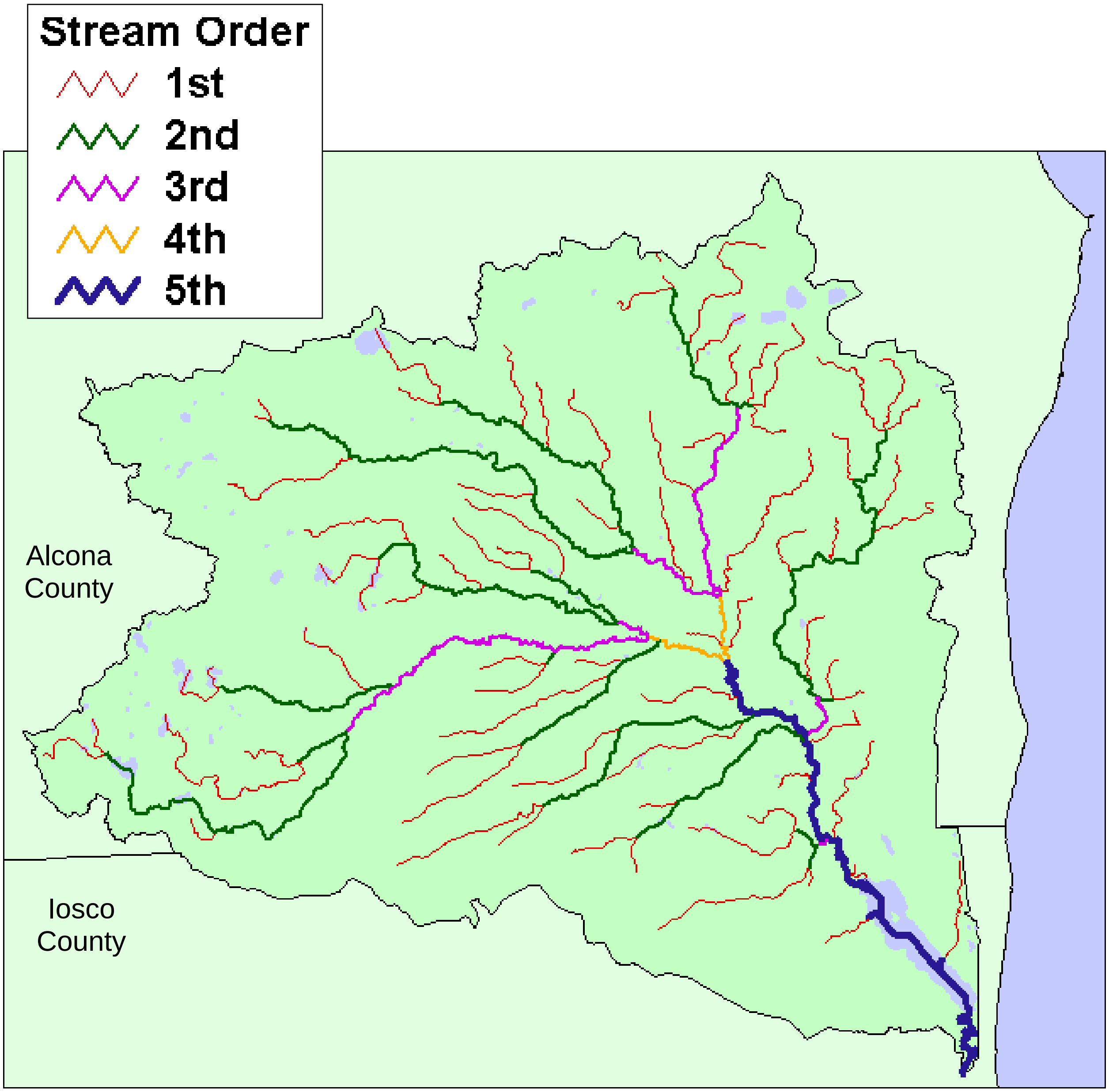

Figure 8: Pine River/Van Etten Lake Watershed Stream Orders

Subbasins

This study divides the watershed into fifteen subbasins, as shown in Figure 9. The subbasin delineations are available from the Michigan Geographic Data Library, www.mcgi.state.mi.us/mgdl/. The drainage area of each subbasin is shown in Table 1.

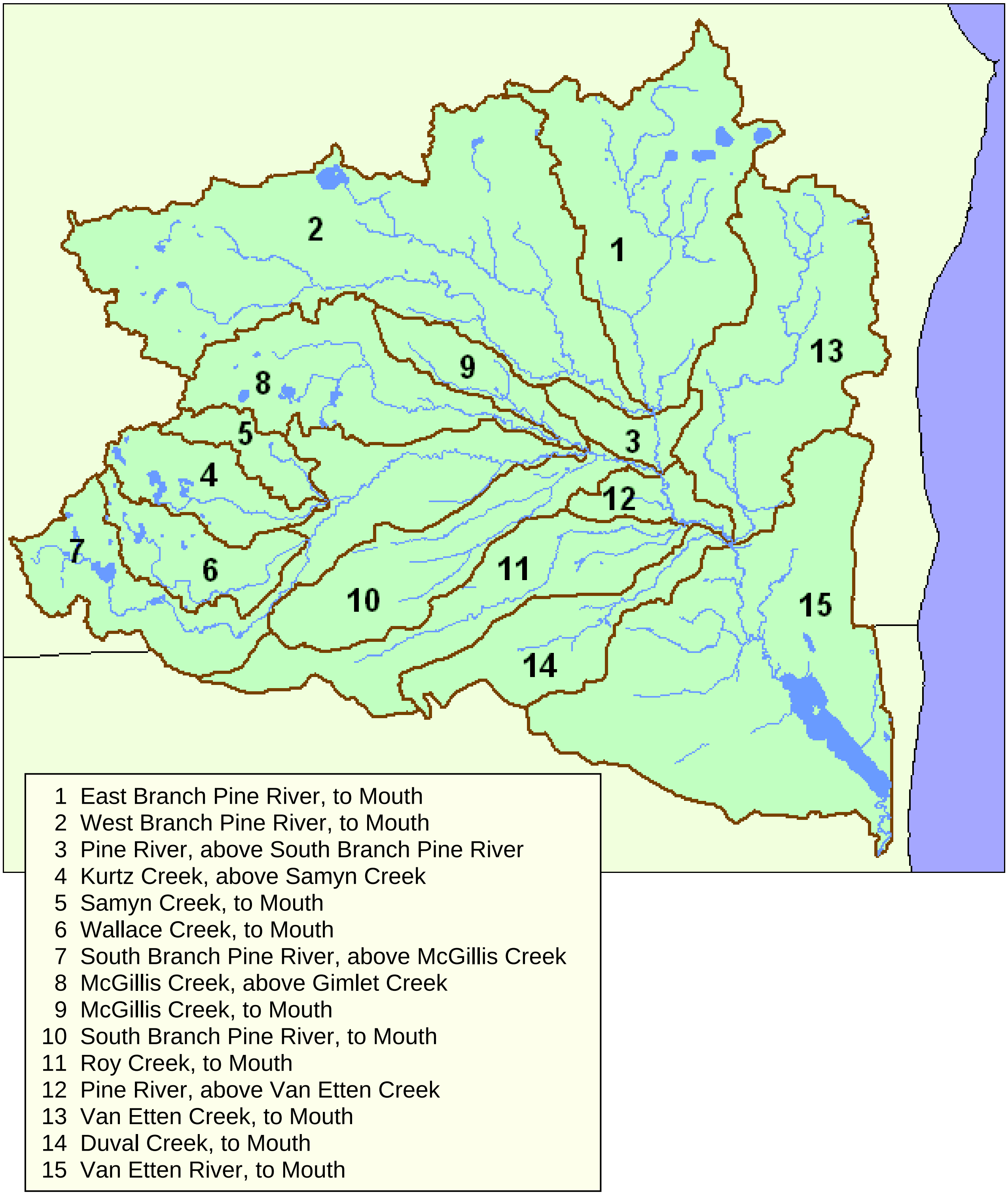

Figure 9: Pine River/Van Etten Lake Watershed Subbasin Identification

Land Use

1800 and 1978 Land Cover

General land use trends for the watershed from 1800 to 1978 are illustrated in Figure 10. More detailed land use information for each subbasin is tabulated in Table 1. Land use maps depicting MDEQ GIS data for 1800 and 1978 are shown in Figures 11 and 12.

The 1800 land use information is provided for reference. Land use circa 1800 is from a statewide database based on original surveyors' tree data and descriptions of the vegetation and land between 1816 and 1856. Michigan was systematically surveyed during that time by the General Land Office, which had been established by the federal government in 1785. The detailed notes taken by the land surveyors have proven to be a useful source of information on Michigan's landscape as it appeared prior to widespread European settlement. The database creators recognize that there are errors in the database due to interpretation and data input. The MDEQ NPS Program does not expect or recommend that flow regimes calculated from 1800 land use be used as criteria for BMP design or as a goal for watershed managers.

The 1978 land cover files represent a compilation of data from county and regional planning commissions or their subcontractors. This data set is intended for general planning purposes. It is not intended for site specific use. Data editing, manipulation, and evaluation was completed by the Michigan State University Center for Remote Sensing and GIS and by the MDNR. Files have been checked by MDNR against original MDNR digital files for errant land cover classification codes.

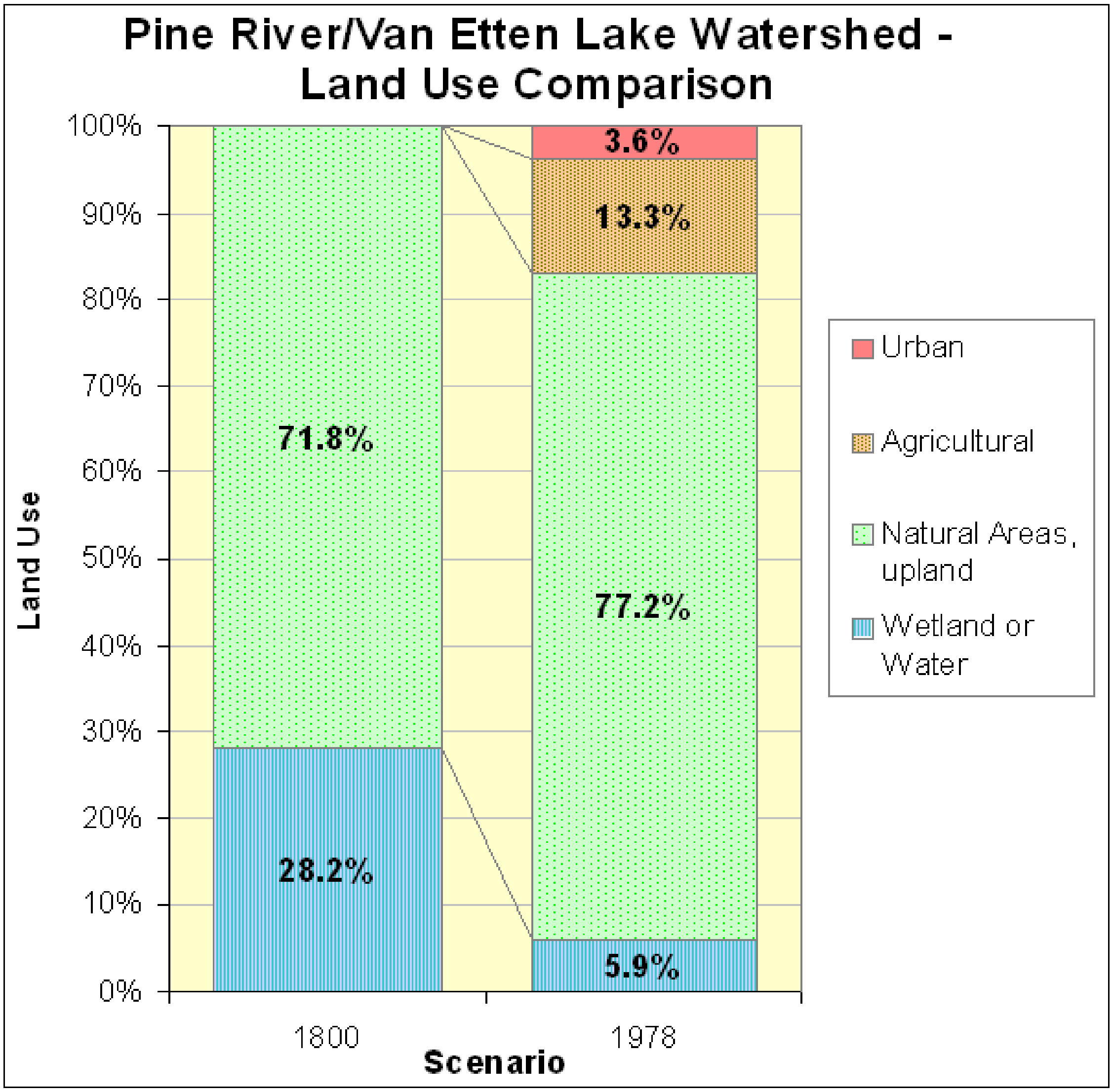

Figure 10: Land Use Comparison, Pine River/Van Etten Lake Watershed

Table 1: Land Use by Subbasins

Description	Scenario	Residential	Commercial	Industrial	Utilities	Gravel Pit	Cemeteries, Outdoor Rec.	Cropland	Orchards	Pasture	Herbaceous Openland	Forest	Water	Wetland
	1800											55.9%	1.3%	42.8%
1	1978	2.2%	0.3%				0.3%	25.1%		5.3%	12.8%	48.3%	1.3%	4.3%
	1800											81.3%	0.8%	17.9%
2	1978	0.6%				0.1%	0.1%	3.5%		1.2%	8.6%	80.8%	0.7%	4.4%
	1800											14.3%		85.7%
3	1978	1.7%		0.1%		0.1%		9.7%		2.4%	9.0%	67.6%		9.4%
	1800											86.2%	2.8%	11.0%
4	1978	4.8%				0.1%		3.9%		1.3%	10.1%	69.0%	3.7%	7.2%
	1800											88.7%	0.1%	11.1%
5	1978	0.1%				0.3%		3.5%		0.7%	5.0%	86.6%	0.3%	3.4%
	1800											91.4%	0.9%	7.7%
6	1978	3.5%	0.5%			0.1%	0.1%	18.6%	0.1%	5.3%	12.7%	47.5%	1.1%	10.3%
	1800										0.4%	81.5%	1.1%	17.0%
7	1978	2.2%	0.1%	0.1%		0.1%	0.3%	7.4%		0.4%	8.0%	74.5%	1.2%	5.8%
	1800											86.7%	1.3%	12.0%
8	1978	1.8%	0.3%					6.5%		2.5%	7.3%	75.4%	1.3%	4.8%
	1800											79.6%		20.4%
9	1978	1.3%						11.4%		1.1%	18.6%	63.8%		3.8%
	1800											77.4%		22.6%
10	1978							0.2%			0.3%	97.4%	0.1%	1.9%
	1800											63.0%		37.0%
11	1978	0.9%						5.1%		0.2%	2.6%	86.5%	0.2%	4.4%
	1800											35.6%	1.1%	63.3%
12	1978	2.4%						10.0%		3.1%	12.5%	67.1%		4.9%
	1800											66.8%		33.2%
13	1978	1.2%	0.2%			0.1%	0.2%	42.8%	0.1%	6.4%	16.5%	29.6%		3.0%
	1800											78.5%		21.5%
14	1978	0.8%			0.5%			3.1%		0.9%	5.4%	86.0%	0.1%	3.4%
	1800											63.9%	4.6%	31.5%
15	1978	4.0%	2.0%	0.1%	5.3%	0.1%	1.2%	3.9%		1.0%	3.4%	70.6%	4.8%	3.8%
Entire Watershed	1800											71.8%	1.4%	26.8%
	1978	1.9%	0.4%		0.9%	0.1%	0.3%	11.1%		2.2%	8.3%	68.9%	1.5%	4.4%

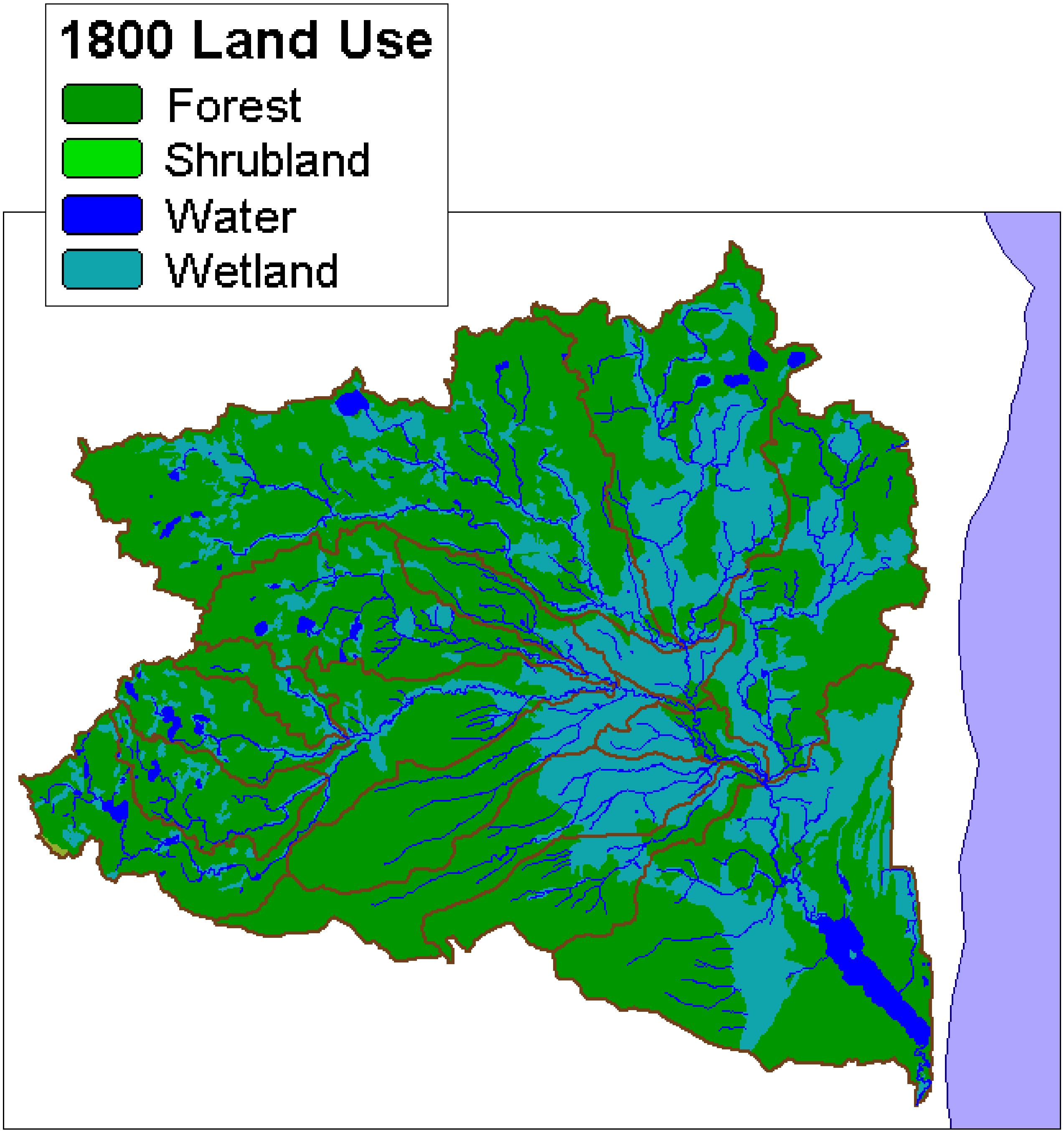

Figure 11: 1800 Land Cover

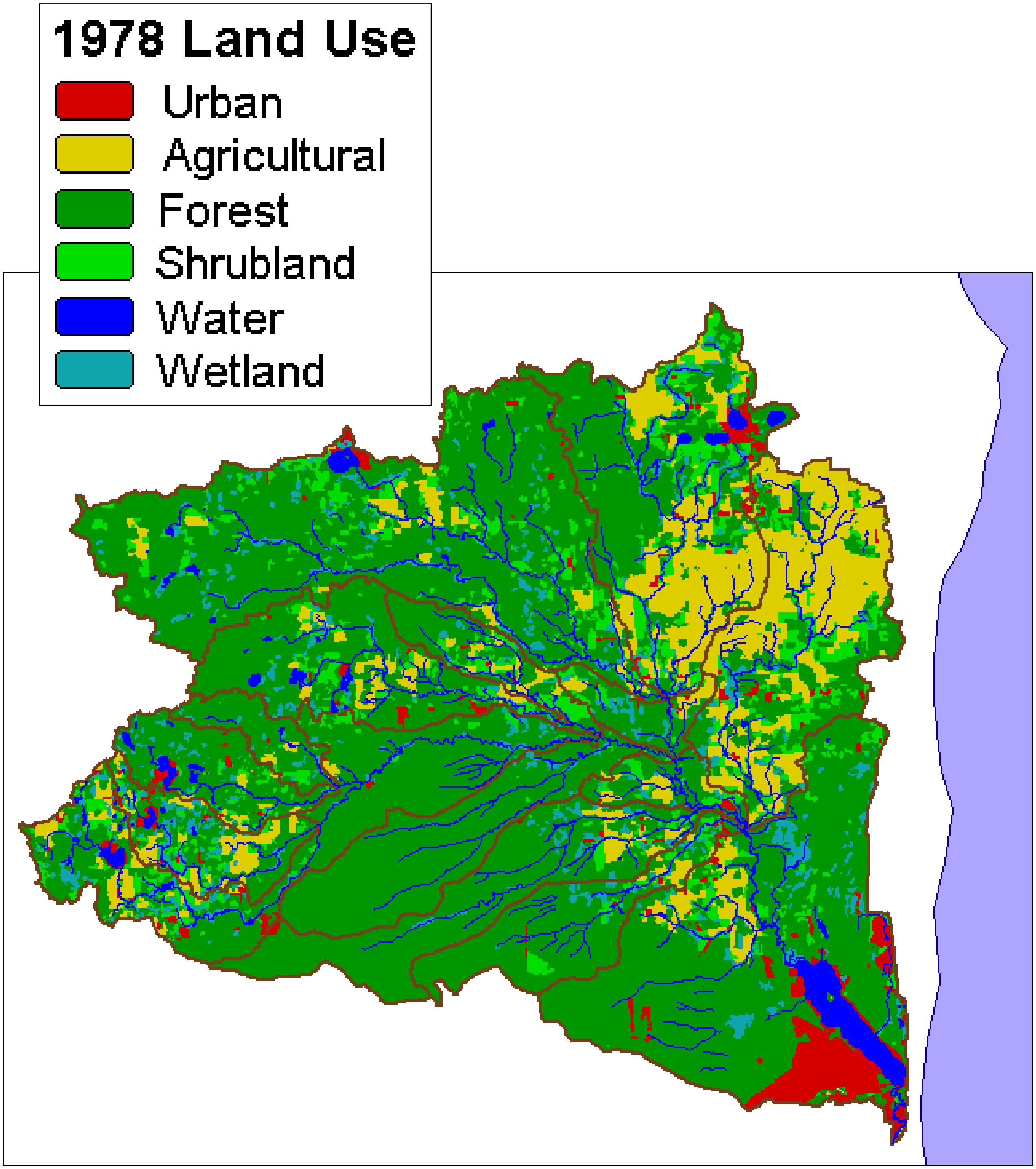

Figure 12: 1978 Land Cover

Conservation and Recreation Lands

With United States Fish and Wildlife Service support, Ducks Unlimited and the Nature Conservancy in Michigan (2007) are creating a comprehensive GIS layer of Conservation and Recreation Lands (CARL) for the Lake Huron watershed. The CARL GIS layer consists of public lands (federal, state, and local government-owned lands), private lands (The Nature Conservancy, Audubon, and local conservancies), and some conservation easements (with permission). The CARL layer should be a valuable tool for planning and development of coastal and inland wetland habitat restoration and protection activities. The CARL layer will also assist other land-use planners by formulating informed decisions, including plans for greenways, conservation, and recreational activities. Figure 13 depicts the conservation and recreation lands for the Pine River/Van Etten Lake watershed as of May 2007. The area of these lands is 120 square miles, which is 42 percent of the watershed. Table 2 shows this information for each subbasin. The information is not final but is expected to be reasonably accurate.

Table 2: Conservation and Recreation Lands – highlighted cells indicate the three lowest values

Subbasin		CARL Area (sq. mi.)	Subbasin Area (sq. mi.)	CARL Percent
ID	Description			
1	East Branch Pine River, to Mouth	2.8	32.4	9%
2	West Branch Pine River, to Mouth	26.9	53.8	50%
3	Pine River, above South Branch Pine River	1.0	4.0	26%
4	Kurtz Creek, above Samyn Creek	1.8	8.1	22%
5	Samyn Creek, to Mouth	2.1	4.1	50%
6	Wallace Creek, to Mouth	1.0	8.2	12%
7	South Branch Pine River, above McGillis Creek	12.2	25.5	48%
8	McGillis Creek, above Gimlet Creek	9.7	17.0	57%
9	McGillis Creek, to Mouth	1.8	5.7	31%
10	South Branch Pine River, to Mouth	14.7	15.1	98%
11	Roy Creek, to Mouth	12.5	17.0	73%
12	Pine River, above Van Etten Creek	0.1	4.0	3%
13	Van Etten Creek, to Mouth	0.1	27.6	0%
14	Duval Creek, to Mouth	8.0	11.4	70%
15	Van Etten River, to Mouth	25.1	48.4	52%
	Total	120	282	42%

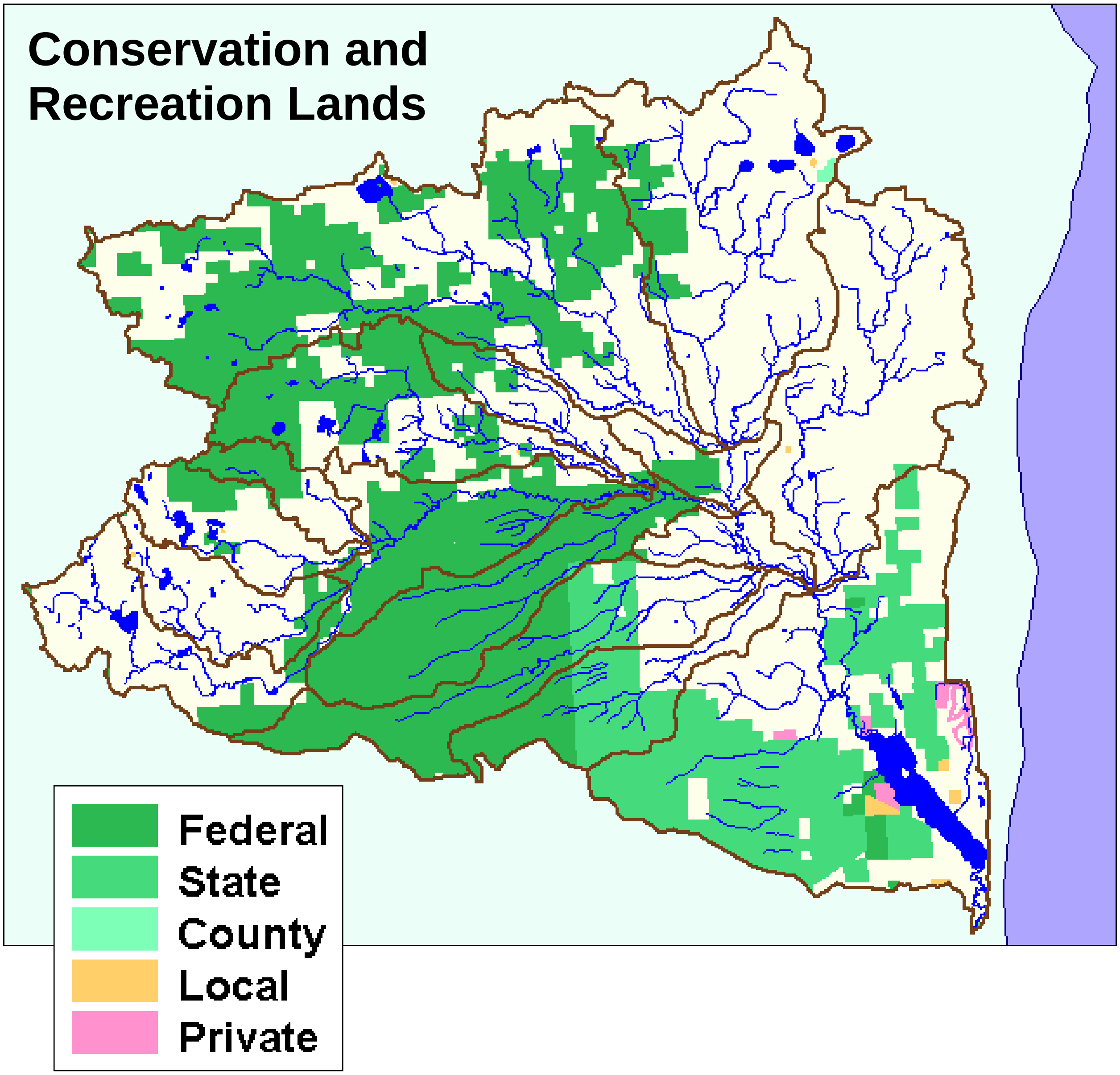

Figure 13: Conservation and Recreation Lands by Ownership

Soils

Hydrologic soil groups, or hydrogroups, are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms, as described in Table 3. Where the soil is given a dual hydrogroup classification, A/D for example, the soil type selected is based on land use. In these cases, the soil type is specified as D for natural land uses, or the alternate classification (A, B, or C) for developed land uses. The soils maps resolved for 1800 and 1978 land use are shown in Figures 14 and 15 respectively. The differences in resolved soil hydrogroups from 1800 to 1978 are minor.

Table 3: Soil Hydrogroups

Hydrologic Soil Group	Infiltration Rate when thoroughly wet	Description
A	High	• Sand • Gravelly sand
B	Moderate	• Moderately fine textured to moderately coarse textured soils
C	Slow	• Moderately fine textured to fine textured soils • Soils with a soil layer that impedes downward movement of water
D	Very Slow	• Clays • Soils with a clay layer near the surface • Soils with a permanent high water table

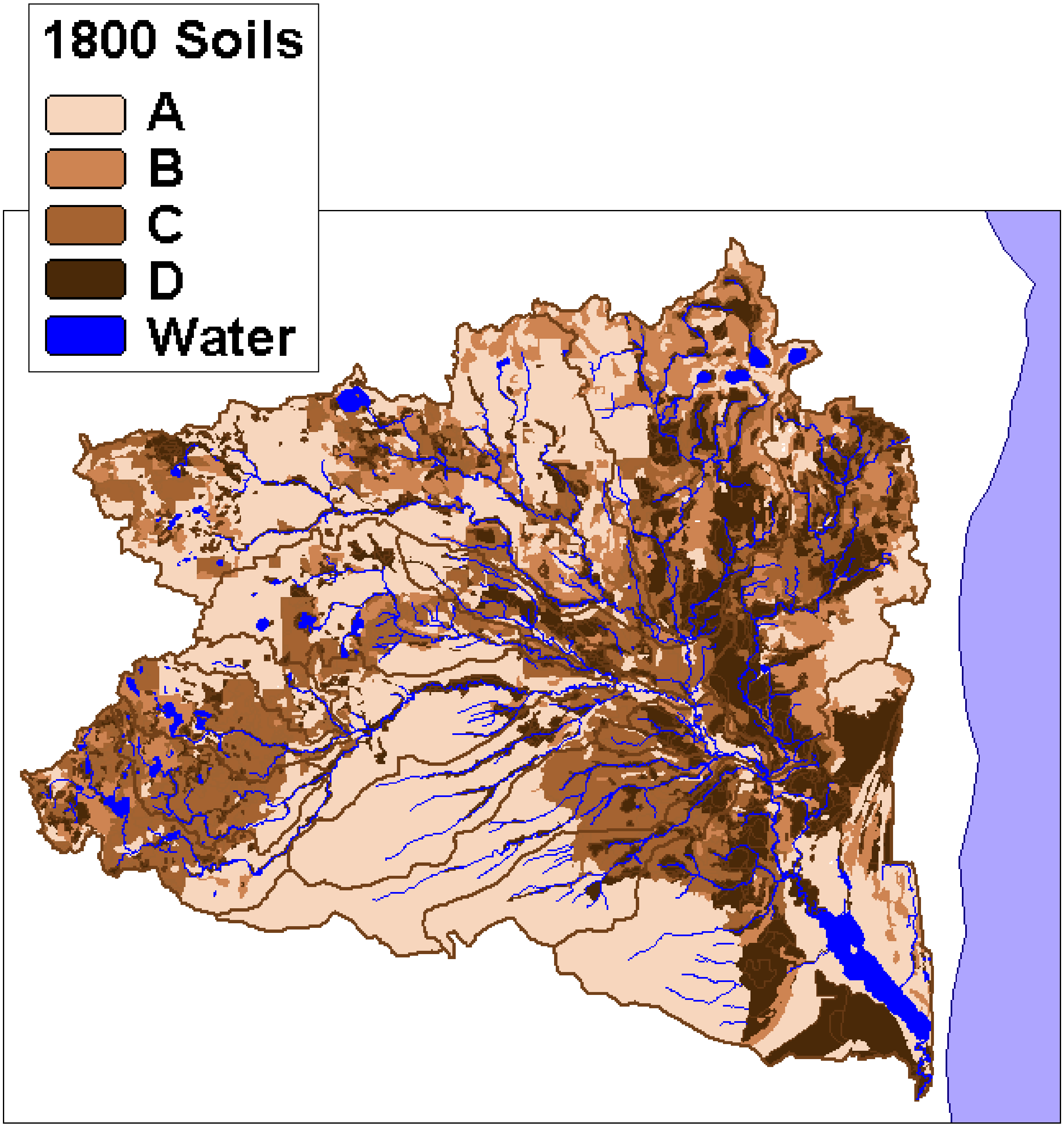

Figure 14: Soil Hydrogroups, 1800 Land Use

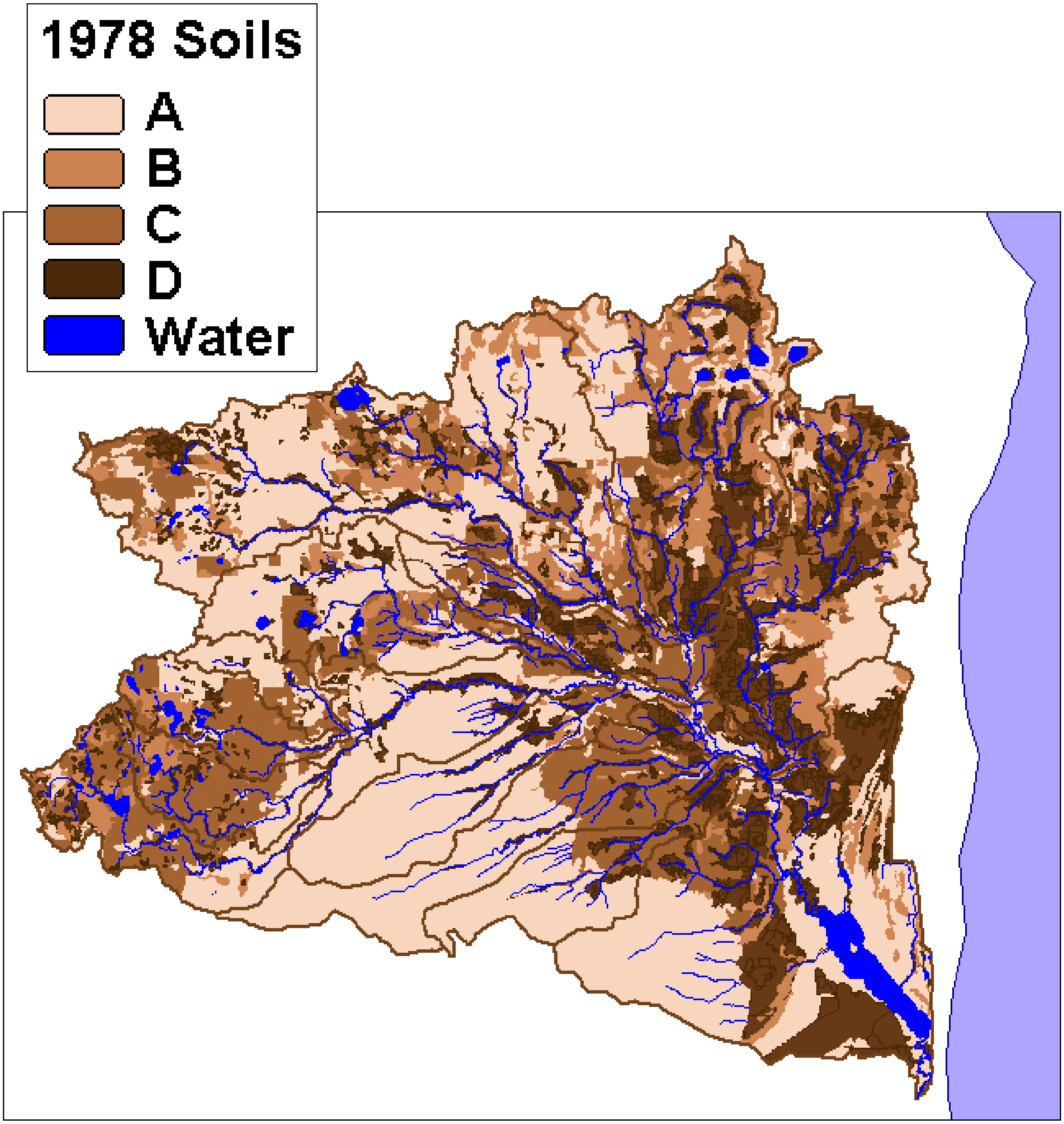

Figure 15: Soil Hydrogroups, 1978 Land Use

Hydrologic Parameters

Rainfall

The 50 percent chance (2-year) and 4 percent chance (25-year) 24-hour design storm rainfall values for this watershed are 2.11 and 3.60 inches respectively, as tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129. Runoff from the 50 percent chance storm can be associated with channel-forming flows. Runoff from the 4 percent chance storm can be associated with flood flows. In this study, only analysis results using the 4 percent chance storm are reported. See the Runoff Curve Numbers section for more information.

Runoff Curve Numbers

Surface runoff volumes and flows were modeled using the runoff curve number technique. This technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land use and soil data as a runoff curve number. The technique, as adapted for Michigan, is described in "Computing Flood Discharges For Small Ungaged Watersheds (Sorrell, 2003). The runoff curve numbers (CN) were calculated using GIS technology from the digital land use and soil data shown in Figures 11, 12, 14, and 15. The drainage area and runoff curve numbers for each subbasin are listed in Table 4.

The runoff curve numbers have not increased from 1800 to 1978 for most of the watershed. Present day runoff characteristics and curve numbers should be similar to the 1978 scenario since most of the watershed land uses are natural and often protected from land use change, or are agricultural but with little apparent development pressure.

An assumption of the runoff curve number technique is that the entire watershed contributes runoff. The curve number technique documentation is the NRCS's Part 630 Hydrology National Engineering Handbook. Chapter 10, Section 630-1003 Accuracy, of this handbook states, "The runoff equation generally did reasonably well where the runoff was a substantial fraction of the rainfall, but poorly in cases where the runoff was a small fraction of the rainfall; i.e., the CNs are low or rainfall values are small. Curve numbers were originally developed from annual flood flows from experimental watersheds, and their application to low flows or small flood peak flows is not recommended. (See Hawkins, et al. 1985, for a precise measure of small.)" According to Hawkins, "relative storm size is then proposed to be defined on the ratio P/S, where a "large" storm has P/S>0.46, when 90 percent of all rainstorms will create runoff." P/S is the ratio of precipitation, P, to potential maximum retention, S. Using the criterion that P/S should exceed 0.46, the minimum modeled rainfall in the Pine River/Van Etten Lake model should range from 1.5 to 4.3 inches, depending on the subbasin and land use scenario. For this reason, the hydrologic analysis in this study only includes results for the 4 percent chance storm. Runoff volumes and peak flows for smaller events would depend upon the portion of each subbasin contributing runoff, which will vary with the rainfall total and intensity and was therefore not included in this study.

Table 4: Subbasin Parameters – Drainage Area and Curve Number

Subbasin		Drainage Area (sq. mi.)	Curve Number	
ID	Description		1800	1978
1	East Branch Pine River, to Mouth	32.4	67.5	69.0
2	West Branch Pine River, to Mouth	53.8	59.5	58.2
3	Pine River, above South Branch Pine River	4.0	76.0	72.4
4	Kurtz Creek, above Samyn Creek	8.1	68.1	68.7
5	Samyn Creek, to Mouth	4.1	56.4	56.3
6	Wallace Creek, to Mouth	8.2	68.4	70.9
7	South Branch Pine River, above McGillis Creek	25.5	61.1	60.3
8	McGillis Creek, above Gimlet Creek	17.0	58.6	58.6
9	McGillis Creek, to Mouth	5.7	66.0	66.0
10	South Branch Pine River, to Mouth	15.1	54.2	51.6
11	Roy Creek, to Mouth	17.0	58.1	57.0
12	Pine River, above Van Etten Creek	4.0	73.3	70.9
13	Van Etten Creek, to Mouth	27.6	68.3	72.1
14	Duval Creek, to Mouth	11.4	57.2	56.9
15	Van Etten River, to Mouth	48.4	64.0	64.2

Hydrologic Analysis Results

Modeled stormwater runoff volumes for most of the watershed have not increased from 1800 to 1978. Peak flow trends were not modeled, but would not necessarily follow the runoff volume trends because of ponding adjustments for wetland storage.

Runoff volumes were calculated for each subbasin from 1800 to 1978 for the 4 percent chance (25-year), 24-hour storm. For comparison, the calculated runoff volumes are divided by the drainage areas, as shown in Figures 16 and 17 and tabulated in Table 5. The units are acre-inches per acre (volume per area), or simply inches. Runoff volumes and peak flows for the 50 percent chance (2-year), 24-hour storm are not reported because the hydrologic modeling of this storm for this watershed does not satisfy model assumptions regarding minimum runoff volume.

Changes in runoff per area from 1800 to 1978 are shown in Figure 18 and are also tabulated in Table 5. Although the percentage change would vary with different design storms, the rank order would not change.

The results highlight subbasins that generate a higher proportion of runoff due to soils and land use. Runoff volume per area can be used to help select critical areas. Higher values can identify areas that need rehabilitation activities. Lower values can identify sensitive areas to be protected. The Van Etten Creek and Wallace Creek subbasins have the largest increases in runoff over this period and are first and third highest in runoff volume per area. The East Branch of the Pine River subbasins has the third largest increase in runoff.

Because the runoff volumes are low and because the runoff volume increases are nonexistent or comparatively minor, large-scale stream channel instability, erosion, and flooding are not likely problems in this watershed. If such problems exist, they would likely be limited to smaller sites or tributary streams, which are beyond the scope of this study, with correspondingly local causes.

Future hydrologic changes can impact stream flows, water quality, channel erosion, and flooding. These changes can be moderated with effective stormwater management techniques such as:

- treatment of the “first flush” runoff
- wetland protection
- retention and infiltration of excess runoff
- low impact development techniques
- 24-hour extended detention of 1-year flows
- properly designed detention of runoff from low probability storms

Refer to the Stormwater Management section for more detail.

Table 5: Runoff Volume by Subbasin – highlighted cells indicate three highest values

Subbasin		1800 Land Use, Runoff Volume per Area (inches)	1978 Land Use, Runoff Volume per Area (inches)	Runoff Volume per Area Change (percent)
ID	Description			
1	East Branch Pine River, to Mouth	0.93	1.02	8.8%
2	West Branch Pine River, to Mouth	0.55	0.50	-9.6%
3	Pine River, above South Branch Pine River	1.44	1.21	-15.8%
4	Kurtz Creek, above Samyn Creek	0.96	1.00	3.4%
5	Samyn Creek, to Mouth	0.43	0.43	-1.6%
6	Wallace Creek, to Mouth	0.98	1.12	14.0%
7	South Branch Pine River, above McGillis Creek	0.62	0.59	-5.2%
8	McGillis Creek, above Gimlet Creek	0.52	0.52	0.2%
9	McGillis Creek, to Mouth	0.86	0.86	-0.1%
10	South Branch Pine River, to Mouth	*0.35	*0.27	-24.0%
11	Roy Creek, to Mouth	0.50	0.45	-8.5%
12	Pine River, above Van Etten Creek	1.27	1.12	-11.5%
13	Van Etten Creek, to Mouth	0.97	1.19	22.3%
14	Duval Creek, to Mouth	0.46	0.45	-2.3%
15	Van Etten River, to Mouth	0.75	0.77	1.6%

* Runoff Volume may be inaccurate; P/S value is 0.43

** Runoff Volume may be inaccurate; P/S value is 0.38

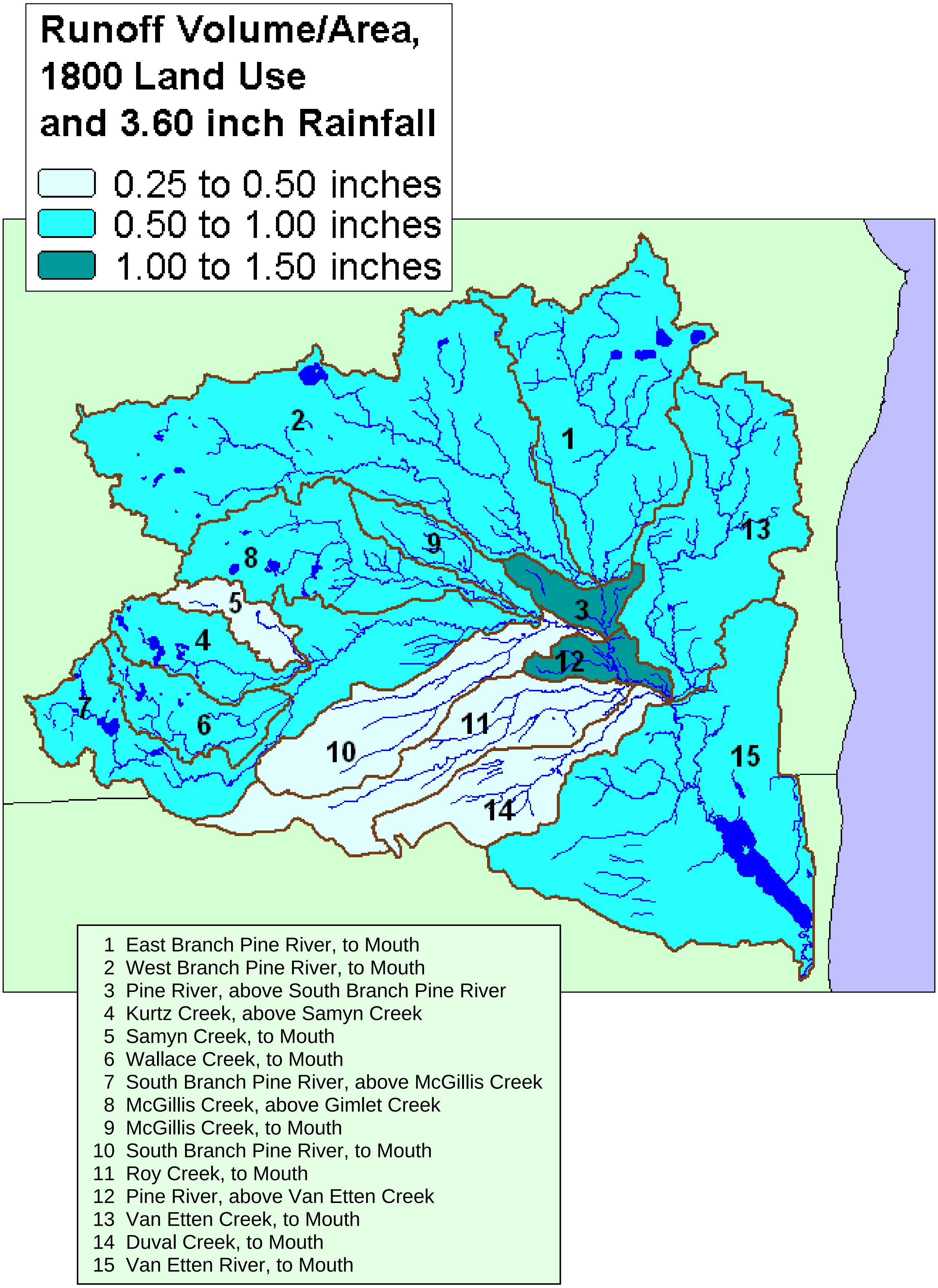

Figure 16: Runoff Volume/Drainage Area, 1800 Land Use

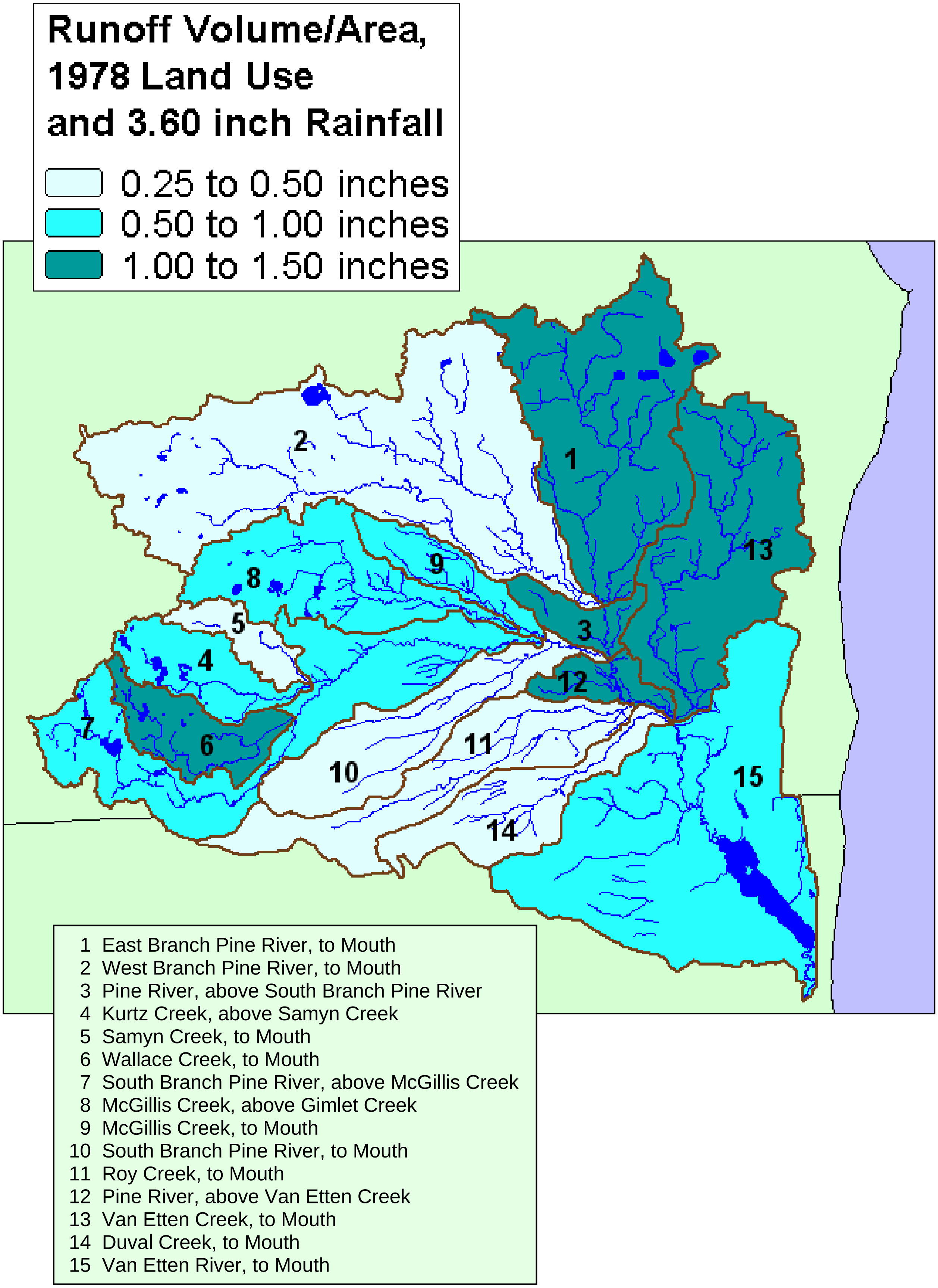

Figure 17: Runoff Volume/Drainage Area, 1978 Land Use

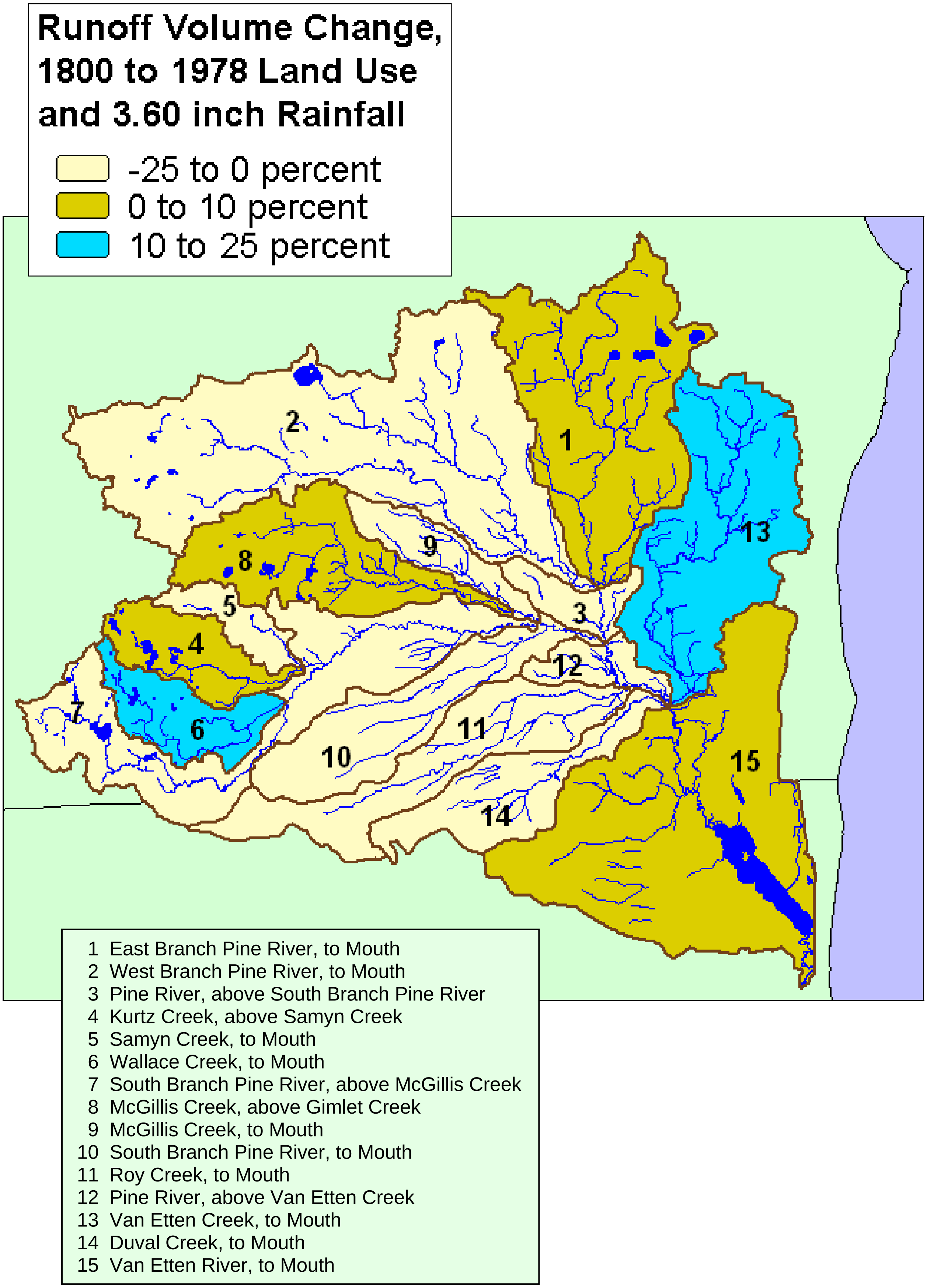

Figure 18: Change in Runoff Volume/Drainage Area, 1800 to 2005 Land Use

Stormwater Management

When precipitation falls, it can infiltrate into the ground, evapotranspirate back into the air, or run off the ground surface to a water body. It is helpful to consider three principal runoff effects: water quality, channel shape, and flood levels, as shown in Figure 19.

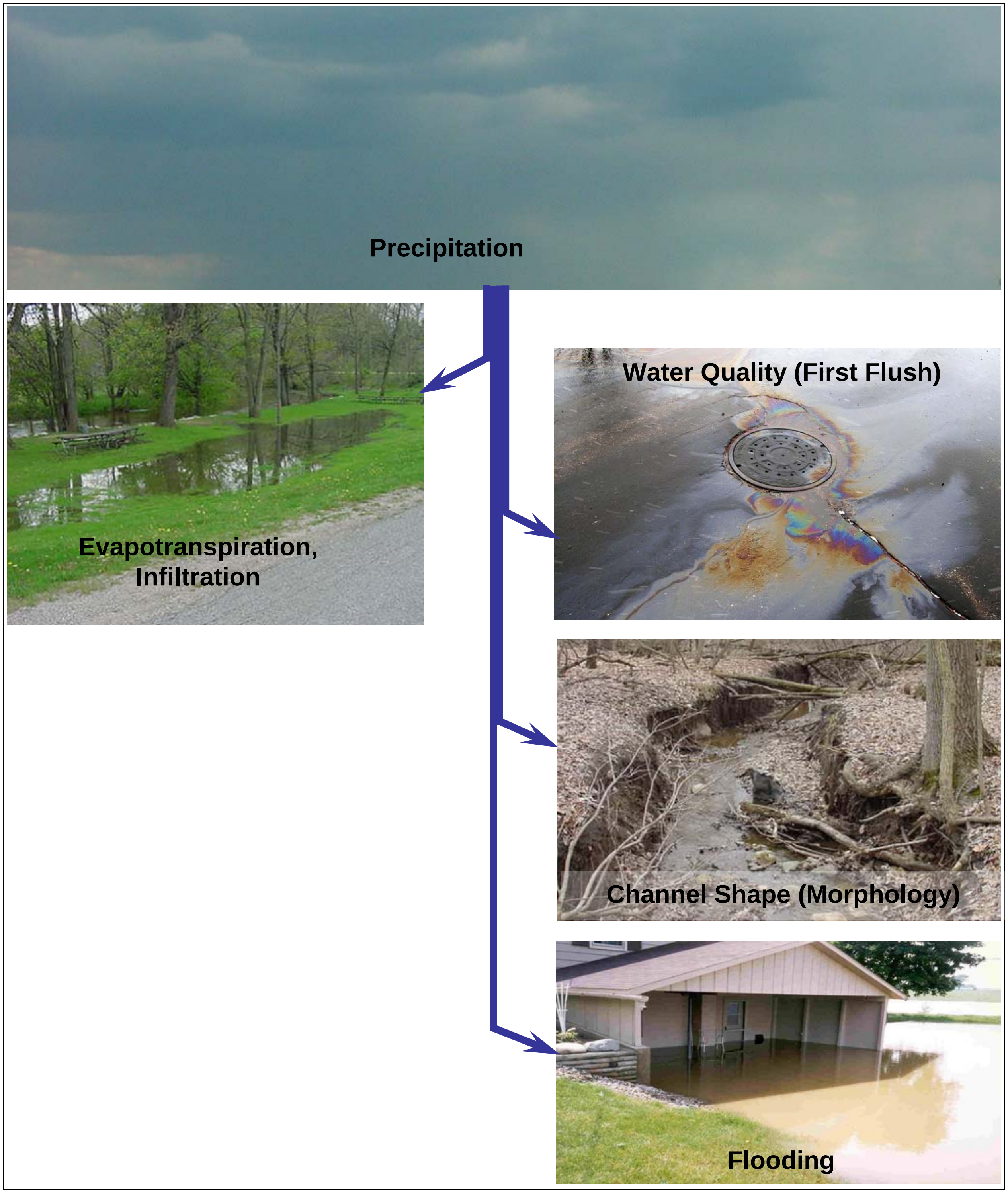

Figure 19: Runoff Impacts

Land use changes that reduce evapotranspiration and infiltration increase runoff. One reason low impact development has become more popular is that it avoids creating more runoff; intercepting and infiltrating the excess runoff instead.

Runoff from small rainfall events and the first portion of the runoff from larger events is termed the "first flush", because it carries the majority of the pollutants. For more information, refer to the Water Quality section.

Larger, but frequent, storms or snowmelts produce the flows that shape the channel. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm may do little to control the runoff from the 50 percent chance, 24-hour storm, unless the outlet is specifically designed to do so. For more information, refer to the Stream Channel Protection section.

Increases in the runoff volume and peak flow from large storms, such as the 4 percent chance (25-year), 24-hour storm, could cause or aggravate flooding problems unless mitigated using effective stormwater management techniques. For more information, refer to the Flood Protection section.

Water Quality

Small runoff events and the first portion of the runoff from larger events typically pick up and deliver the majority of the pollutants to a watercourse in an urban area (Menerey, 1999 and Schueler, 2000). As the rain continues, there are fewer pollutants available to be carried by the runoff, and thus the pollutant concentration becomes lower. Figure 20 shows a typical plot of pollutant concentration versus time. The sharp rise in the plot has been termed the "first flush." Some of the pollutants can settle out before discharging to a stream if this first flush runoff is detained for a period of time. Filtering systems are also used at some sites to treat the first flush stormwater.

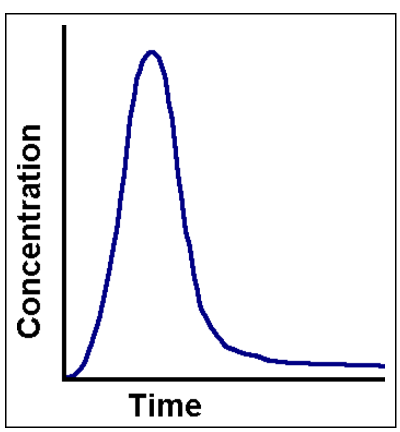

Figure 20: Plot of Pollutant Concentration versus Time

Nationally, the amount of runoff recommended for capture and treatment varies from 0.5 inch per impervious acre to the runoff from a 50 percent chance storm. Michigan BMP guidelines recommend capture and treatment of 0.5 inch of runoff from a single site (Guidebook of Best Management Practices for Michigan Watersheds, 1998). The runoff is then released over 24 to 48 hours or is allowed to infiltrate into the ground within 72 hours. Dry detention ponds are less effective than retention or wet detention ponds, because the accumulated sediment in a dry detention pond may be easily resuspended by the next storm (Schueler, 2000).

Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet. For multiple sites or watershed wide design, it is best to design to capture and treat 90 percent of runoff-producing storms. This "90 percent rule" effectively treats storm runoff that could be reaching the treatment at different times during the storm event. It was designed to provide the greatest amount of treatment that is economically feasible. In Michigan, values calculated for these storms range from 0.77 to 1.00 inches. For the Pine River/Van Etten Lake watershed climatic regions, the calculated value is 0.78 inches. Additional information is available at www.michigan.gov/documents/deq/lwm-hsu-nps-ninety-percent_198401_7.pdf.

Stream Channel Protection

Channels are shaped primarily by flows that recur fairly frequently; every one to two years in a stable stream. Bankfull flows are the channel-forming flows in a stable stream. Increases in runoff volumes and peak flows from 1- to 2-year storms increase channel-forming flows, which increase streambank and bed erosion as the stream enlarges to accommodate the higher flows. A stream can take 50 years or more to adapt to flow changes (Schueler, 2000, *Dynamics of Urban Stream Channel Enlargement*).

A stable stream is one that, over time, maintains a stable morphology: a constant pattern (sinuosity), slope, and cross-section, and neither aggrades or degrades. Stream stability is not the absence of erosion; some sediment movement and streambank erosion are natural.

Possible causes of erosion are:

- Natural river dynamics
- Sparse vegetative cover due to too much animal or human traffic
- Concentrated runoff adjacent to the streambank, i.e. gullies, seepage
- In-stream flow obstructions, i.e. log jams, failed bridge supports
- An infrequent event, such as an ice jam or low probability flood
- Unusually large or frequent wave action
- A significant change in the hydrologic characteristics (typically land use) of the watershed
- A change in the stream form impacting adjacent portions of the stream, i.e. dredging, channelization

An assessment of the cause(s) of erosion is necessary so that proposed solutions will be permanent and do not simply move the erosion problem to another location. The first six listed causes can produce localized erosion. Either of the last two causes, however, could produce a morphologically unstable stream. Symptoms of active channel enlargement in an unstable stream include:

- Knickpoint migration of the channel bottom
- Extensive and excessive erosion of the stream banks
- Erosion on the inside bank of channel bends
- Evidence in the streambanks of bed erosion down through an armor layer
- Exposed sanitary or storm sewers that were initially installed under the steam bed

Erosion in a morphologically unstable stream is caused by increases in the relatively frequent channel-forming flows that, because of their higher frequency, have more effect on channel form than extreme flood flows. As shown in Figure 21, multiplying the sediment transport rate curve (a) by the storm frequency of occurrence curve (b) yields a curve (c) that, at its peak, indicates the flow that moves most of the sediment in a stream. This flow is termed the effective discharge. The effective discharge usually has a one- to two-year recurrence interval and is the dominant channel-forming flow in a stable stream.

Increases in the frequency, duration, and magnitude of these flows cause stream bank and bed erosion as the stream adapts. According to the *Stream Corridor Restoration* manual, stream channels can often enlarge their cross-sectional area by a factor of two to five (FISRWG, 10/1998). In *Dynamics of Urban Stream Channel Enlargement, The Practice of Watershed Protection*, ultimate channel enlargement ratios of up to approximately 10 are reported, as shown in Figure 22 (Schueler, 2000).

To prevent or minimize this erosion, watershed stakeholders should specifically consider stormwater management to protect channel morphology. Low impact development and infiltration BMPs can be incorporated to offset flow increases. Stormwater management ordinances can specifically address channel protection. However, where ordinances have included channel protection criteria, it has typically been focused on controlling peak flows from the 2-year storm.

The nationally recognized Center for Watershed Protection asserts that 24-hour extended detention for runoff from 1-year storms better protects channel morphology than 2-year peak discharge control because it does not reduce the frequency of erosive bankfull and sub-bankfull flows that often increase as development occurs within the watershed. Indeed, it may actually increase the duration of these erosive, channel-forming flows. The intent of 24-hour extended detention for runoff from 1-year storms is to limit detention pond outflows from these storms to non-erosive velocities, as shown in Figure 23. A few watershed plans funded through the MDEQ NPS Program have recommended requirements based on this criterion. One such example is from the Anchor Bay Technical Report and is shown in Figure 24. This analysis, which is for climatic region 10, is for 2.06 inches of rainfall. The Pine River/Van Etten Lake watershed is mostly in climatic region 4, which has a 50 percent chance (2-year)

24-hour storm design rainfall value of 2.11 inches, as tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992, pp. 126-129. The MDEQ NPS Program is exploring funding this analysis for Michigan. The results would be provided to the Pine River/Van Etten Lake stakeholders when available.

Control of channel-forming flows is not essential for some drainage areas. For example, detention designed to prevent streambank erosion may not be needed for runoff routed from a city through storm sewers to a large river, simply because the runoff routed through the storm sewers enters the river well ahead of the peak flow in the river. In this case, the city's management plan for stormwater routed through storm sewers should focus on treating the runoff to maintain water quality and providing sufficient drainage capacity to minimize flooding. Detention/retention might also be encouraged or required for other reasons, such as water quality improvement, groundwater replenishment, or if watershed planning indicates continued regional development would alter the river's flow regime or increase flood levels.

Hydrologic and hydraulic modeling may be justified to determine if runoff from a drainage area should be limited, either by detention or infiltration, to prevent flow or flood level increases or to verify that flood peaks are not increased due to the timing of the peak flows from detention ponds and in the stream. Pine River/Van Etten Lake stakeholders may elect to recommend some conditions when detention or retention for channel protection is not necessary. For example, the watershed stakeholders may adopt a watershed plan that calls for channel protection measures, unless runoff discharges from a storm drain directly to a specific order or higher stream, as shown in Figure 8.

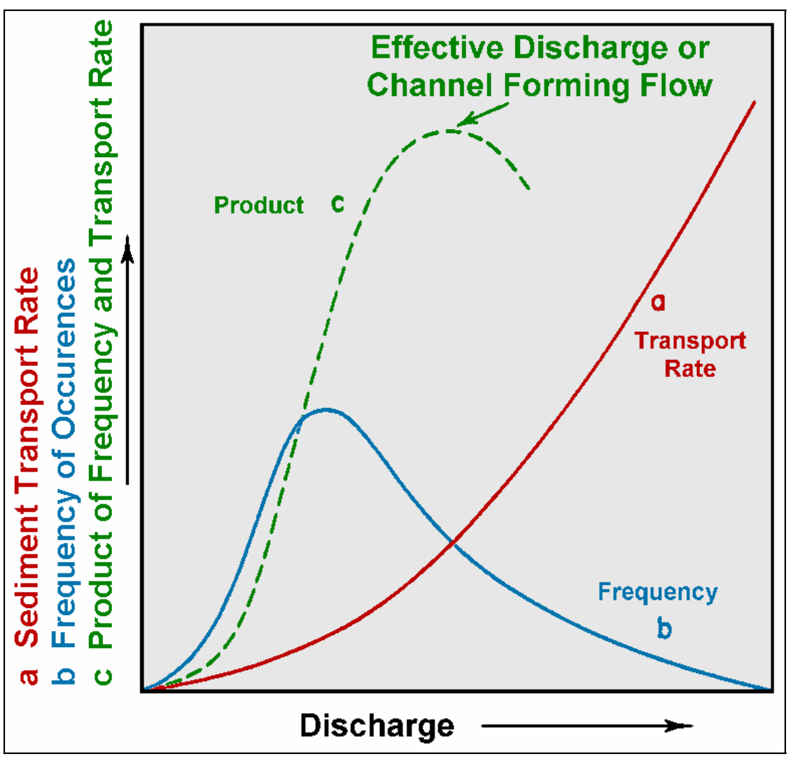

Figure 20: Effective Discharge (from *Applied River Morphology*. 1996. Dave Rosgen)

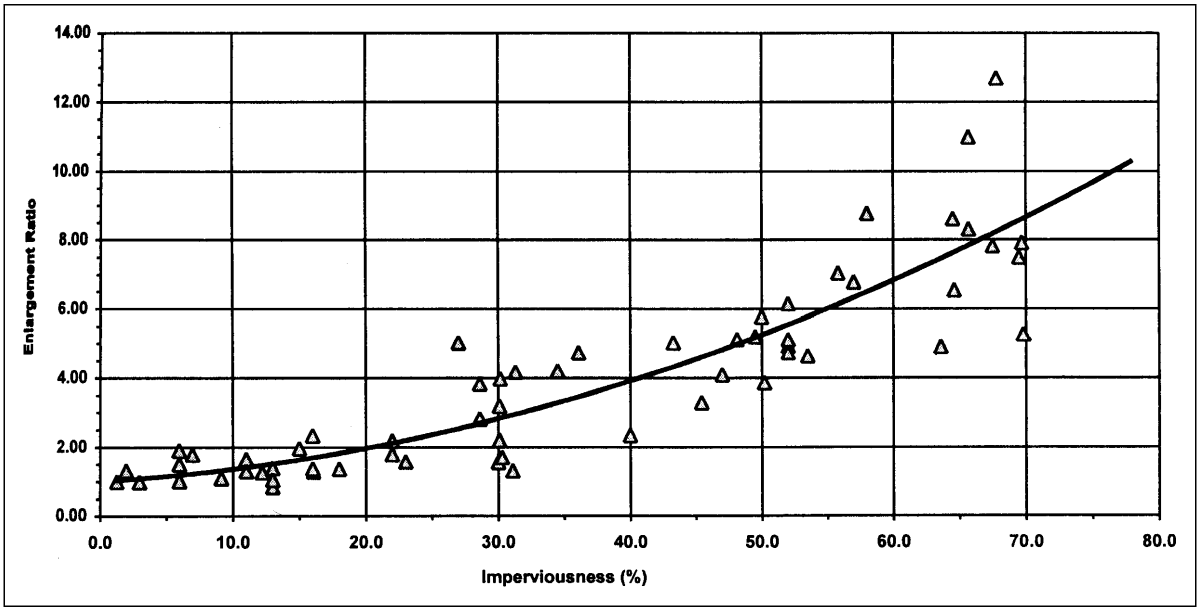

Figure 21: “Ultimate” Channel Enlargement as a Function of Impervious Cover in Alluvial Streams in Maryland, Vermont, and Texas (MacRae and DeAndrea, 1999; and Brown and Claytor, 2000) (From *The Practice of Watershed Protection*, Thomas R. Schueler and Heather K. Holland, 2000)

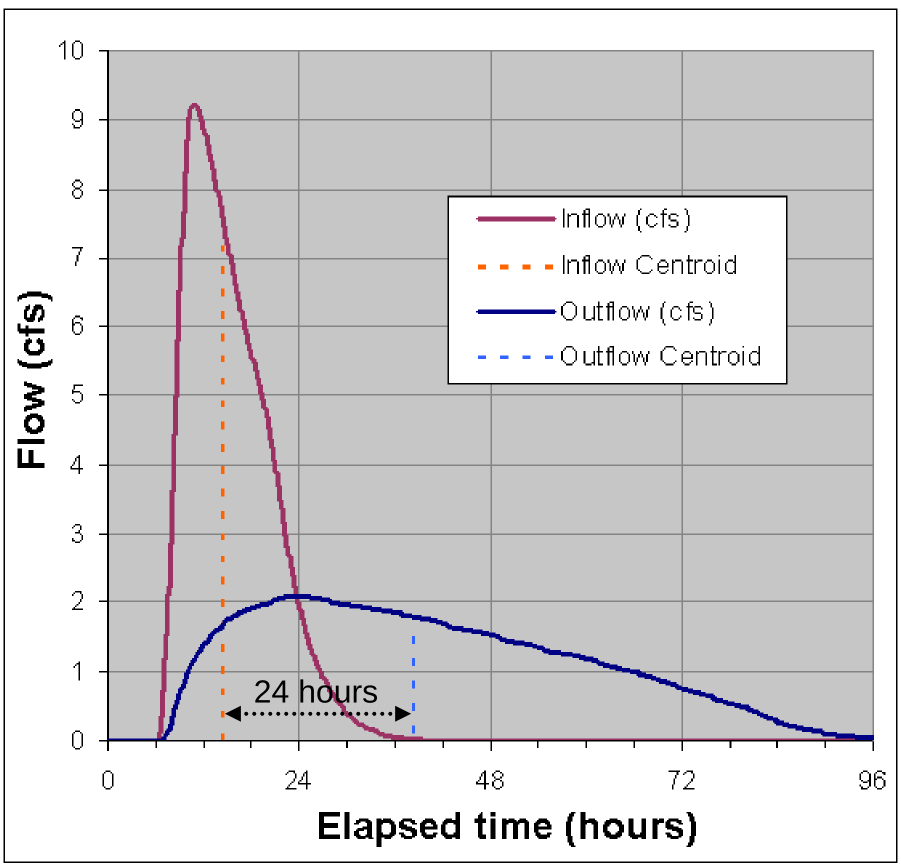

Figure 22: Example of 24-hour extended detention criterion applied to detention pond design

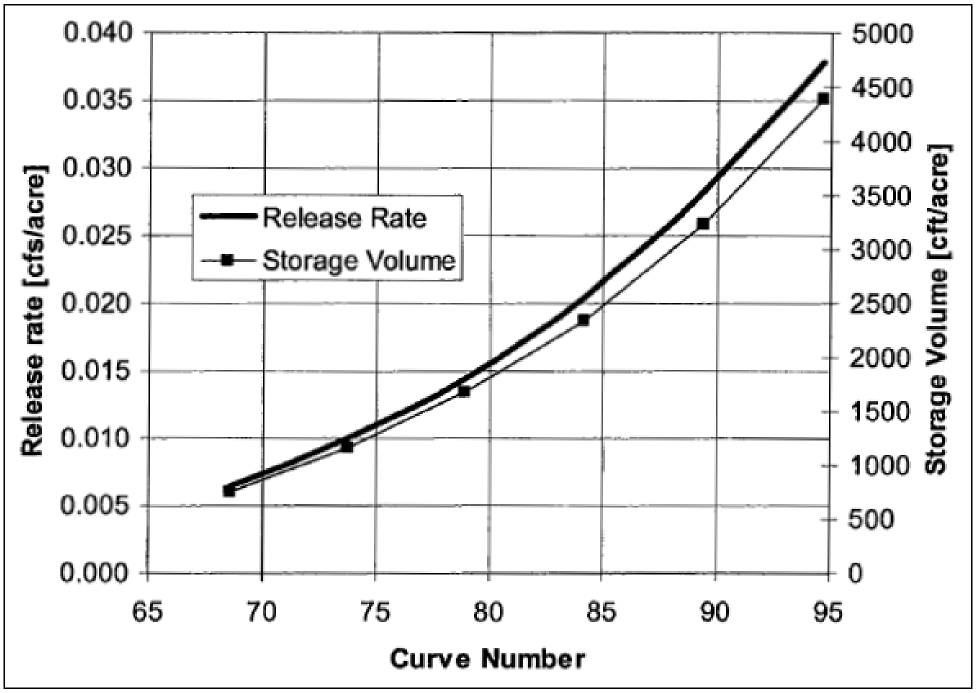

Figure 23: Example of detention pond requirements derived from the 24-hour extended detention criterion

Flood Protection

A river, stream, lake, or drain may occasionally overflow its banks and inundate adjacent land. This land is the floodplain. The floodplain refers to the land inundated by the 1 percent chance flood, commonly called the 100-year flood. Typically, a stable stream will recover naturally from these infrequent events. Developments should always include stormwater controls that prevent flood flows from exceeding pre-development conditions and putting people, homes, and other structures at risk. Many localities require new development to control the 4 percent chance flood, commonly called the 25-year flood, with some adding requirements to control the 1 percent chance flood.

References

Anchor Bay Watershed Transition/Implementation Project, Technical Report for Watershed Management Plan, Fishbeck, Thompson, Carr and Huber, April 2006. www.michigan.gov/deq/0,1607,7-135-3313_3682_3714_31581-104205--,00.html

Ducks Unlimited and The Nature Conservancy in Michigan. Conservation and Recreation Land of Michigan [ESRI shapefile]. 2007. Ann Arbor, MI: Ducks Unlimited Great Lakes/Atlantic Regional Office. http://glaro.ducks.org/carl

FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (15 Federal agencies of the US government). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. www.nrcs.usda.gov/technical/stream_restoration/

Hawkins, R.H., A.T. Hjelmfelt, and A.W. Zevenbergen. 1985. Runoff Probability, Storm Depth, and Curve Numbers. J. Irr. and Drain. ASCE, Vol. 111, No. 4, pp. 330-340. www.pubs.asce.org/WWWdisplay.cgi?8503450

Guidebook of Best Management Practices for Michigan Watersheds. Michigan Department of Water Quality, Surface Water Quality Division, 1993 (Reprinted October 1998). www.deq.state.mi.us/documents/deq-swq-nps-WholeGuidebook.pdf

Menerey, Bruce, *Stormwater Management Guidebook.* Michigan Department of Natural Resources, Land and Water Management Division, March 1992 (Revised August 1999 and distributed by Michigan Department of Environmental Quality, Land and Water Management Division). www.michigan.gov/documents/deq/lwm-smg-all_202833_7.pdf

Natural Resources Conservation Service, Part 630 Hydrology National Engineering Handbook, Chapter 10. http://policy.nrcs.usda.gov/media/pdf/H_210_630_10.pdf

Rosgen, Dave, Applied River Morphology. Printed Media Companies, Minneapolis, Minnesota, 1996.

Schueler, Thomas R. and Holland, Heather K., editors. The Practice of Watershed Protection, Center for Watershed Protection. Elliot City, Maryland, 2000.

Sorrell, Richard C., Computing Flood Discharges for Small Ungaged Watersheds, Michigan Department of Environmental Quality, revised July 2003. www.michigan.gov/documents/deq/lwm-scs_198408_7.pdf

Appendix A: Acronyms

BMP – Best Management Practice

CARL – Conservation and Recreation Lands

CN – Runoff Curve Number

EPA – United States Environmental Protection Agency

GIS – Geographic Information Systems

MDEQ – Michigan Department of Environmental Quality

MDNR – Michigan Department of Natural Resources

NHD – National Hydrography Dataset

NPS – Nonpoint Source

NRCS – Natural Resources Conservation Service

P/S – Ratio of precipitation, P, to potential maximum retention, S

Appendix B: Glossary

Aggrade - to fill and raise the level of a stream bed by deposition of sediment.

Alluvium - sediment deposited by flowing rivers and consisting of sands and gravels.

Bankfull discharge - that discharge of stream water that just begins to overflow in the active floodplain. The active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at recurrence interval of about 2 years or less. Erosion, sediment transport, and bar building by deposition are most active at discharges near bankfull. The effectiveness of higher flows, called over bank or flood flows, does not increase proportionally to their volume above bankfull in a stable stream, because overflow into the floodplain distributes the energy of the stream over a greater area. See also channel-forming and effective discharge.

Base Flow - the part of stream flow that is attributable to long-term discharge of groundwater to the stream. This part of stream flow is not attributable to short-term surface runoff, precipitation, or snow melt events.

Best Management Practice (BMP) - structural, vegetative, or managerial practices used to protect and improve our surface waters and groundwaters.

Channel-forming Discharge - a theoretical discharge which would result in a channel morphology close to the existing channel. See also effective and bankfull discharge.

Critical Areas - the geographic portions of the watershed contributing the majority of the pollutants and having significant impacts on the waterbody.

Critical Depth - depth of water for which specific energy is a minimum.

Curve Number (CN) - see Runoff Curve Number.

Design Flow - projected flow through a watercourse which will recur with a stated frequency. The projected flow for a given frequency is calculated using statistical analysis of peak flow data or using hydrologic analysis techniques.

Detention - practices which store stormwater for some period of time before releasing it to a surface waterbody. See also retention.

Dimensionless Hydrograph - a general hydrograph developed from many unit hydrographs, used in the Soil Conservation Service method.

Direct Runoff Hydrograph - graph of direct runoff (rainfall minus losses) versus time.

Discharge - volume of water moving down a channel per unit time. See also channel-forming, effective, and bankfull discharge.

Drainage Divide - boundary that separates subbasin areas according to direction of runoff.

Effective Discharge - the calculated measure of channel forming discharge. This calculation requires long-term water and sediment measurements, although modeling results are sometimes substituted. See also channel-forming and bankfull discharge.

Ephemeral Stream - a stream that flows only during or immediately after periods of precipitation. See also intermittent and perennial streams.

Evapotranspiration - the combined process of evaporation and transpiration.

First Flush - the first part of a rainstorm that washes off the majority of pollutants from a site. The concept of first flush treatment applies only to a single site, even if just a few acres, because of timing of the runoff. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet.

Flashiness - has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes.

Flood Hazard Zone - area that will flood with a given probability.

Groundwater - that part of the subsurface water that is in the saturated zone.

Headwater Stream - the system of wetlands, swales, and small channels that mark the beginnings of most watersheds.

Hydraulic Analysis - an evaluation of water elevation for a given flow based on channel attributes such as slope, cross-section, and vegetation.

Hydrograph - graph of discharge versus time.

Hydrologic Analysis - an evaluation of the relationship between stream flow and the various components of the hydrologic cycle. The study can be as simple as determining the watershed size and average stream flow, or as complicated as developing a computer model to determine the relationship between peak flows and watershed characteristics, such as land use, soil type, slope, rainfall amounts, detention areas, and watershed size.

Hydrologic Cycle - When precipitation falls to the earth, it may:

- be intercepted by vegetation, never reaching the ground.
- infiltrate into the ground, be taken up by vegetation, and evapotranspirated back to the atmosphere.
- enter the groundwater system and eventually flow back to a surface water body.
- runoff over the ground surface, filling in depressions.
- enter directly into a surface waterbody, such as a lake, stream, or ocean.

When water evaporates from lakes, streams, and oceans and is re-introduced to the atmosphere, the hydrologic cycle starts over again.

Hydrology - the occurrence, distribution, and movement of water both on and under the earth's surface. It can be described as the study of the hydrologic cycle.

Hyetograph - graph of rainfall intensity versus time.

Impervious - a surface through which little or no water will move. Impervious areas include paved parking lots and roof tops.

Infiltration Capacity - rate at which water can enter soil with excess water on the surface.

Interflow - flow of water through the upper soil layers to a ditch, stream, etc.

Intermittent Stream - a stream that flows only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year. See also ephemeral and perennial streams.

Invert - bottom of a channel or pipe.

Knickpoint - a point of abrupt change in bed slope. If the streambed is made of erodible material, the knickpoint, or downcut, may migrate upstream along the channel and have undesirable effects, such as undermining bridge piers and other manmade structures.

Lag Time - time from the center of mass of the rainfall to the peak of the hydrograph.

Low Impact Development (LID) - a comprehensive design and development technique that strives to mimic pre-development hydrologic characteristics and water quality with a series of small-scale distributed structural and non-structural controls.

Losses - rainfall that does not runoff, i.e. rainfall that infiltrates into the ground or is held in ponds or on leaves, etc.

Low Flow - minimum flow through a watercourse which will recur with a stated frequency. The minimum flow for a given frequency may be based on measured data, calculated using statistical analysis of low flow data, or calculated using hydrologic analysis techniques. Projected low flows are used to evaluate the impact of discharges on water quality. They are, for example, used in the calculation of industrial discharge permit requirements.

Morphology, Fluvial - the study of the form and structure of a river, stream, or drain.

Nonpoint Source (NPS) Pollution - pollutants carried in runoff characterized by multiple discharge points. Point sources emanate from a single point, generally a pipe.

Overland Flow - see Runoff.

Peak Flow - maximum flow through a watercourse which will recur with a stated frequency. The maximum flow for a given frequency may be based on measured data, calculated using statistical analysis of peak flow data, or calculated using hydrologic analysis techniques. Projected peak flows are used in the design of culverts, bridges, and dam spillways.

Perched Ground Water - unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone.

Perennial Stream - a stream that flows continuously during both wet and dry times. See also ephemeral and intermittent streams.

Precipitation - water that falls to earth in the form of rain, snow, hail, or sleet.

Rating Curve - relationship between depth and amount of flow in a channel.

Recession Curve - portion of the hydrograph where runoff is from base flow.

Retention - practices which capture stormwater and release it slowly though infiltration into the ground. See also detention.

Riparian - pertaining to the bank of a river, pond, or small lake.

Runoff - flow of water across the land surface as surface runoff or interflow. The volume is equal to the total rainfall minus losses.

Runoff Coefficient - ratio of runoff to precipitation.

Runoff Curve Number - parameter developed by the Natural Resources Conservation Service (NRCS) that accounts for soil type and land use.

Saturated Zone - (1) those parts of the earth's crust in which all voids are filled with water under pressure greater than atmospheric; (2) that part of the earth's crust beneath the regional water table in which all voids, large and small, are filled with water under pressure greater than atmospheric; (3) that part of the earth's crust beneath the regional water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

Scarp - the sloped bank of a stream channel.

Sediment - soil fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice.

Sinuosity - the ratio of stream length between two points divided by the valley length between the same two points.

Simulation Model - model describing the reaction of a watershed to a storm using numerous equations.

Soil - unconsolidated earthy materials which are capable of supporting plants. The lower limit is normally the lower limit of biological activity, which generally coincides with the common rooting of native perennial plants.

Soil Moisture Storage - volume of water held in the soil.

Storage Delay Constant - parameter that accounts for lagging of the peak flow through a channel segment.

Storage-Discharge Relation - values that relate storage in the system to outflow from the system.

Stream Corridor - generally consists of the stream channel, floodplain, and transitional upland fringe.

Subbasins - hydrologic divisions of a watershed that are relatively homogenous.

Synthetic Design Storm - rainfall hyetograph obtained through statistical means.

Synthetic Unit Hydrograph - unit hydrograph for ungaged basins based on theoretical or empirical methods

Thalweg - the "channel within the channel" that carries water during low-flow conditions.

Time of Concentration - time at which outflow from a basin is equal to inflow or time of equilibrium.

Transpiration - conversion of liquid water to water vapor through plant tissue.

Tributary - a river or stream that flows into a larger river or stream.

Unit Hydrograph - graph of runoff versus time produced by a unit rainfall over a given duration.

Unsaturated Zone - the zone between the land surface and the water table which may include the capillary fringe. Water in this zone is generally under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric.

Vadose Zone - see Unsaturated Zone.

Watershed - area of land that drains to a single outlet and is separated from other watersheds by a divide.

Watershed Delineation - determination of watershed boundaries. These boundaries are determined by reviewing USGS quadrangle maps. Surface runoff from precipitation falling anywhere within these boundaries will flow to the waterbody.

Water Surface Profile - plot of the depth of water in a channel along the length of the channel.

Water Table - the surface of a groundwater body at which the water pressure equals atmospheric pressure. Earth material below the groundwater table is saturated with water.

Yield (Flood Flow) - peak flow divided by drainage area