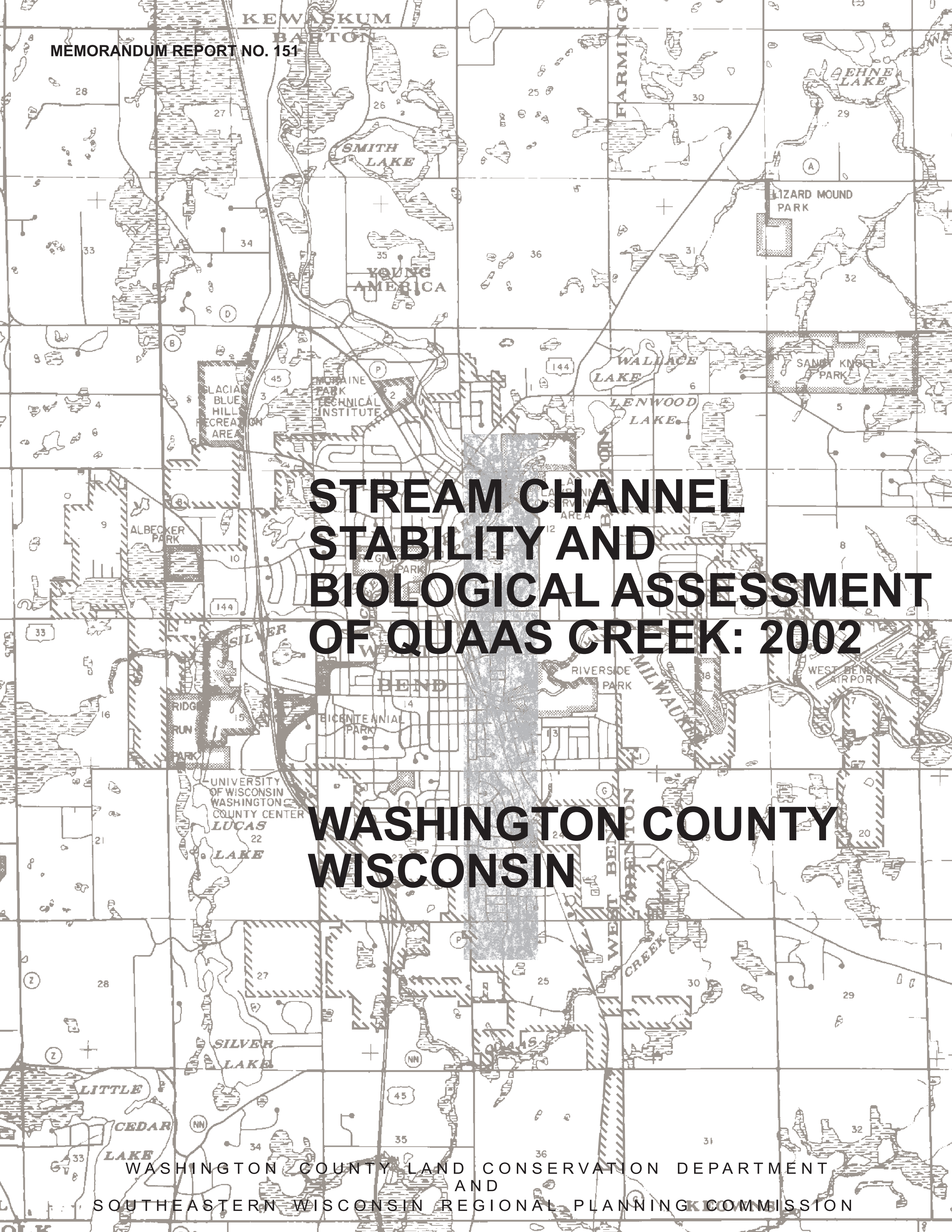
MEMORANDUM REPORT NO. 151



STREAM CHANNEL STABILITY AND BIOLOGICAL ASSESSMENT OF QUAAS CREEK: 2002

WASHINGTON COUNTY WISCONSIN

WASHINGTON COUNTY LAND CONSERVATION DEPARTMENT
AND
SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

This report was prepared as a cooperative effort between the:

City of West Bend
Town of Polk
Town of Trenton
Town of West Bend
Washington County

In cooperation with the:

Wisconsin Department of Natural Resources
University of Wisconsin-Milwaukee
Southeastern Wisconsin Regional Planning Commission

Special acknowledgement is due Dr. Thomas M. Slawski, SEWRPC Senior Planner, for his contribution to the conduct of this study and the preparation of this report.

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Prepared by the

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July 2002

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Chapter I

INTRODUCTION

Quaas Creek and its major tributaries are perennial streams extending over a linear distance of about six miles with a gradient of approximately 19 feet per mile.[1] The South Branch of Quaas Creek originates as a stream from Quaas Lake and a nearby wetland complex, while the North Branch of Quaas Creek originates just southeast of the intersection of USH 45 and Paradise Drive. The confluence of the North and South Branches of Quaas Creek lies just upstream of CTH P and north of CTH NN. From that point, Quaas Creek flows generally northeasterly before discharging to the Milwaukee River east of the City of West Bend. The Quaas Creek system is located within the Towns of Polk, Trenton, and West Bend, and the City of West Bend. Quaas Creek offers a variety of water-based recreational opportunities and is an important feature of the communities surrounding the system. The majority of the stream and adjacent riparian corridors present a rural character among changing land uses in an urbanizing watershed area.

Quaas Creek is utilized for fishing and also provides ecological and aesthetic benefits for recreational and other users. Notwithstanding, Quaas Creek has experienced various problems during recent years, including decreased water clarity, accelerated erosion, sedimentation, and degradation of the fishery. Related issues include concerns over variable water quality conditions, contamination by nonpoint source pollution, loss of riparian wetlands, and modifications of the riparian areas. These issues have been quantified to the extent possible and documented in the Washington County land and water resource management plan[2] and the Washington County land and stream classification inventory.[3]

Based upon the issues identified, the Quaas Creek Watershed Protection Committee was created by the Washington County Board of Supervisors and charged with the responsibility of preparing a watershed protection plan for Quaas Creek. Under that planning program, the Committee would refine issues, develop goals, and establish recommendations designed to preserve and protect the natural resources within the Quaas Creek watershed. As

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[1]*See SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend, Washington County, Wisconsin, *Volume Four*, Alternatives and Recommended Plan for the Quaas Creek Subwatershed*, July 1996.*

[2]*Washington County,* Washington County Land And Water Resource Management Plan: 2000-2005*, August 2000.*

[3]*SEWRPC Memorandum Report No. 139,* Surface Water Resources of Washington County Wisconsin, Lake and Stream Classification Project: 2000*, September 2001.*

part of that management plan, this channel stability and biological assessment was prepared to guide the development of recommended management actions identifying potential protection, revitalization, and restoration alternatives that may potentially be incorporated in the Quaas Creek Watershed Protection Plan.

This report represents an ongoing commitment of the Washington County Land Conservation Department in cooperation with the Washington County Planning and Parks Department; the Towns of Polk, Trenton, and West Bend; the City of West Bend; the Wisconsin Department of Natural Resources; the University of Wisconsin-Extension; the University of Wisconsin-Milwaukee; and the Southeastern Wisconsin Regional Planning Commission to sound environmental planning with respect to Quaas Creek. This report describes instream management measures that may potentially be applied to enhance the water quality conditions, biological communities, and recreational opportunities in the Creek. More specifically, this report: 1) presents an evaluation and assessment of the historical trends and current status of habitat quality and ecological integrity within Quaas Creek; 2) identifies potential limitations to water quality and fishery resources; 3) presents a bank stability analysis of the main channel of Quaas Creek; and 4) identifies and develops specific types of revitalization/restoration and management activities which are potentially applicable to improve the ecological and aesthetic values of the Creek, and enhance its resource value.

Chapter II

BACKGROUND AND SUMMARY OF INVENTORY FINDINGS

INTRODUCTION

This chapter presents an inventory and analysis of the surface waters and related features of the Quaas Creek watershed. Included is descriptive information pertaining to water use objectives and water quality standards, surface water classification of Quaas Creek, current and future land use within the watershed, historical trends and current status of habitat (physical, chemical, and biological) quality and ecological integrity within Quaas Creek, bank stability analysis of the main channel of Quaas Creek, and potential limitations to water quality and fishery resources.

STUDY AREA

The study area is shown on Map 1. The Quaas Creek watershed contains four major subwatersheds designated as the East Tributary, South Branch, North Branch, and Main Stem. These four subwatersheds were developed from nine hydrologic units and 92 subbasins identified in the stormwater management plan for the City of West Bend.[1] This study specifically considered the following stream reaches as shown on Map 1: East Tributary from its headwaters to confluence with the Quaas Creek; South Branch from Mile View Road to the confluence with the North Branch; North Branch from a private drive approximately 3,190 feet upstream of CTH P to the confluence with the South Branch; and Main Stem from the confluence of the North and South branches to the confluence with the Milwaukee River.

WATER USE OBJECTIVES AND WATER QUALITY STANDARDS

The water use objectives for the surface waters of Washington County are set forth in Chapters NR 102 and NR 104 of the *Wisconsin Administrative Code*. Under that code, Quaas Creek is classified to meet the standards for warmwater sport fish, and be fully compliant with the fishable and swimmable goals set for the waters of the United States by the Federal Clean Water Act. The recommended water quality standards associated with the various water use objectives are set forth in Appendix A. The level of pollutant control needed to achieve the

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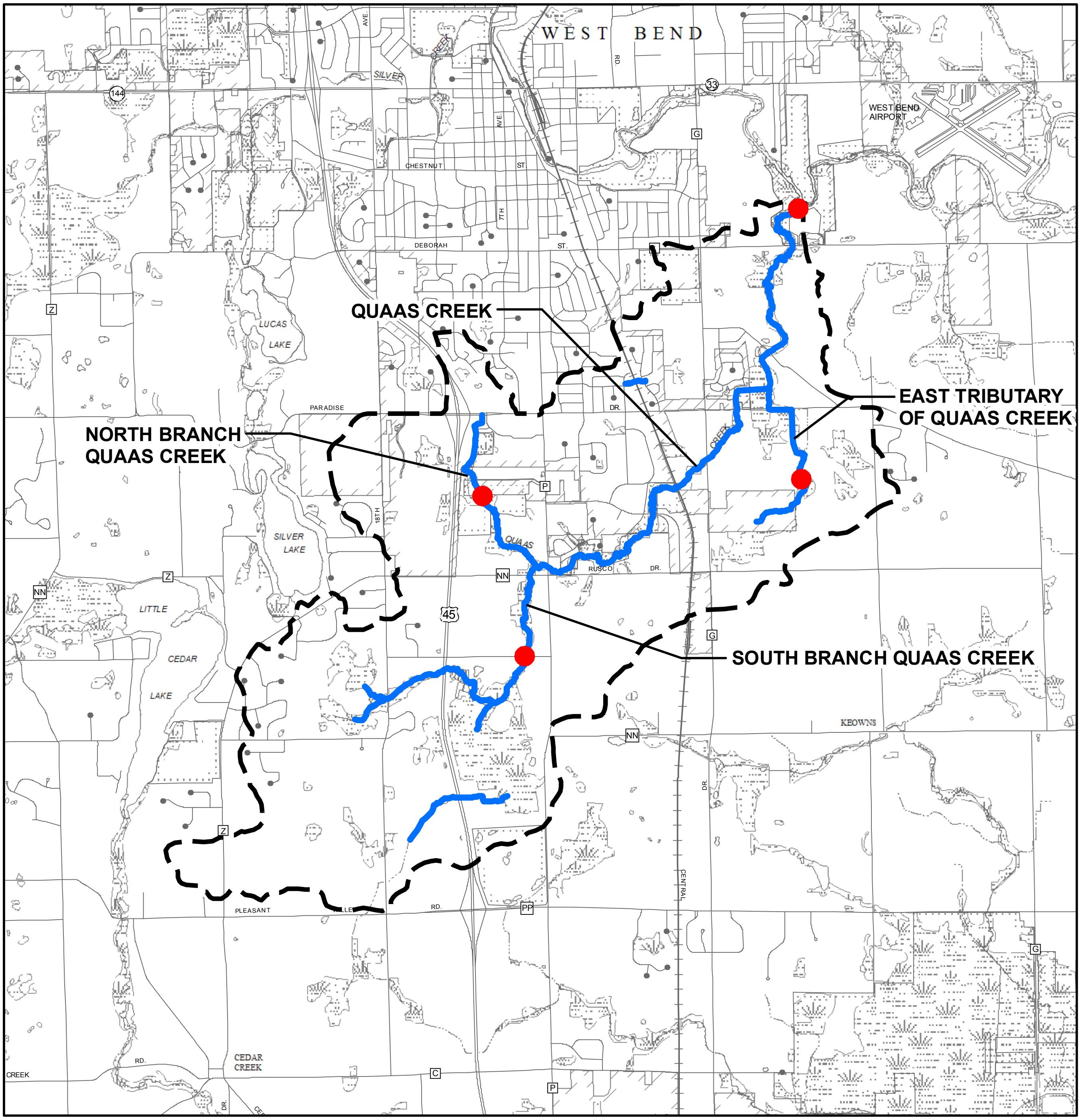
[1]*See SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend Washington County Wisconsin, *Volume Four*, Alternatives and Recommended Plan for the Quaas Creek Subwatershed, *July 1996.*

Map 1

PROJECT LOCATION MAP FOR THE QUAAS CREEK WATERSHED



PROJECT LIMIT

QUAAS CREEK WATERSHED

Source: SEWRPC.

N

0 2,500 5,000 7,500 Feet

established water use objectives were initially identified in the regional water quality management plan[2] and was refined under the City of West Bend stormwater management plan[3] and the Wisconsin Department of Natural Resources nonpoint source priority watershed plan.[4] These plans contained consistent recommendations on the levels of nonpoint source controls needed to achieve water use objectives for Quaas Creek.

The reach of Quaas Creek downstream of CTH G was found to be potentially capable of meeting the warmwater sport fish and full recreational water use objectives. The reach currently supports a diverse population of forage fish and aquatic life intolerant to very tolerant of degraded water quality and habitat. Water use objective summaries prepared by the Wisconsin Department of Natural Resources for the priority watershed plan for the East and West Branches of the Milwaukee River watershed indicated that the factors which currently limit achievement of the recommended water use objectives within this reach include sedimentation, loss of habitat, and bacterial contamination.

Upstream of CTH G, Quaas Creek, including the entire North and South Branches of Quaas Creek, have been reported by the Wisconsin Department of Natural Resources to potentially support a Class II brook trout fishery.[5] Water use objective summaries prepared by the Wisconsin Department of Natural Resources for the priority watershed study indicate that under existing conditions sedimentation and limited habitat prevent this reach from attaining a potential use as a Class II trout stream. In addition, current water quality sampling data indicate that the North and South Branches within this area upstream of CTH G are currently not likely to support a healthy Class II brook trout fishery.

Quaas Lake, at the headwaters of the South Branch of Quaas Creek, has been determined to be capable of meeting the warmwater sport fish and full recreation water use objectives. The habitat of the Lake has been rated from fair to good for sport fish spawning, but no sport fish have been reported by the Wisconsin Department of Natural Resources to be present in the Lake. Sedimentation and winter-kills limit achievement of the recommended water use objectives.[6]

SURFACE WATER CLASSIFICATION OF QUAAS CREEK

During 2000, Washington County undertook a revision of Chapter 23 of the Washington County Code, which incorporated waterbody classification into the Code as provided in Section 281.69(5), *Wisconsin Statutes*. The technical basis for this surface water classification system is set forth in a surface water resource report.[7] This system classified the stream resources of the County based upon their physical and biological characteristics. Stream systems classified pursuant to this system are subject to specific performance standards set forth in Chapter 23 of the Washington County Code, including setback requirements, minimum lot size requirements, and

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[2]*SEWRPC Memorandum Report No. 93,* A Regional Water Quality Management Plan for Southeastern Wisconsin: An Update and Status Report*, March 1995.*

[3]*SEWRPC Community Assistance Planning Report No. 173,* op. cit.

[4]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* A Non-point Source Control Plan for East and West Branches of the Milwaukee River Priority Watershed Project*, March 1992.*

[5]*Wisconsin Department of Natural Resources, Water Resource Appraisal Report and Stream Classification for the Quas Creek Subwatershed, File No. Quascr.rev, Milwaukee River East-West Watershed, Milwaukee River Basin, December 1991.*

[6]Ibid.

[7]*SEWRPC Memorandum Report No. 139,* Surface Water Resources of Washington County, Wisconsin, Lake and Stream Classification Project: 2000*, September 2001.*

density limitations. Pursuant to these provisions, Quaas Creek was classified as a Class II stream, and is subject to the performance standards outlined below.

Lots within the shoreland zone adjacent to Quaas Creek within areas served by public sanitary sewerage systems must meet the following standards, among others:

- Minimum lot size of 20,000 square feet;
- Minimum lot width of 85 feet;
- Minimum setback from the ordinary high water mark of 100 feet or 75 feet with mitigation;
- Minimum average setback of principal structures from the ordinary high water mark is 75 feet, or 50 feet with mitigation in those areas where setback averaging is permitted;
- Principal structures are not to exceed 30 percent of the lot; and
- Total of all impervious surfaces should not exceed 40 percent of the lot.

Lots within the shoreland zone adjacent to Quaas Creek within areas served by onsite sewage disposal systems must meet the following standards, among others:

- Minimum lot size of 30,000 square feet;
- Minimum lot width of 125 feet;
- Minimum setback from the ordinary high water mark of 100 feet or 75 feet with mitigation;
- Minimum average setback of principal structures from the ordinary high water mark is 75 feet, or 50 feet with mitigation in those areas where setback averaging is permitted;
- Principal structures are not to exceed 30 percent of the lot; and
- Impervious surface should not exceed 40 percent of the lot.

Lots included within areas affected by joint boundaries or intergovernmental agreements must have a minimum lot size of 15,000 square feet and minimum average lot width of 90 feet. Other requirements may also apply and shoreland development in the Quaas Creek subwatershed remains subject to all applicable Federal, State, County, and local government permitting requirements.

LAND USE

The land use information presented here is derived from inventories and plans developed by the Southeastern Wisconsin Regional Planning Commission. Data are available on the amount, type, and spatial location of land uses under existing year 2000 and planned 2020 conditions. Land use data are presented for the entire Quaas Creek drainage area and major subwatersheds including the East Tributary, South Branch, North Branch, and Main Stem in Tables 1 through 5 and Maps 2 and 3. The land use data shown on Maps 2 and 3 is based on regional plans and local planning data through 1998. In addition, the City of West Bend in currently preparing an updated land use plan that may refine these land use maps.

Table 1

LAND USE WITHIN THE QUAAS CREEK DRAINAGE AREA: 2000 AND 2020

Land Use Category	Existing 2000		Planned Increment		Total 2020	
	Acres	Percent of Total	Acres	Percent Change	Acres	Percent of Total
Urban						
Residential	746	13.5	839	112.5	1,585	28.7
Commercial	157	2.9	139	88.5	296	5.4
Industrial	100	1.8	388	388.0	488	8.8
Governmental and Institutional	68	1.2	- -	- -	68	1.2
Transportation, Communication, and Utilities	144	2.6	- -	- -	144	2.6
Recreational	38	0.7	82	215.8	120	2.2
Subtotal	1,253	22.7	1,448	115.6	2,701	48.9
Rural						
Woodlands	420	7.6	- -	- -	420	7.6
Wetlands	700	12.7	- -	- -	700	12.7
Surface Water	18	0.3	- -	- -	18	0.3
Agricultural and Other Open Lands	3,130	56.7	-1,448	-46.3	1,682	30.5
Subtotal	4,268	77.3	-1,448	-33.9	2,820	51.1
Total	5,521	100.0	- -	- -	5,521	100.0

Source: SEWRPC.

Urban Land Use

As indicated in Table 1, urban land uses encompassed about two square miles, or approximately 23 percent of the total land area, in the Quaas Creek watershed in 2000. Residential land uses comprised the largest urban land use in the watershed in 2000, encompassing more than one square mile, or about 14 percent of the total watershed area. Under future year 2020 conditions, about four square miles of the watershed, or nearly 50 percent of the watershed area, are anticipated to be in urban land uses. Residential development is anticipated to comprise the majority of the increase in urban land use, encompassing about 2.5 square miles, or nearly 30 percent of the total land area in the Quaas Creek watershed.

Urban land uses distributed among the East Tributary, South Branch, North Branch, and Main Stem subbasins of the Quaas Creek watershed as shown in Tables 2 through 5 comprised about 3, 30, 19, and 48 percent of the total urban land uses within the entire watershed in 2000, respectively. Residential land uses comprised the largest urban land use in the East Tributary, South Branch, and Main Stem subbasins in 2000, encompassing about 9, 14, and 16 percent of each of the subbasins, respectively. Between 2000 and 2020, urban land uses in the watershed are anticipated to be expanded by more than one-half square mile or 170 percent within the North Branch and by about 1.5 square miles or 150 percent within the Main Stem subbasins.

Rural Land Use

Rural lands, consisting of woodlands, wetlands, surface water, agricultural lands and other unused open lands, comprised more than 6.5 square miles, or about 77 percent of the total land area, in the Quaas Creek watershed in 2000. Agricultural land uses comprised the largest rural land usage in the watershed, encompassing nearly five square miles, or about 57 percent of the total land area. Surface water, wetlands, and woodlands comprised nearly two square miles, or about 20 percent of the land area, in the watershed. Between 2000 and 2020, rural lands in the watershed are anticipated to decrease from about 6.5 square miles to about 4.5 square miles, or approximately

Table 2

LAND USE WITHIN THE EAST TRIBUTARY OF THE QUAAS CREEK DRAINAGE AREA: 2000 AND 2020

Land Use Category	Existing 2000		Planned Increment		Total 2020	
	Acres	Percent of Total	Acres	Percent Change	Acres	Percent of Total
Urban						
Residential	40	8.8	92	230.0	132	28.9
Commercial	- -	- -	- -	- -	- -	- -
Industrial	- -	- -	- -	- -	- -	- -
Governmental and Institutional	- -	- -	- -	- -	- -	- -
Transportation, Communication, and Utilities	- -	- -	- -	- -	- -	- -
Recreational	- -	- -	- -	- -	- -	- -
Subtotal	40	8.8	92	230.0	132	28.9
Rural						
Woodlands	47	10.3	- -	- -	47	10.3
Wetlands	76	16.6	- -	- -	76	16.6
Surface Water	- -	- -	- -	- -	- -	- -
Agricultural and Other Open Lands	294	64.3	-92	-31.3	202	44.2
Subtotal	417	91.2	-92	-22.0	325	71.1
Total	457	100.0	- -	- -	457	100.0

Source: SEWRPC.

34 percent. The majority of this loss is anticipated to be from the conversion of agricultural and other open lands to urban lands for residential, commercial, and industrial uses. Wetlands, woodlands, and surface water are not anticipated to experience any significant losses within this watershed. Wetlands and woodlands are primarily located adjacent to Quaas Creek and its major tributaries and are largely considered to be Class II wildlife habitat.[8] In addition, the majority of this area was encompassed within primary environmental corridors as shown on Map 3.

Rural land uses distributed among the East Tributary, South Branch, North Branch, and Main Stem subbasins of the Quaas Creek watershed comprised about 10, 38, 14, and 38 percent of the total rural land in the Quaas Creek watershed in 2000, respectively. Agricultural land use comprised the largest rural land use category in 2000, encompassing about 64 percent of the East Tributary, 57 percent in the South Branch, 53 percent in the North Branch, and 57 percent in the Main Stem of the total land surface in each of these subbasins. Wetlands are predominantly located within the South Branch and Main Stem subbasins, which account for nearly 80 percent of the total wetland acreage within the Quaas Creek watershed. Woodlands comprised about 7 to 10 percent of the land surface within each of the four subbasins. Between 2000 and 2020, agricultural and other open lands are anticipated to decrease throughout the watershed by about 31 percent in the East Tributary, 6 percent in the South Branch, 88 percent in the North Branch, and 72 percent in the Main Stem subbasins (Tables 2 through 5).

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[8]*Washington County,* Washington County Land And Water Resource Management Plan: 2000-2005*, August 2000.*

Table 3

LAND USE WITHIN THE SOUTH BRANCH OF THE QUAAS CREEK DRAINAGE AREA: 2000 AND 2020

Land Use Category	Existing 2000		Planned Increment		Total 2020	
	Acres	Percent of Total	Acres	Percent Change	Acres	Percent of Total
Urban						
Residential	284	14.1	64	22.5	348	17.3
Commercial	15	0.7	- -	- -	15	0.7
Industrial	- -	- -	- -	- -	- -	- -
Governmental and Institutional	2	0.1	- -	- -	2	0.1
Transportation, Communication, and Utilities	56	2.8	- -	- -	56	2.8
Recreational	24	1.2	- -	- -	24	1.4
Subtotal	381	18.9	64	16.8	445	22.1
Rural						
Woodlands	131	6.5	- -	- -	131	6.5
Wetlands	348	17.3	- -	- -	348	17.3
Surface Water	16	0.8	- -	- -	16	0.8
Agricultural and Other Open Lands	1,137	56.5	-64	-5.6	1,073	53.3
Subtotal	1,632	81.1	-64	-3.9	1,568	77.9
Total	2,013	100.0	- -	- -	2,013	100.0

Source: SEWRPC.

HYDROLOGY

Figure 1 shows the peak flow rates for the two-year recurrence interval floods under planned land use and recommended drainage conditions from the headwaters of Quaas Creek to the confluence with the Milwaukee River set forth in the stormwater management plan for the City of West Bend.[9] Discharges range from 110 cubic feet per second in the upstream area to 370 cubic feet per second in the downstream reaches as shown in Figure 1. The two-year storm event is considered the dominant discharge event, which is responsible for the largest volume of sediment transport over a long period of record and typically ranges from a one- to three-year storm event.[10] In addition to the changes in discharge, Figure 1 also demonstrates changes in the bottom channel elevation profile of Quaas Creek within the limits of the project area.

Stream Reaches

Based upon the analysis of discharge, bottom elevation, bridge and culvert crossings, in combination with slope and sinuosity, specific sections of stream, defined as stream reaches, were developed, as set forth in Table 6 and shown on Map 4.

Slope is a ratio of elevation change between two points on a channel to the length of the channel between the same two points. Slope is an indicator of stream energy or power. The lower the slope, the lower the energy, and

[9]*SEWRPC Community Assistance Planning Report No. 173,* op. cit.

[10]*U.S. Department of Agriculture, Natural Resources Conservation Service, Fluvial Geomorphology Workshop, Wautoma, Wisconsin, September 13-17, 1999.*

Table 4

LAND USE WITHIN THE NORTH BRANCH OF THE QUAAS CREEK DRAINAGE AREA: 2000 AND 2020

Land Use Category	Existing 2000		Planned Increment		Total 2020	
	Acres	Percent of Total	Acres	Percent Change	Acres	Percent of Total
Urban						
Residential	69	8.1	108	156.5	177	20.9
Commercial	65	7.7	115	176.9	180	21.2
Industrial	11	1.3	114	1,036.4	125	14.8
Governmental and Institutional	- -	- -	- -	- -	- -	- -
Transportation, Communication, and Utilities	86	10.2	- -	- -	86	10.2
Recreational	2	0.2	56	2,800.0	58	6.8
Subtotal	233	27.5	393	168.7	626	73.9
Rural						
Woodlands	92	10.9	- -	- -	92	10.9
Wetlands	73	8.6	- -	- -	73	8.6
Surface Water	1	0.1	- -	- -	1	0.1
Agricultural and Other Open Lands	448	52.9	-393	-87.7	55	6.5
Subtotal	614	72.5	-393	-64.0	221	26.1
Total	847	100.0	- -	- -	847	100.0

Source: SEWRPC.

the slower the water flows. Stream slopes within mountainous stream systems are typically greater than 10 percent. However, slopes within the Quaas Creek reaches are more indicative of lowland streams and do not exceed 1 percent, except for short reaches which approach one percent slope, as shown in Table 6.

Sinuosity is a measure of channel pattern and is defined as the ratio of channel length between two points on a channel to the straight-line distance between the same two points. Sinuosity or channel pattern can range from straight to a winding pattern, or "meandering." The more a stream meanders within a given distance, the more "sinuous" it is. Channels with sinuosities of 1.5 or greater are considered "meandering." Channelized or sections of streams that have been straightened typically have low sinuosity or a number closer to one. Stream reaches within the Quaas Creek watershed have sinuosities that range from 1.3 to 2.3 as shown in Table 6, and include both channelized and nonchannelized segments. Each of these reaches can be further characterized by physical characteristics. Stream channel width, depth, and entrenchment are common measures used to delineate hydrological reaches.

Width

Figure 2 shows changes in width among reaches within the Quaas Creek watershed. There is an overall increase in width from the upstream reaches to downstream and there is considerable variability in width within a particular reach. However, there appears to be three distinct breaks or differences among reaches within this watershed. The East Tributary, South Branch, and North Branch reaches contain the narrowest channels in the watershed. Reaches CTH P through to CTH G seem to contain the mid-range of channel widths. Whereas, the widest reaches within the watershed are the Sand Drive and Decorah Road reaches. These differences in width among the reaches seem to be associated to the differences in discharge among these reaches, as shown in Figure 1, and may be indicative of a response to discharge. The narrowest upstream reaches receive the lowest

Table 5

LAND USE WITHIN THE MAIN STEM OF THE QUAAS CREEK DRAINAGE AREA: 2000 AND 2020

Land Use Category	Existing 2000		Planned Increment		Total 2020	
	Acres	Percent of Total	Acres	Percent Change	Acres	Percent of Total
Urban						
Residential	353	16.0	575	162.9	928	42.1
Commercial	77	3.5	24	31.2	101	4.6
Industrial	89	4.0	274	307.9	363	16.5
Governmental and Institutional	66	3.0	- -	- -	66	3.0
Transportation, Communication, and Utilities	2	0.1	- -	- -	2	0.1
Recreational	12	0.5	26	216.7	38	1.7
Subtotal	599	27.2	899	150.1	1,498	68.0
Rural						
Woodlands	150	6.8	- -	- -	150	6.8
Wetlands	203	9.2	- -	- -	203	9.2
Surface Water	1	- -	- -	- -	1	- -
Agricultural and Other Open Lands	1,251	56.8	-899	-71.9	352	16.0
Subtotal	1,605	72.8	-899	-56.0	706	32.0
Total	2,204	100.0	- -	- -	2,204	100.0

Source: SEWRPC.

discharge while the two downstream reaches receive the highest discharge within the watershed. The reaches within the middle part of the watershed from CTH P to CTH G receive discharges that range between the extreme lowest and highest compared to the rest of the watershed.

Depth

Stream depth also demonstrates an overall increase from upstream to downstream as shown in Figure 3. The upstream reaches appear to be shallower and the downstream reaches appear to be deeper than other areas within the watershed. However, the range of variability in depth among all of the reaches obscures any obvious patterns. This wide range in depth is indicative that each of these reaches contains a variety of deep and shallow areas typically referred to as pool and riffle habitats (see habitat discussion below).

Entrenchment

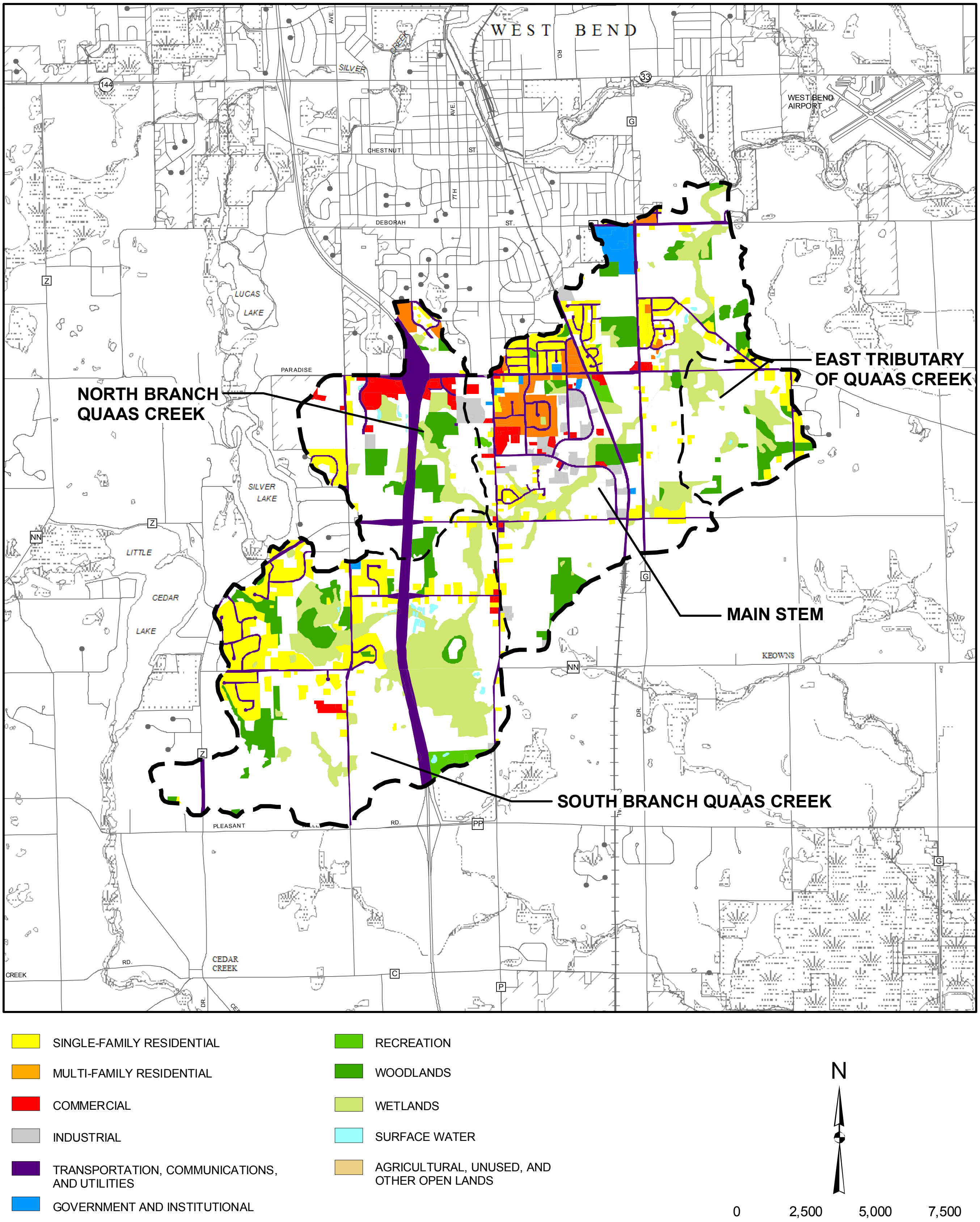
An important element of stream systems is the interrelationship of the stream to its valley and/or landform features. This interrelationship determines whether the river system is deeply incised or entrenched in the valley floor or not. Entrenchment is defined as the vertical containment of a river and the degree to which it is incised in the valley floor.[11] This makes an important distinction of whether the flat area adjacent to the channel is an active floodplain, abandoned floodplain (terrace), or outside of the floodprone area. The entrenchment ratio is a quantitative expression of this feature and is a ratio of the width of the floodprone area to the bankfull surface width of the channel. A river is considered entrenched if the entrenchment ratio is less than 1.4, moderately entrenched if the ratio is between 1.4 and 2.2, and only slightly entrenched if the ratio is greater than 2.2.[12]

[11]*D.L. Rosgen, "A Classification of Natural Rivers,"* Catena*, Vol. 22, 1994, pp. 169-199.*

[12]Ibid.

Map 2

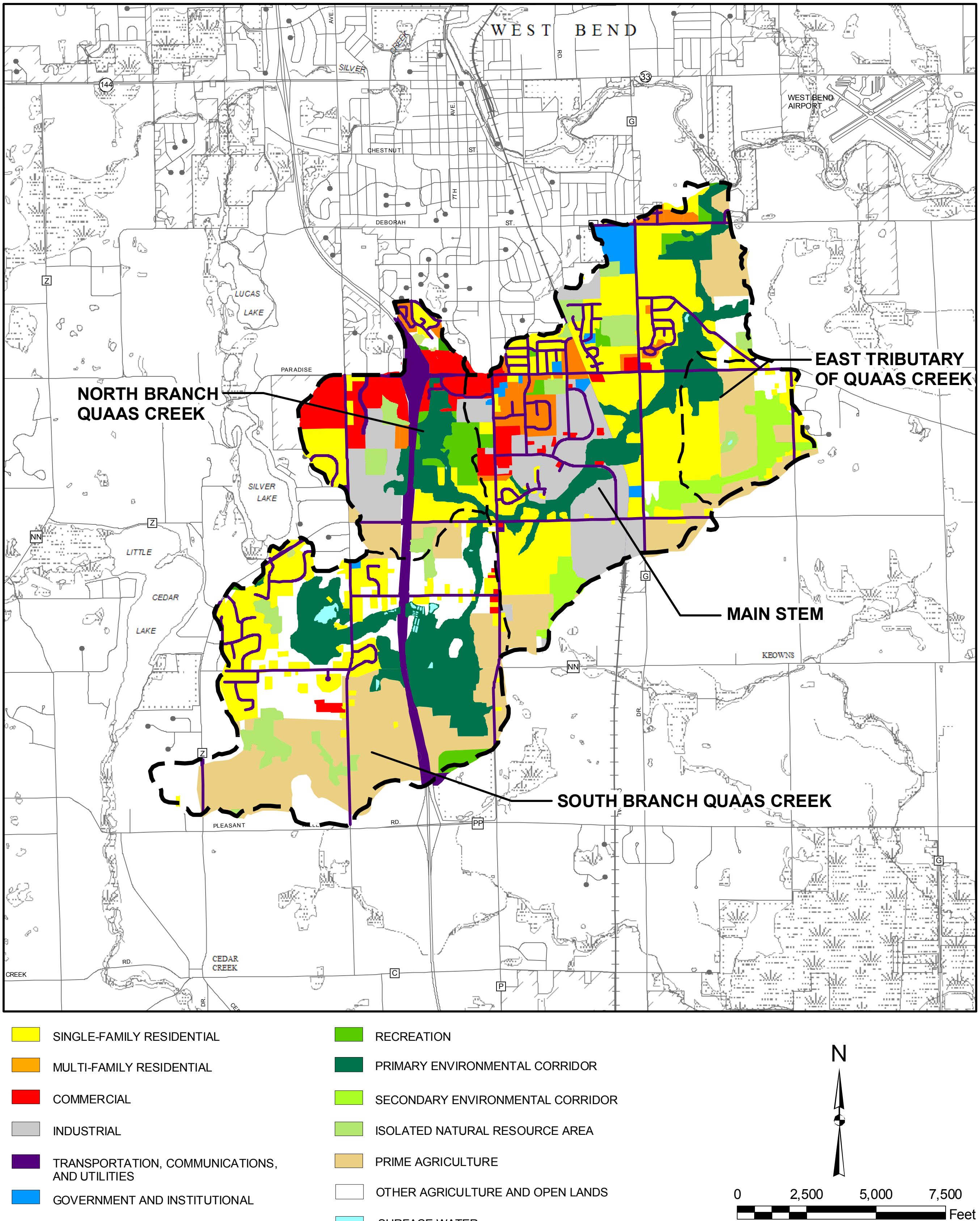
EXISTING LAND USE WITHIN THE QUAAS CREEK DRAINAGE AREA:2000



Source: SEWRPC.

Map 3

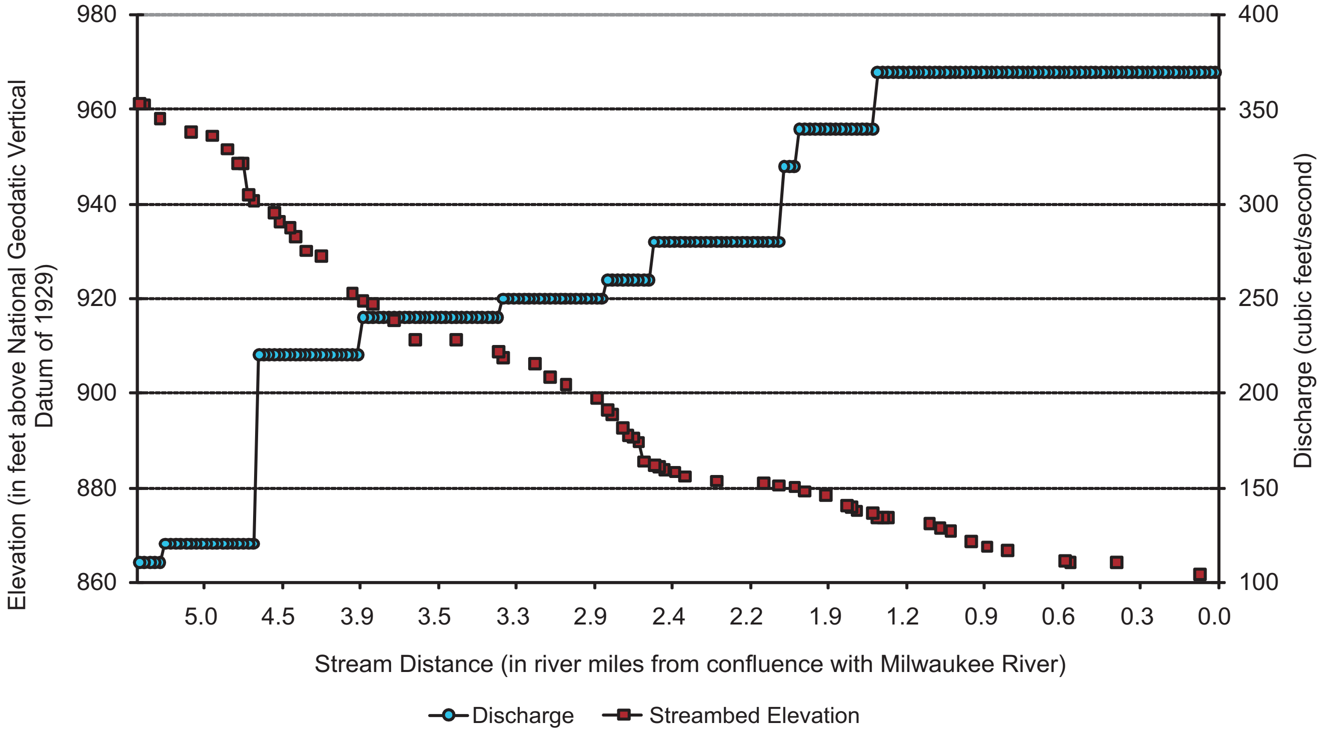
PLANNED LAND USE WITHIN THE QUAAS CREEK DRAINAGE AREA:2020



Source: SEWRPC.

Figure 1

TWO-YEAR RECURRENCE INTERVAL DISCHARGE AND STREAMBED ELEVATION PROFILES FOR QUAAS CREEK: 1996



Source: SEWRPC.

Figure 4 shows that most of the areas of the Quaas Creek watershed are not entrenched and therefore has an active connection to the adjacent floodplain. The CTH G reach contains the greatest entrenchment ratios compared to the rest of the watershed followed by the Private Drive and North Branch reaches. However, Figure 4 also indicates that entrenchment may be a potential problem within some areas of the North Branch, Private Drive, Railroad, and CTH G reaches (i.e. entrenchment ratio less than 2.2). These areas may be associated with the increased bank erosion or instabilities within certain portions of these particular reaches within the Quaas Creek watershed, which is discussed below.

Streambank Erosion

The energy of flowing water in a stream is dissipated along the stream length by turbulence, streambank and bed erosion, and sediment resuspension. In general, increased urbanization may be expected to result in increased stream flow rates and volumes, with potential increases in streambank erosion and bottom scour. Streambank erosion destroys aquatic habitat, spawning, and feeding areas; contributes to downstream water quality degradation by releasing sediments to the water; and provides material for subsequent sedimentation downstream, which, in turn, covers valuable benthic habitats, impedes navigation, and fills wetlands. These effects may potentially be mitigated by utilization of proper stormwater management and streambank bioengineering practices.

In fall 2001, the Washington County Land Conservation Department and SEWRPC staffs conducted a survey of streambank erosion in the Quaas Creek watershed. The stream surveys identified streambank erosion problems

Table 6

LEVEL I AND II ROSGEN STREAM CLASSIFICATION AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED, WASHINGTON COUNTY, WISCONSIN: 2002

Reach	Location	River Mile	Entrenchment Ratio[a]	Width/ Depth Ratio[b]	Sinuosity[a]	Level I	Slope	Dominant Channel Material[c]	Level II
East Tributary	About 9,400 feet upstream from confluence with the Main Stem of Quaas Creek	1.78	- -[d]	7.1	1.30	E	0.0047	Sand	E5
	At confluence with the Main Stem of Quaas Creek downstream of Paradise Drive	0.00							
South Branch	At Mile View Road	0.72	- -[d]	8.1	1.32	E	0.0041	Silt, sand	E5-E6
	At confluence with the North Branch of Quaas Creek upstream of CTH P	0.00							
North Branch	About 3,190 feet upstream of CTH P	5.19	12.0	5.6	1.34	E	0.0073	Sand	E5
	CTH P	4.53							
CTH P	CTH P	4.53	12.0	7.6	1.62	E	0.0055	Sand, gravel	E4-E5
	At Private Drive	3.89							
Private Drive	At Private Drive	3.89	18.0	10.0	1.58	E	0.0028	Sand, gravel	E4-E5
	Progress Road	3.31							
Progress Road	Progress Road	3.31	11.0	8.2	2.16	E	0.0040	Sand, gravel	E4-E5
	Wisconsin Central Railroad	2.85							
Wisconsin Central Railroad	Wisconsin Central Railroad	2.85	6.0	7.8	1.53	E	0.0065	Sand, gravel	E4-E5
	CTH G	2.50							
CTH G	CTH G	2.50	33.0	12.7	1.32	C	0.0020	Silt, sand	C5-C6
	Sand Drive	1.51							
Sand Drive	Sand Drive	1.51	12.0	11.6	1.45	C	0.0018	Silt, sand	C5-C6
	Decorah Road	0.54							
Decorah Road	Decorah Road	0.54	7.0	13.2	2.26	C	0.0009	Sand, gravel	C4-C5
	Confluence with the Milwaukee River	0.00							

[a]*Values of entrenchment and sinuosity ratios can vary by ∀0.2 units when applying the Rosgen Stream Classification System.*

[b]*Values of width/depth ratio can vary by ∀2.0 units when applying the Rosgen Stream Classification System.*

[c]*Dominant channel material was determined from visual estimates of overlying substrates by SEWRPC staff during the Fall 2001 bank stability survey.*

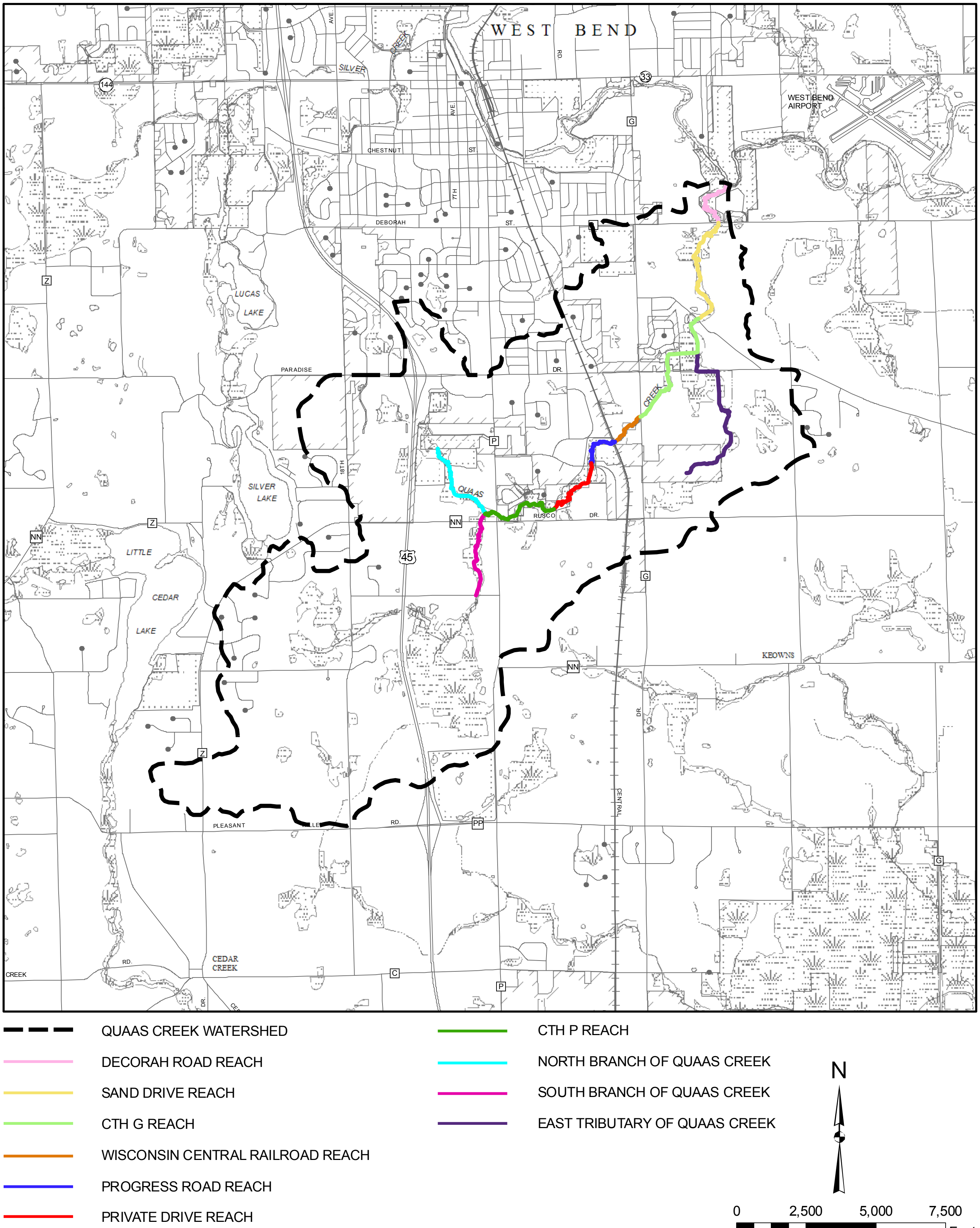
[d]*Data were not available, but SEWRPC staff observed these areas to contain relatively low bank heights and evidence of an active floodplain, which indicates these reaches to be slightly entrenched (i.e. entrenchment ratio greater than 2.2).*

Source: SEWRPC.

and quantified the following: location of active erosion site, height of the eroding streambank, length of the erosional scour, slope of the bank, habitat type, stream width at the water surface, maximum depth of the water, sediment depth, relative amount of woody debris, and substrate composition (see Appendix B for definitions). Active eroding streambank sites identified by the survey are shown on Maps 5 and 6 for the lower and upper portions of the Quaas Creek watershed, respectively. A result of the field survey indicates that there were more

Map 4

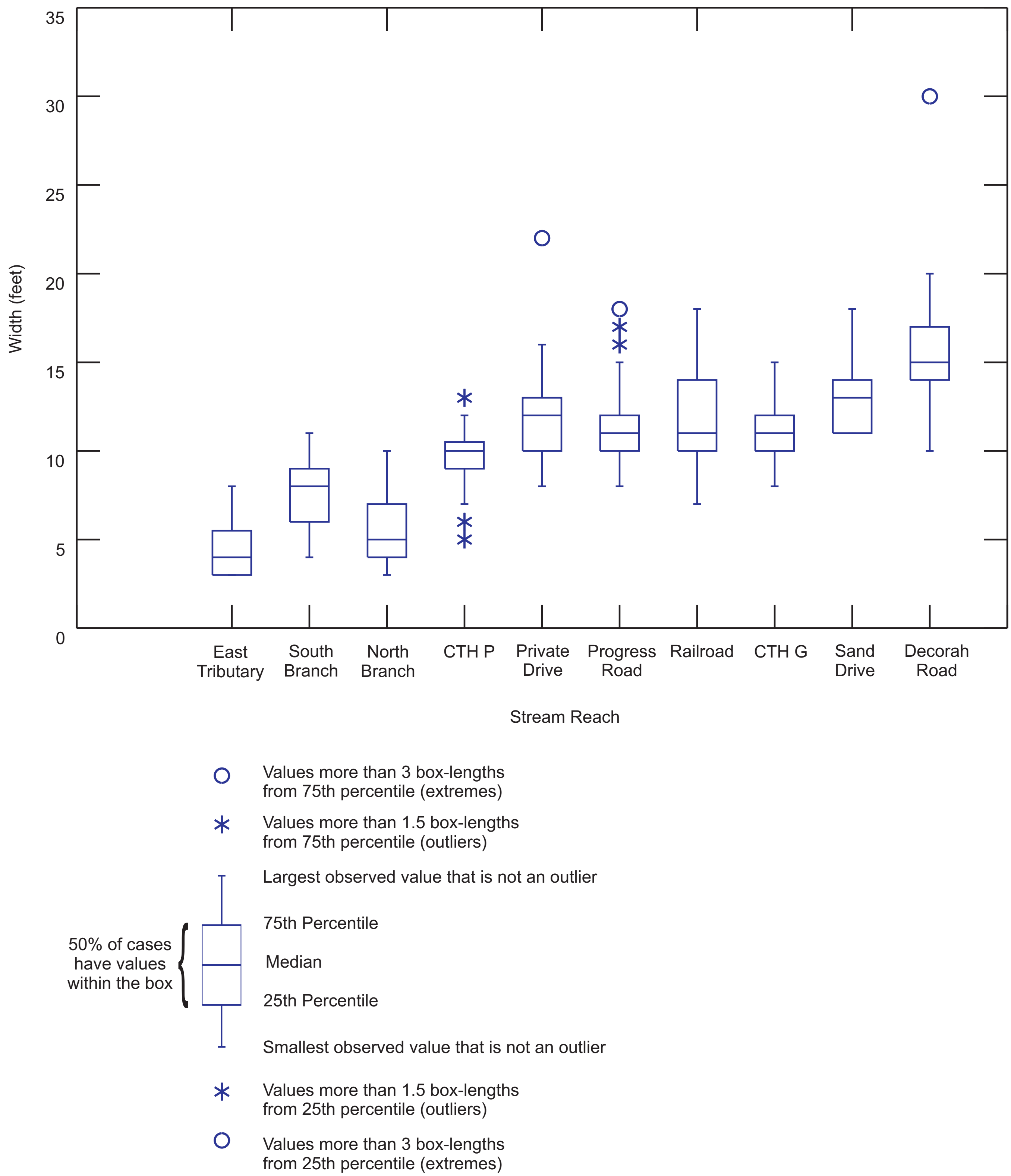
STREAM REACHES WITHIN THE QUAAS CREEK WATERSHED



Source: SEWRPC.

Figure 2

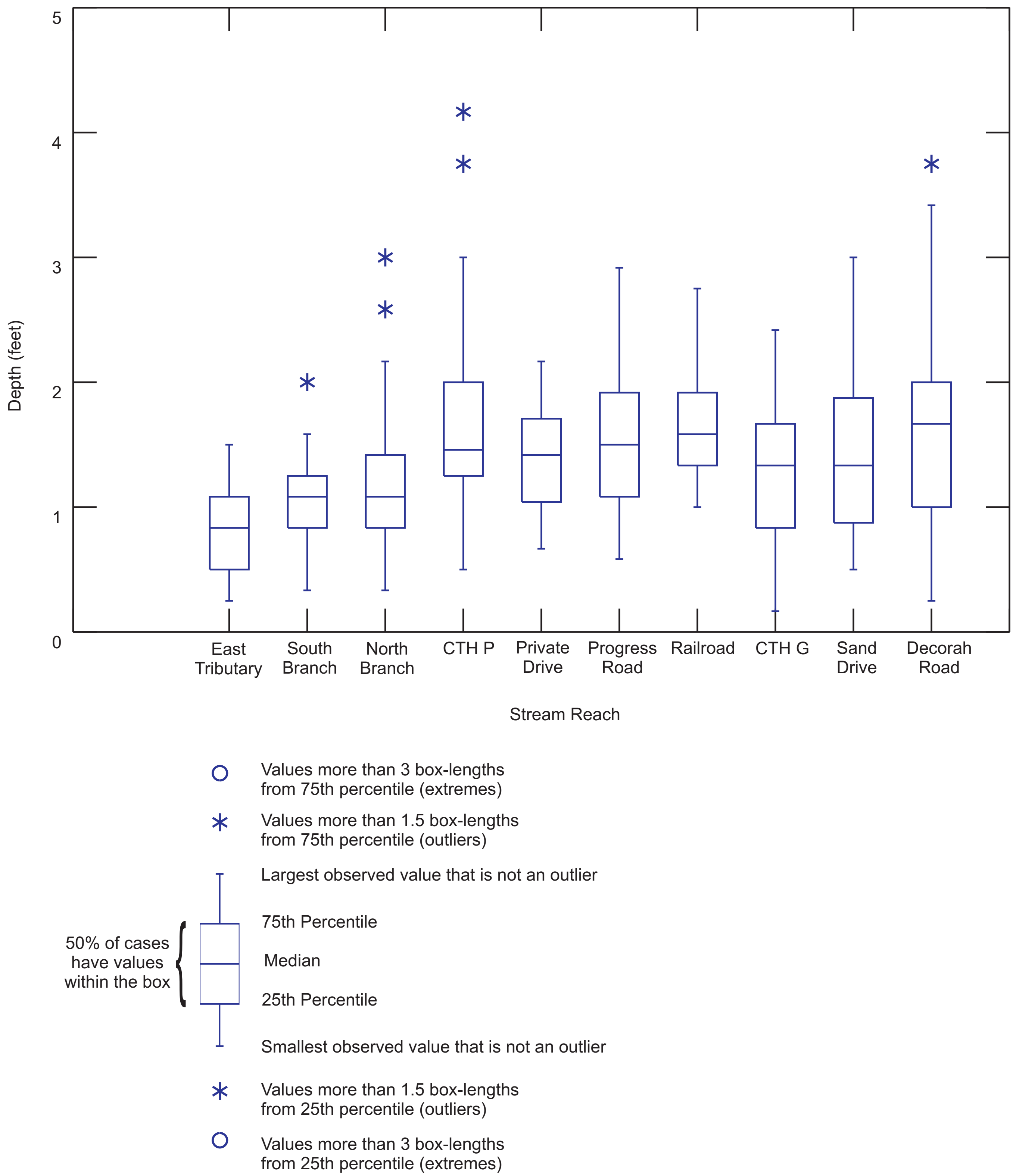
STREAM WIDTH AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



Source: SEWRPC.

Figure 3

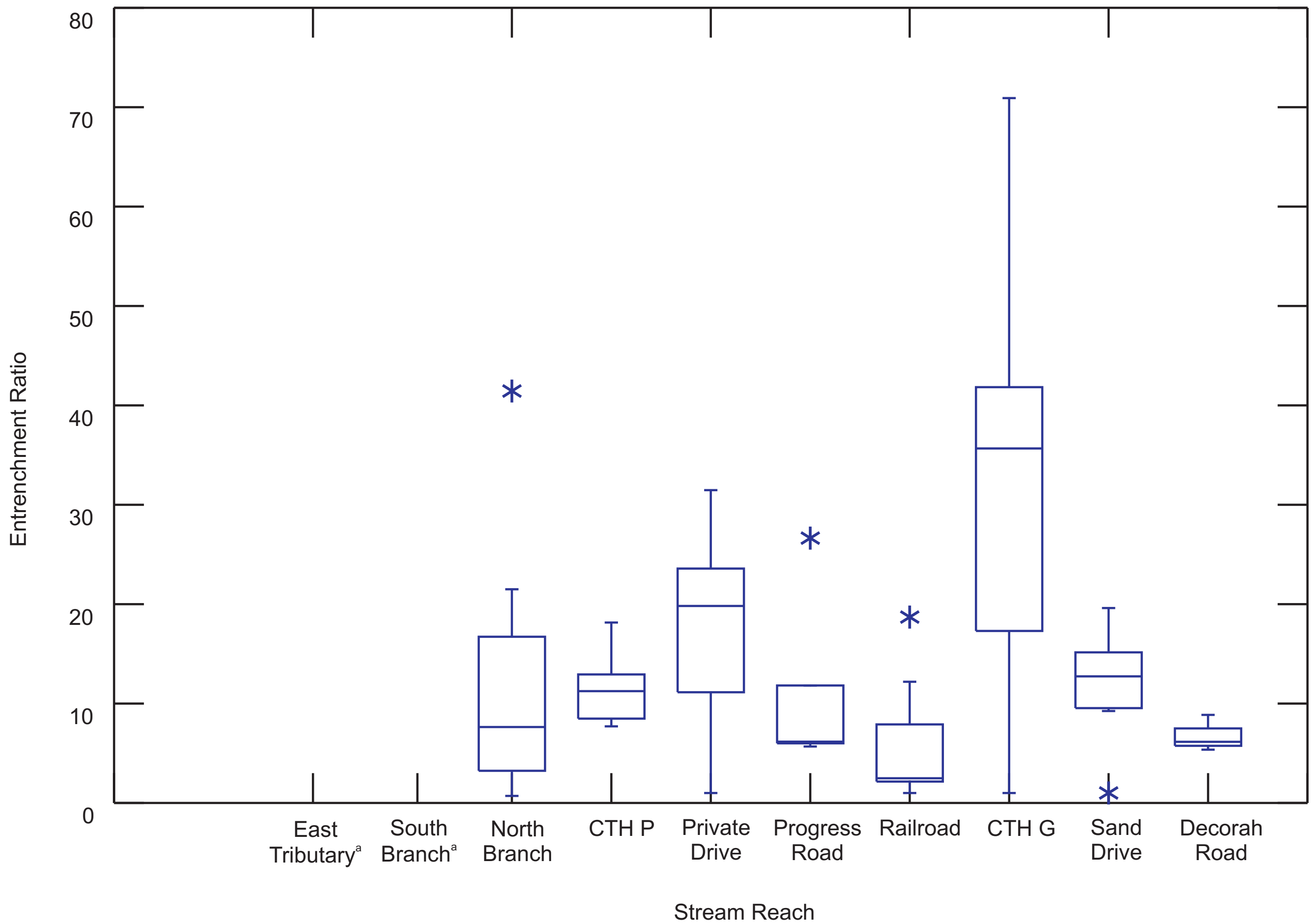
STREAM DEPTH AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



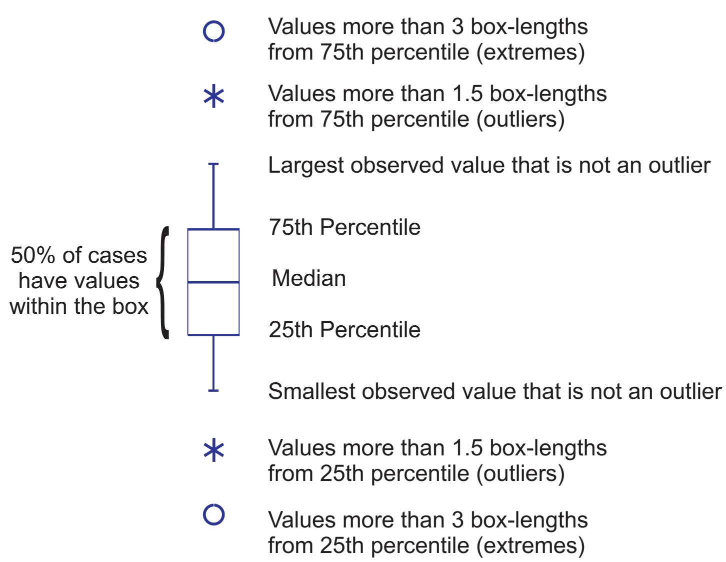
Source: SEWRPC.

Figure 4

ENTRENCHMENT RATIO AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



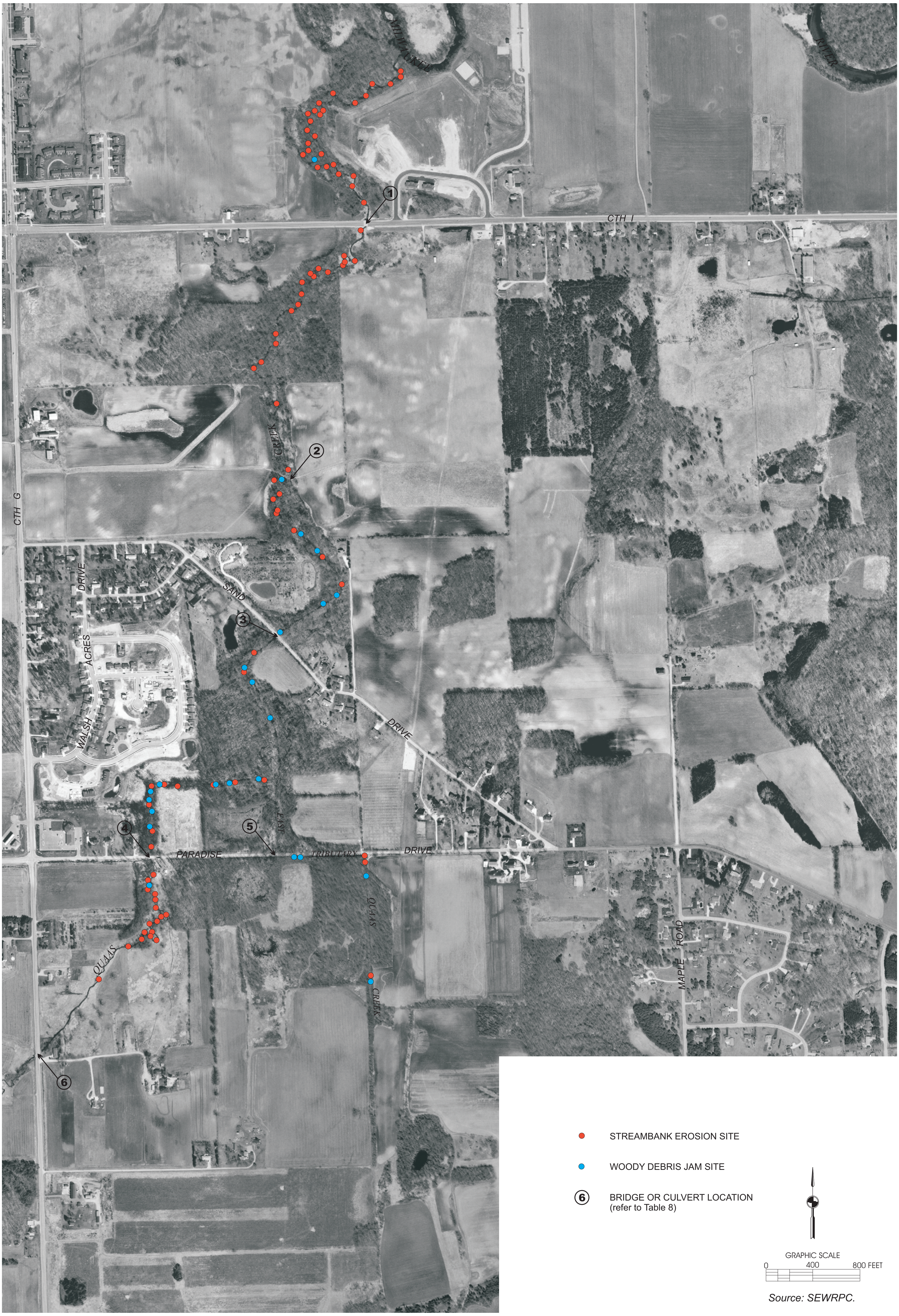
[a]Data were not available to assess these reaches.



Source: SEWRPC.

Map 5

STREAMBANK EROSION AND WOODY DEBRIS JAM SITES LOCATED WITHIN THE LOWER HALF OF THE QUAAS CREEK WATERSHED: FALL 2001

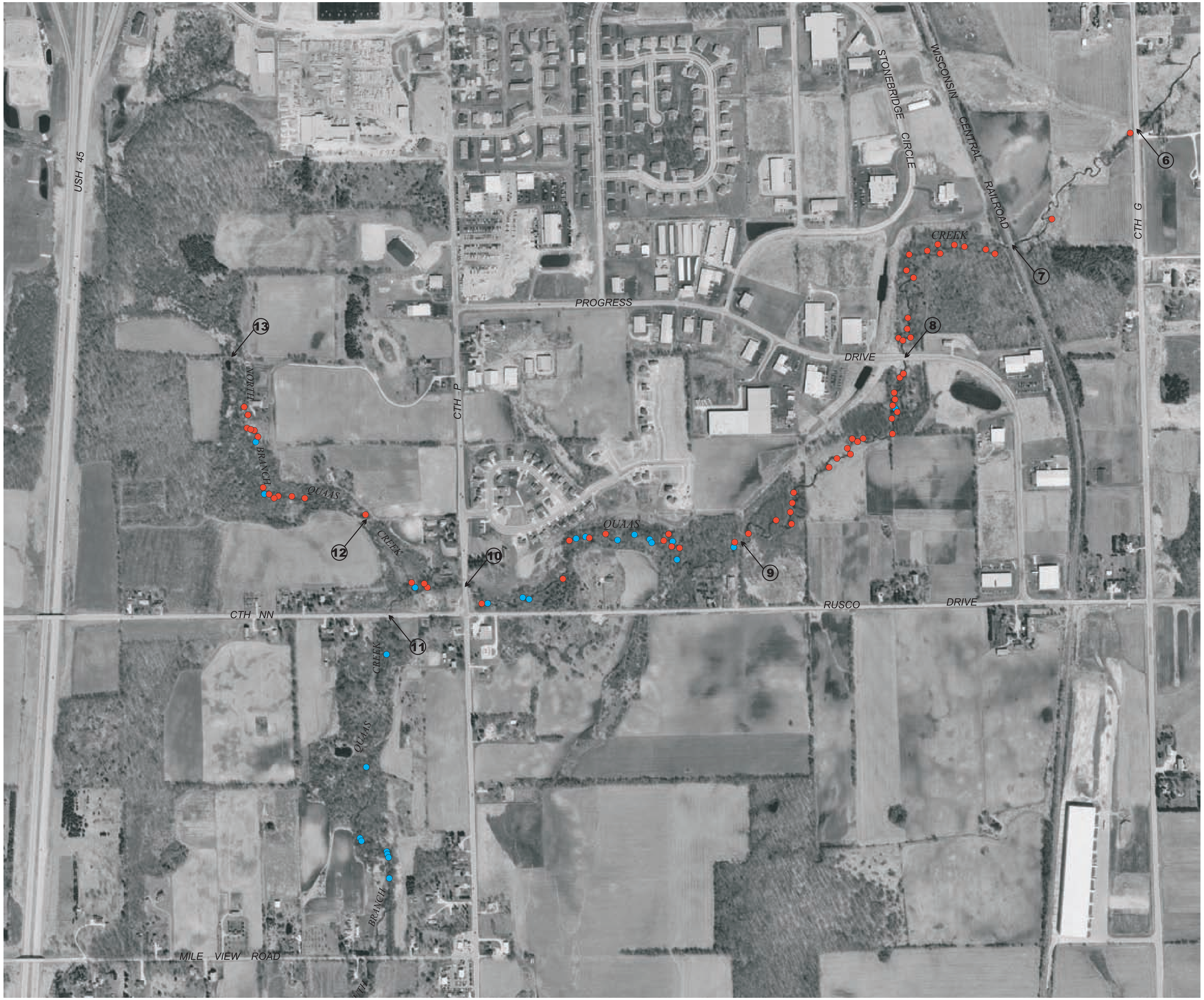


DATE OF PHOTOGRAPHY: MARCH 2000

Source: SEWRPC.

Map 6

STREAMBANK EROSION AND WOODY DEBRIS JAM SITES LOCATED WITHIN THE UPPER HALF OF THE QUAAS CREEK WATERSHED: FALL 2001



STREAMBANK EROSION SITE

WOODY DEBRIS JAM SITE

6 BRIDGE OR CULVERT LOCATION (refer to Table 8)

GRAPHIC SCALE
0 400 800 FEET

Source: SEWRPC.

than 130 sites totaling about 1.5 miles of streambank where active erosion was found. The average length of these actively eroding sites was about 65 feet and ranged from 20 to 550 feet. In an effort to analyze the amount and determine the potential relationship between bank stability and other physical characteristics of the stream system, bank length was standardized into a percent or proportion of erosion among reaches.[13]

More rigorous statistical analysis indicates that stream width explains the greatest amount of variation in the proportion of failure as opposed to either depth or bank height. In addition, the proportion of failure was also found to change significantly among reaches, such that the lower reaches were found to be relatively less stable than the upper reaches of the watershed. This relationship was not well-correlated to river miles. Hence, there does not seem to be a significant difference in the extent of bank instability linearly from the headwaters to the mouth at the Milwaukee River, although there is significant difference in bank stability among reaches within the Quaas Creek watershed (see Appendix B for analysis results).

Comparison of stream width among stable versus actively eroding or unstable sites throughout the entire watershed demonstrates that in general the unstable sites are wider than the stable sites as shown in Figure 5. However, as Figure 5 also indicates the extent and variability of width seems to be determined at the reach scale. Analysis further demonstrates that bank stability is significantly different in terms of stream width and frequency of erosion between pool and riffle habitats among the Quaas Creek watershed. This difference is likely partially due to the physical position of pool versus riffle habitats, but it also seems to be determined by the position within the watershed or reach scale. Pool habitats are generally located at the outside bends of stream and riffles are located within straight sections between pool habitats. Therefore, pool habitats should theoretically have a greater incidence of erosion than riffle habitats, which is consistent with the results of the survey. Figure 6 shows that pools habitats are eroding in all reaches from the North Branch through Decorah Road. In contrast, Figure 7 shows that none to very few actively eroding riffle habitats were found throughout the watershed. However, in places where they were found, such as the most downstream reaches at Sand Drive and Decorah Road, active eroding riffles were significantly wider than stable riffle habitats. This increased incidence of riffle instability may be indicative of active ongoing channel adjustment and therefore enhanced instability compared to the rest of the watershed. These downstream reaches are the widest reaches in the watershed and receive the greatest amount of stormwater discharge compared to the rest of the watershed. In addition, the actively eroding sites within these downstream reaches are associated with the greatest amount of undercut bank depth compared to the rest of the watershed as shown in Table 7.

It is important to note that not only is the total discharge a determinant of bank stability, but the frequency of runoff events is a bank stability determinant as well. In an urbanizing watershed, not only does quantity of discharge tend to increase, but the frequency of runoff events of a given magnitude also tends to increase as well. Results from the stormwater analysis indicate that the headwater areas originating in the North Branch were predicted to have increased frequency of high flow rates as compared to the downstream reaches where the frequency is not predicted to change substantially based upon the City of West Bend stormwater management plan.[14] More specifically, a 120 percent increase in peak flow rates of flow was projected along the 1,480-foot-long reach of Quaas Creek between River Miles 5.11 and 5.39, and a 70 percent increase in peak rates of

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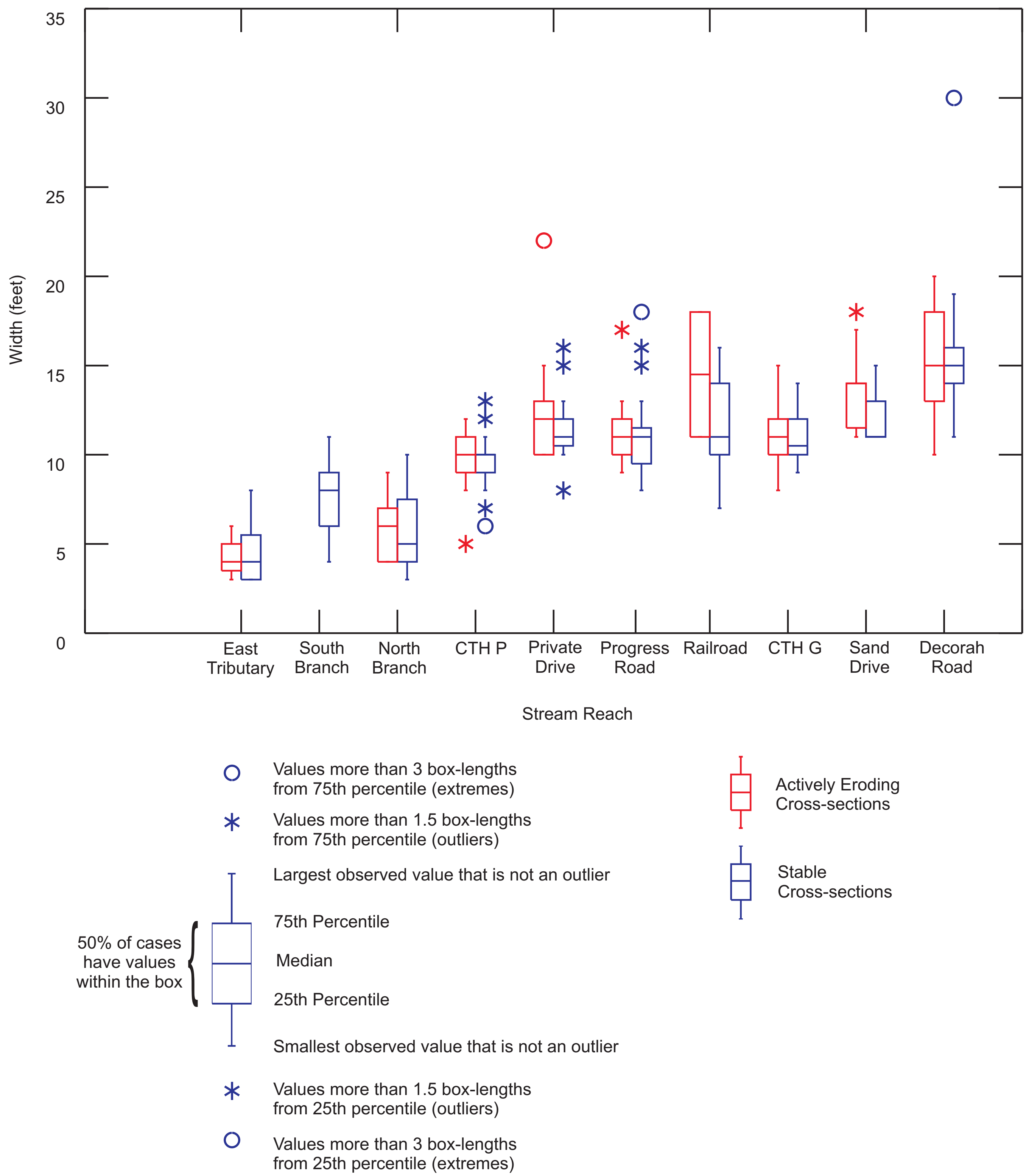
[13]*Standardizing the erosion value among reaches is justified, given the known differences in stormwater discharge, watershed area, and land use as noted in previous sections above. The bank length of each site was divided by the entire length of the reach within which the particular site was located. For example, site number 85 within the Progress Road reach of Quaas Creek, which is 2,165 feet in total length, contained an eroding bank 75 feet in total length that would correspond to a proportional failure of 3.5 percent (75 feet/2,165 feet). Prior to analysis all physical habitat data were transformed using* $\log_e (x + 1)$ *to homogenize variance, as set forth in Charles, J. Krebs,* Ecological Methodology*, Harper Collins, University of British Columbia, 1989.*

[14]*SEWRPC Community Assistance Planning Report No. 173,* op. cit.

Figure 5

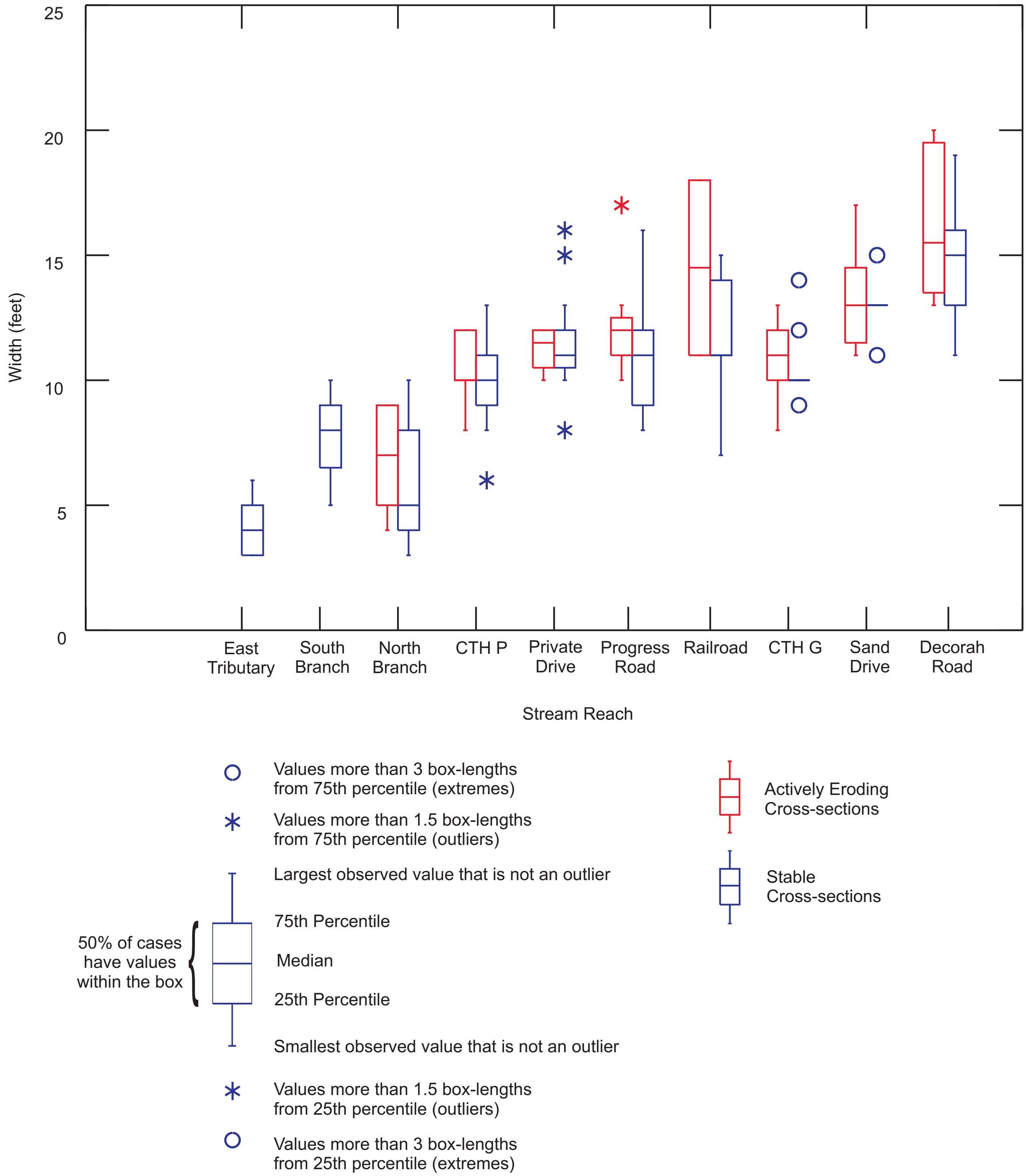
STABLE VERSUS ACTIVELY ERODING STREAM SITES COMPARING WIDTH AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



Source: SEWRPC.

Figure 6

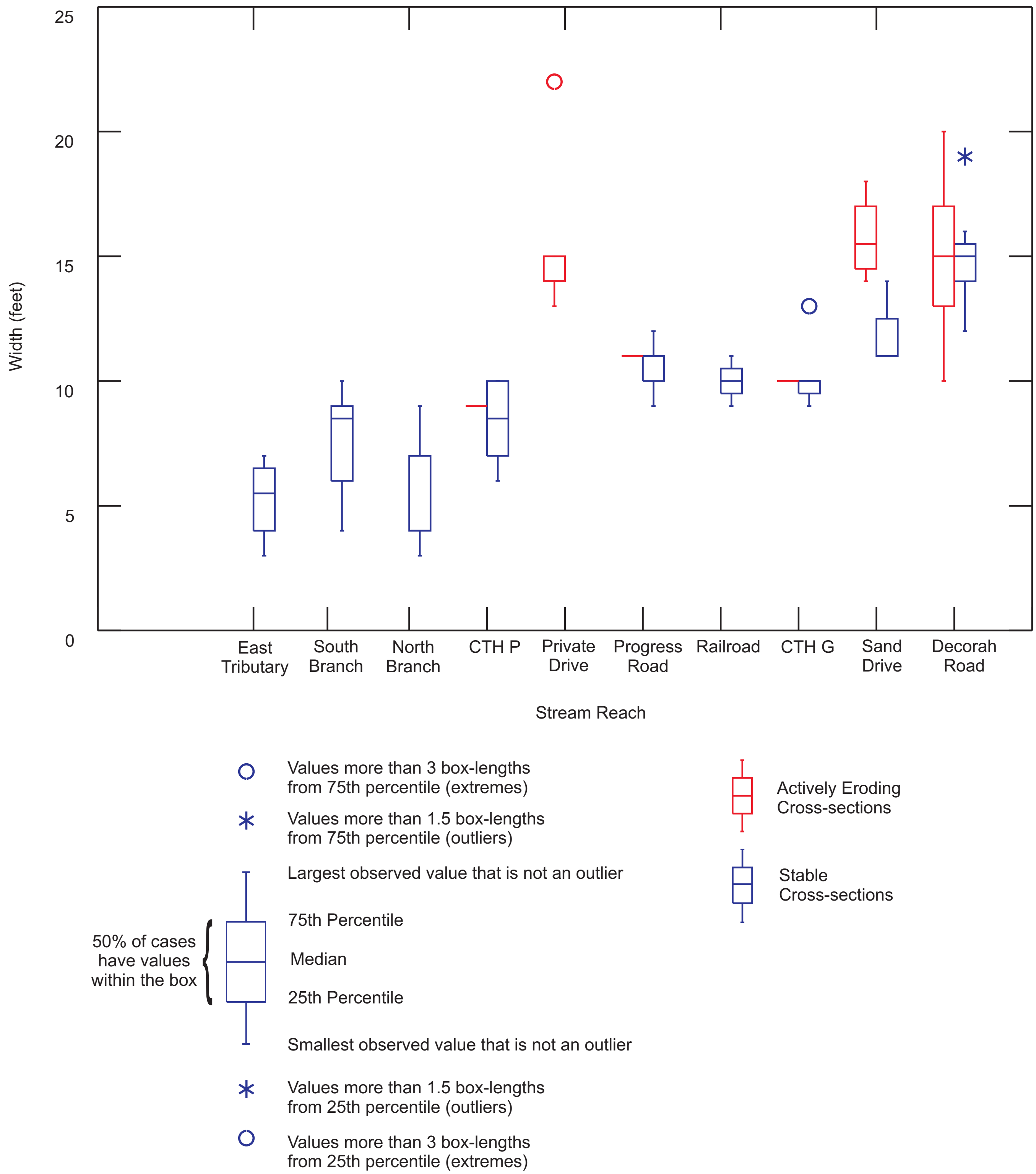
STABLE VERSUS ACTIVELY ERODING STREAM SITES COMPARING WIDTH AMONG POOL HABITATS AND REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



Source: SEWRPC.

Figure 7

STABLE VERSUS ACTIVELY ERODING STREAM SITES COMPARING WIDTH AMONG RIFFLE HABITATS AND REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001



Source: SEWRPC.

Table 7

PHYSICAL HABITAT CHARACTERISTICS AMONG STREAM REACHES WITHIN THE QUAAS CREEK WATERSHED: 2001

Parameters	River Reach									
	East Tributary	South Branch	North Branch	CTH P	Private Drive	Progress Road	Wisconsin Central Railroad	CTH G	Sand Drive	Decorah Road
Habitat										
Composition										
Number of Pools	6	35	42	26	19	21	13	20	16	26
Number of Riffles	4	8	14	7	6	7	3	10	7	22
Pool/Riffle Ratio	1.5	4.4	3.0	3.7	3.2	3.0	4.3	2.0	2.3	1.2
Width										
Average Pool Width (feet)	4.2	7.6	6.1	10.1	11.5	11.4	12.4	10.7	13.1	15.6
Average Riffle Width (feet)	5.3	7.6	5.1	8.4	15.3	10.7	10.0	10.1	14.1	14.9
Average Run Width (feet)	4.3	8.0	5.1	8.8	11.0	12.1	12.0	11.4	12.6	17.1
Depth										
Average Pool Depth (feet)	1.2	1.2	1.4	2.0	1.7	1.7	1.7	1.8	2.1	2.1
Average Riffle Depth (feet)	0.4	0.5	0.6	0.7	1.0	0.8	1.0	0.6	0.7	0.9
Average Run Depth (feet)	0.7	0.9	1.0	1.2	1.1	1.3	1.4	1.0	1.2	1.6
Substrate										
Sediment Depth										
Average Depth (feet)	0.36	0.87	0.77	0.52	0.04	0.03	0.34	0.63	0.67	0.01
Total accumulated depth of all sites combined (feet)	2.5	24.4	34.0	13.5	1.0	0.4	2.8	44.1	34.9	0.33
Composition										
Silt (percent)	29	28	16	17	5	14	0	34	34	6
Sand (percent)	47	43	49	39	35	26	23	33	26	35
Gravel (percent)	18	17	18	26	28	28	26	19	19	33
Cobble (percent)	6	11	14	17	32	3	26	11	18	26
Boulder (percent)	0	1	2	0	0	2	25	2	3	0
Cover										
Undercut Banks										
Deep (percent >1.0 feet)	- -[a]	- -[a]	0	10	10	0	- -[a]	0	30	19
Moderate (percent >0.5 and ≤1.0 feet)	- -[a]	- -[a]	19	0	10	7	- -[a]	7	4	12
Shallow (percent <0.5 feet)	- -[a]	- -[a]	31	60	38	60	- -[a]	11	26	42
None (percent)	- -[a]	- -[a]	50	30	42	33	- -[a]	82	40	27
Woody Debris										
High Abundance (percent)	- -[a]	- -[a]	13	10	14	7	- -[a]	36	26	8
Moderate Abundance (percent)	- -[a]	- -[a]	38	60	10	13	- -[a]	18	22	23
Low abundance (percent)	- -[a]	- -[a]	43	0	19	80	- -[a]	25	37	65
None (percent)	- -[a]	- -[a]	6	10	14	0	- -[a]	21	15	4
Debris Jams (total number)	2	8	3	14	1	1	0	15	5	1

[a] *There was not enough data within these reaches to compute percentages for these variables.*

Source: SEWRPC.

flow may be expected along the 2,380-foot-long reach of Quaas Creek above its confluence with the South Branch at River Mile 4.53. Therefore, it is possible that bank stability in these upstream reaches is more recent and eroding faster than compared to areas downstream.

Rosgen Stream Classification
The Rosgen stream classification system was applied to the Quaas Creek watershed in order to categorize reaches based on channel morphology so that consistent, reproducible, and quantitative descriptions can be made.[15] The Rosgen stream classification system consists of four hierarchical levels, three of which are diagnostic and are addressed in this study, with the fourth level being a verification step that is addressed in Chapter III. Through a combination of modeling and field measurements, variations in stream processes were grouped into distinct stream types using this system.

The diagnostic portion of the Rosgen stream classification system consists of three hierarchical levels, the first two of which are shown in Table 6. These diagnostic levels include such variables as entrenchment ratio, (wetted) width/depth ratio, sinuosity, slope and dominant channel material. The third diagnostic level was completed using a modification of the Rosgen methodology,[16] as set forth above in the discussion of bank stability characteristics of Quaas Creek. Based upon these parameters the majority of the reaches in the watershed are classified as "E" type streams and the three most downstream reaches are classified as "C" type streams. This change in stream type is also associated with significant increases in discharge, stream width, and streambank instability as previously noted in sections above. The dominant channel materials found in each of these reaches further demonstrates potential shifts in substrate composition from headwaters to the confluence of Milwaukee River. The upstream North Branch and East Tributary reaches are dominated by sand—classifying as Rosgen Type E5, while sand and silt are the dominant substrates in the South Branch reach, which classifies as Rosgen Type E5-E6. A shift to sand and gravel substrates occurs at CTH P, which reach classifies as an E4-E5 channel type. Sand and gravel substrates dominate in the next three reaches, including the Private Drive, Progress Road, and Wisconsin Central Railroad reaches that classify as E4-E5 channel types. Channel type and substrate composition dramatically shifts within the CTH G reach to a C5-C6 classification, or silt and sand dominated section. The Sand Drive reach also contains a channel type of C4-C5. The Decorah Road reach demonstrates a final shift in substrate dominance to sand and gravel or C4-C5 channel type.

Based upon these classifications, the Rosgen methodology would suggest that Quaas Creek is very sensitive to disturbances within the drainage area, with a fair to good recovery potential. These classifications also suggest that the potential for streambank erosion within this system is moderate to very high, with streambank vegetation having a very high controlling influence on moderating this erosion potential. The gradation of classification from E4-E5 in the upper reaches of the Quaas Creek system to C4-C6 in the lower reaches is consistent with the observed moderate to high erosion potential in the upstream reaches and high to very high erosion potential in the downstream reaches.

WATER QUALITY

Historic
Quaas Creek is a perennial stream with a water quality varying from poor to excellent, depending upon the indicators considered. From 1983 to 1986, the Wisconsin Department of Natural Resources collected various instantaneous dissolved oxygen and temperature measurements for specific areas within Quaas Creek that indicated it could support full fish and aquatic life standards.[17] Although, it should be noted that these measurements were taken in the spring and late fall months when cool water temperatures were generally present. Notwithstanding, dissolved oxygen and temperature data from June 1984 further indicated sufficient levels to

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[15]*D.L. Rosgen, "A Classification of Natural Rivers,"* op. cit.

[16]*The Level III Rosgen analysis is based upon the statistical extrapolation of data obtained from representative reaches of the stream being studied. For the purposes of this study, the entire stream system was investigated, resulting in a significantly more detailed basis upon which to classify Quaas Creek.*

[17]*Wisconsin Department of Natural Resources, File No. Quascr.rev,* op. cit.

support a salmonid and coolwater forage fishery upstream of CTH P. Temperatures increased to 25.5 degrees Celsius at CTH G and then decreased to 23.0 degrees Celsius at Decorah Road. Springs in the headwater reaches, while tile drainage and canopy cover in the lower reaches, was thought to be some of the factors contributing to these temperature trends. Furthermore, cooler water was reportedly discharged from the North Branch of Quaas Creek compared to the South Branch by Wisconsin Department of Natural Resources.

Surface bacteriological water samples were collected by the Wisconsin Department of Natural Resources from Quaas Creek at Decorah Road during the summer and fall of 1985. Results from these summer and fall samples exceeded the existing Wisconsin State Recreational Use Standards. It was determined that these samples were indicative of mixed or livestock sources of pollution as opposed to human sources. At the time of this survey, cattle had direct access to the Creek in at least two pasture sites. There have not been any additional bacteriological samples taken since 1985.

Existing

Based upon quality monitoring efforts by Dr. Timothy Ehlinger at the University of Wisconsin-Milwaukee as part of the Great Lakes Protection Fund Project, extensive water quality information exists for certain portions of the watershed. These data were used to assess the current status of the Quaas Creek watershed. As part of the aforementioned project, a continuous monitoring station was established on the main stem of the Creek, located at approximately River Mile 0.91 within the Sand Drive reach. Additional temporary sites were also monitored within the North and South Branch reaches of this watershed. No data on total phosphorus, ammonia nitrogen, chloride, or fecal coliform concentrations exist from which to assess whether or not the Quaas Creek watershed currently meets the warmwater sportfish and recreational use standards set forth in Appendix A.

Water quality results at the River Mile 0.91 site are shown to adequately support warmwater sportfish community and full recreational use standards for pH, dissolved oxygen, and temperature. Continuous monitoring data from the period from June 2000 through August 2001 demonstrated an average pH of 7.9, conductivity of 564 micro Seimens, turbidity of 51.9 nephelemetric turbidity units, dissolved oxygen of 10.6 milligrams per liter, and temperature of 10.5 degrees Celsius. These parameters ranged from a minimum to a maximum of 7.0 to 8.6 for pH, 222 to 1,691 microSiemens for conductivity, zero to 1,908 nephelemetric turbidity units for turbidity, 5.5 to 20.1 milligrams per liter for dissolved oxygen, and 0.04 to 25.4 degrees Celsius for temperature. These ranges in water quality conditions for Quaas Creek are well within the recommended ambient water quality criteria for streams and rivers as set forth for the larger ecoregional area as defined by the Ecological Protection Agency (see Appendix A, Figure A-2).

Seasonal water temperature data collected during the fall of 1999 within the upper reaches of the Quaas Creek watershed indicate that these areas could support a salmonid fishery as shown in Figure 8. These results generally agree with the Wisconsin Department of Natural Resources conclusion that cooler water enters the main channel of Quaas Creek from the North Branch compared to the South Branch. As shown in Figure 8, the upper portion of the South Branch consistently contains the coldest temperatures during this period of time. Prior to the confluence with the North Branch, the lower portion of the South Branch is significantly warmer than the upper South Branch, lower North Branch, and oftentimes the upper North Branch as well. In addition, the lower South Branch tends to have the highest maximum and lowest minimum temperatures compared to the rest of the areas. In contrast, the upper portion of the North Branch is significantly warmer than the lower portion of the North Branch. Prior to the confluence with the South Branch the North Branch is nearly the same temperature of the main channel of Quaas Creek and tends to track the main channel temperatures ranges.

Nevertheless, seasonal water temperature data collected during the summers of 1999 through 2001 indicate that Quaas Creek would be less likely to support a salmonid fishery. Data collected from the North and South Branches of Quaas Creek during an 18-day period in July of 1999 often exceeded 20 degrees Celsius, as shown in Figure 9. The North Branch water temperatures were consistently warmer than the South Branch temperatures.

Figure 8

WATER TEMPERATURE AMONG THE UPPER AND LOWER PORTIONS OF THE NORTH AND SOUTH BRANCHES AND MAIN STEM OF QUAAS CREEK: FALL 1999

Source: University of Wisconsin-Milwaukee and SEWRPC.

The North Branch was also shown to reach the lethal limit for salmonids, of 25 degrees Celsius, on two occasions (Figure 9).[18] Similarly, data collected from the South Branch and main channel at River Mile 0.91 of Quaas Creek during 2000 and 2001 also often exceeded 20 degrees Celsius, and exceeded the lethal limit for salmonids, of 25 degrees Celsius, on several occasions during 2001 (Figure 10).[19] The South Branch water temperatures were consistently warmer than the main channel temperatures. Salmonids, such as brook trout, survive best in 20 degrees Celsius water temperatures or less and have been shown to prefer temperatures in the wild from 13.9 to 15.6 degrees Celsius. Optimum feeding temperature is about 19 degrees Celsius, and temperatures recommended

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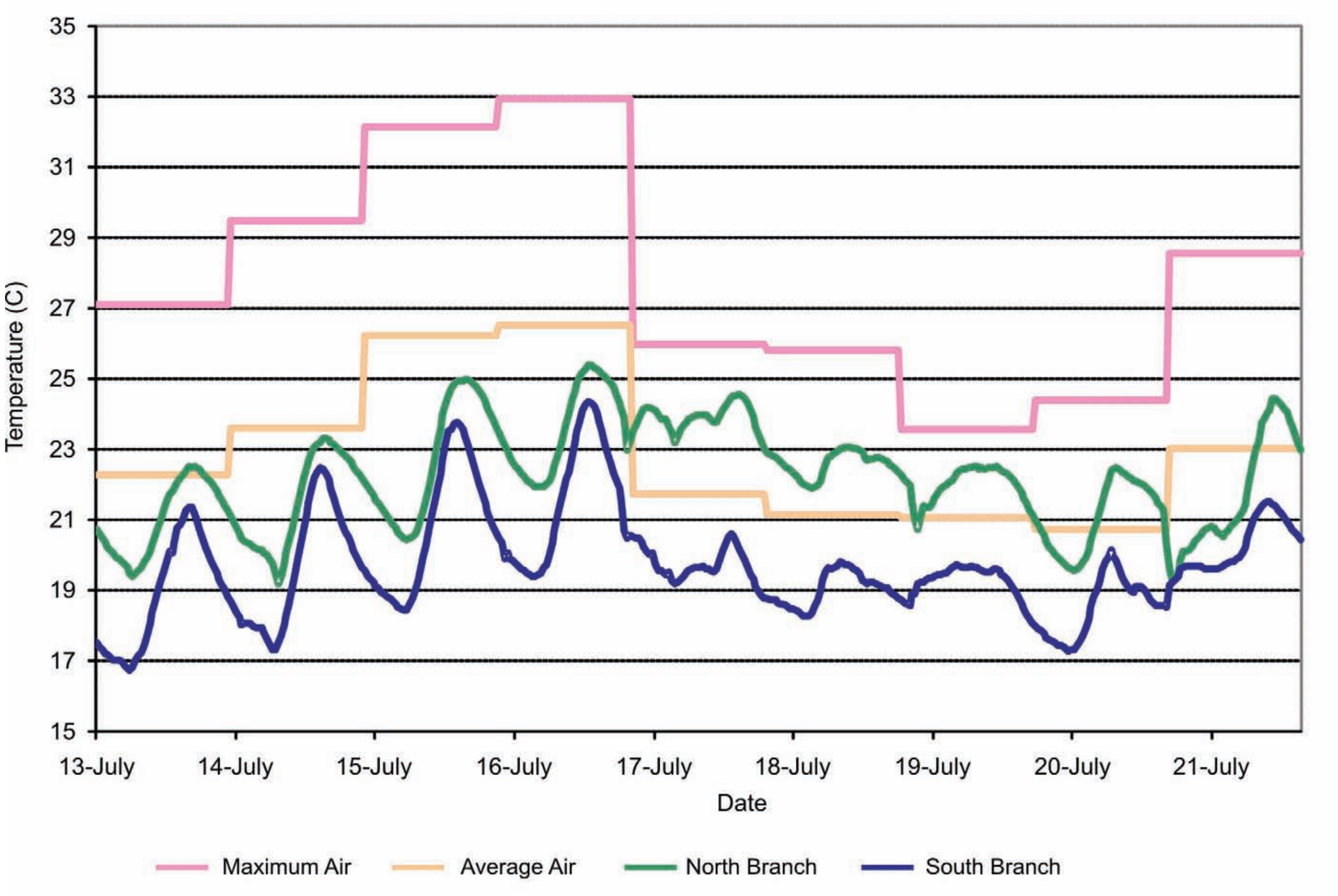
[18]*G.S. Becker,* Fishes of Wisconsin*, University of Wisconsin Press, 1983.*

[19]*See John Lyons, Lizhu Wang and Timothy D. Simonson, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin,"* North American Journal of Fisheries Management*, Volume 16, No. 2, pages 241-256, May 1996, which distinguishes warmwater habitats having maximum daily mean water temperatures in excess of 24°C from coldwater habitats having maximum daily mean water temperatures of less than 22°C.*

Figure 9

AVERAGE AND MAXIMUM AIR TEMPERATURE AND WATER TEMPERATURE WITHIN THE NORTH AND SOUTH BRANCHES OF QUAAS CREEK: SUMMER 1999



Source: University of Wisconsin-Milwaukee and SEWRPC.

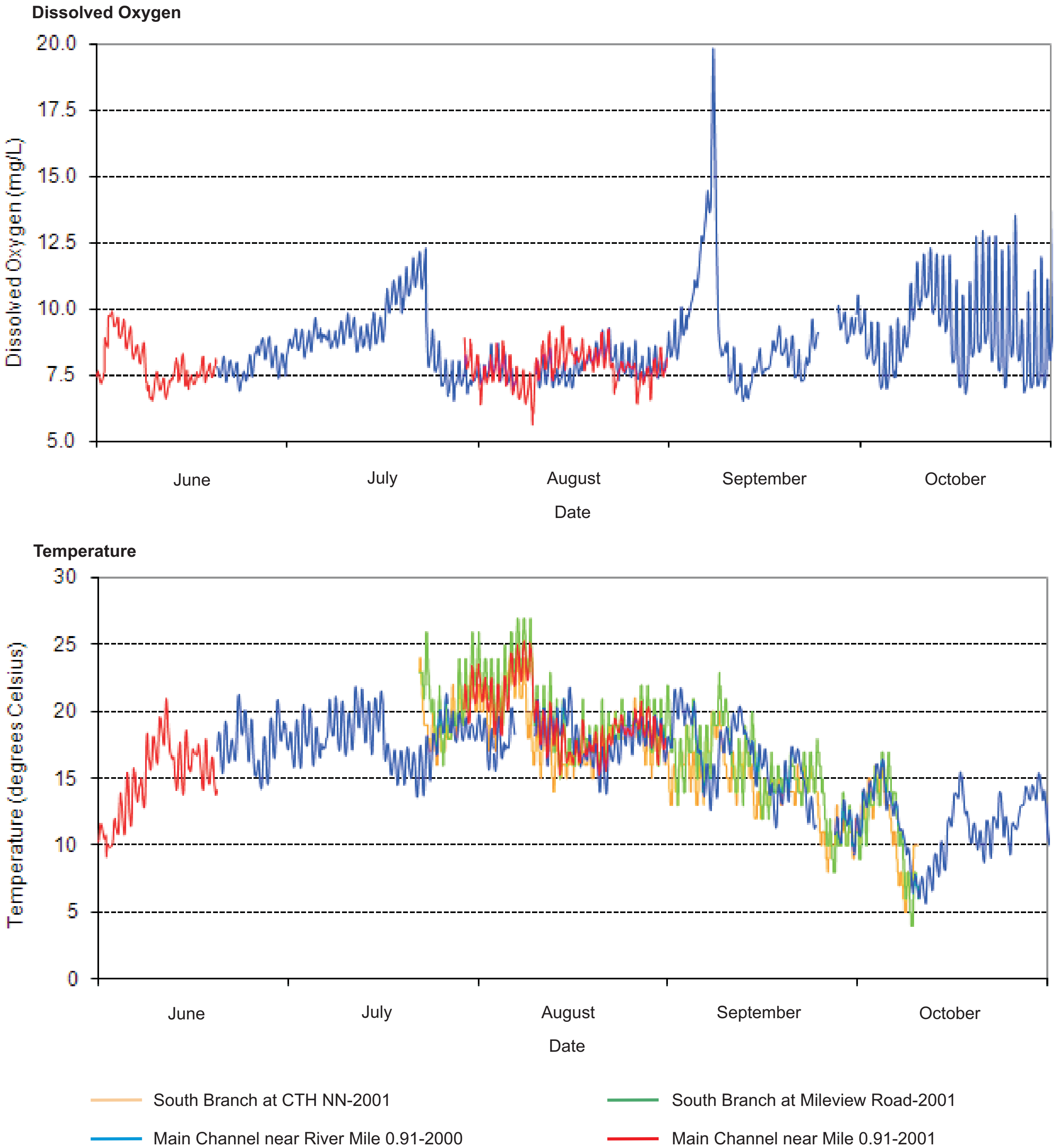
for optimum growth and for spawning are 20 and 12.8 degrees Celsius, respectively.[20] Temperatures well below the lethal limit, however, can cause significant stress that can lead to illness, infection, and ultimately death.

Finally, during the summers of 2000 and 2001, seasonal dissolved oxygen concentrations in the main channel of Quaas Creek dropped below six milligrams per liter only on one day during these time periods, as shown in Figure 10. At other times during the summer season, the seasonal dissolved oxygen concentrations averaged about eight milligrams per liter, which concentrations are indicative of being able to support a high-quality warmwater fishery.

[20]*G.S. Becker,* op. cit.

Figure 10

AVERAGE HOURLY DISSOLVED OXYGEN CONCENTRATION AND WATER TEMPERATURE WITHIN THE MAIN CHANNEL AND SOUTH BRANCH OF QUAAS CREEK: 2000 AND 2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

HABITAT

The amount, quality, and diversity of available instream fisheries and macroinvertebrate habitat are generally very good within the Quaas Creek watershed as shown in Table 7. The total number of pool habitats was lowest in the East Tributary, Wisconsin Central Railroad, and Sand Drive reaches compared to the rest of the watershed. Similarly, total number of riffles were lowest in the East Tributary and Wisconsin Central Railroad reaches, which further indicates that these areas contain less diversity of habitat types compared to the rest of the watershed. The proportion of the number of pool to riffle habitats is highest in the Decorah Road, Sand Drive, and CTH G reaches compared to the rest of the watershed, which indicates these areas contain the highest diversity of habitat types compared to the rest of the watershed. However, as indicated in the stream reach section above, width and depth generally increase from headwater areas to the confluence of the Milwaukee River. Therefore, average width and depth of pool, riffle, and run habitats also changes from headwater areas to the confluence of the Milwaukee River. These changes indicate that, although nominally the same type of habitat area, the pools, riffles and runs in the upper portions of the watershed effectively form smaller habitat types than those similarly named types of habitat in the lower reaches of the watershed. These differences can affect and determine the biological community type, abundance, and distribution present within these distinct hydrologic reaches, which, in effect, can result in significant differences in species composition within each of the distinct hydrologic reaches.

Substrate diversity was generally high throughout the Quaas Creek watershed as shown in Table 7. However, the headwater East Tributary, South Branch, and North Branch reaches demonstrate a much higher proportion of sand, which suggests these areas contain less diversity than other areas of the watershed. The CTH P, Private Drive, Wisconsin Central Railroad, Sand Drive, and Decorah Road reaches show the highest proportion of both gravel and cobble compared to the rest of the watershed, which offers excellent habitat for macroinvertebrates and spawning habitat for fishes. Although substrate diversity was generally high, sediment deposition was also observed throughout the Quaas Creek watershed. Sediment was observed to be greatest within channelized sections of streams or near obstructions such as culverts, bridges, rock weirs, and woody debris jams. Based on the average depth and total accumulated depth of the combined measurements within a reach, it appears that sedimentation is a potential problem in specific areas of the South Branch, North Branch, CTH P, CTH G, and Sand Drive reaches.

The Quaas Creek watershed also generally contained a high amount of in-stream cover for fish and macro-invertebrates in terms of undercut banks, woody debris, as well as large boulders (Table 7). Although undercut banks are related to streambank stability issues (see streambank erosion section above), these are also areas of overhead protection for fishes. Results indicate that most of the watershed is composed of undercut banks with less than 0.5 foot in depth. The proportion of deepest undercut banks is located within the Sand Drive and Decorah Road reaches compared to the rest of the watershed. Woody debris is also a significant habitat component within this river system most likely due to the extensive woody riparian buffers that exist throughout most of the watershed. The presence and diversity of woody debris within the system is excellent, however, woody debris has been observed to accumulate excessively causing debris jams. These debris jams function much like a beaver dam, which can cause a significant disruption in sediment dynamics, cause localized flooding, and localized bank stability problems, and may inhibit movement of fishes to feeding and spawning areas. The CTH P and CTH G reaches contain two to 15 times more woody debris jams than the rest of the watershed, which may indicate a potential problem in these areas.

In addition to the woody debris jams, there were a number of other potential physical and hydrological migratory barriers to fisheries movements particularly at culverted and bridged road crossings as shown in Table 8 (see Appendix B, Figures B-7 and B-8). The most common hydrological obstructions at culverts within Quaas Creek were reduced water depths and increased velocities, which were observed at structures numbered 4, 6, 10, 11, and 12 (see Maps 5 and 6). Excessive woody debris accumulations at the inlets of several culverts were also observed at structures numbered 2, 5, 9, and 12. Because of the relatively high number of culverts within the Quaas Creek

Table 8

COMPARISON OF POTENTIAL OBSTRUCTIONS TO FISHERIES PASSAGE AMONG BRIDGE AND CULVERT LOCATIONS WITHIN THE QUAAS CREEK WATERSHED: 2002

Structure Number on Maps 5 and 6	Description	Road Crossing	River Mile	River Channel Section	Potential Fisheries Passage Obstructions	
					Hydrological	Physical
1	24-foot-wide, 33.5-foot-long single-span bridge	CTH I	0.54	Main channel	Low	Low
2	Two four-foot-diameter, 23.2-foot-long concrete pipe culverts	Private drive	1.141	Main channel	Moderate–segregated flows among pipes	High–woody debris accumulation observed at both inlets
3	Two 8.5-foot-wide, six-foot-high, 40-foot-long steel pipe box culverts	Sand Drive	1.511	Main channel	Low	Low
4	Two eight-foot-wide, four-foot-high concrete box culverts	Paradise Drive	2.105	Main channel	High–shallow depths and increased velocity	Low
5	One approximately two-foot-diameter corrugated metal pipe culvert	Paradise Drive	- -[a]	East Tributary	High–submerged outlet	High–woody debris accumulation observed at inlet
6	Two 9.5-foot-wide, 6.4-foot-high, 67-foot-long structural plate pipe arch culverts	CTH G	2.501	Main channel	High–shallow depths and increased velocity	Moderate–woody debris accumulation observed at both inlets, see Appendix B Figure B-7
7	13.5-foot-wide, 15-foot-high, 50-foot-long bridge	Wisconsin Central Railroad	2.851	Main channel	Low	Low
8	Two 20-foot-wide, eight-foot-high, 42.2-foot-long concrete spans	Progress Road	3.311	Main channel	Low	Low
9	Concrete span bridge	Private drive	3.89	Main channel	Low	High–woody debris accumulation observed near inlet
10[b]	Box culvert with seven-foot-diameter corrugated metal pipes at each end	CTH P	4.534	Main channel	High–narrow width and increased velocities	Moderate–narrow box culvert width may induce woody debris accumulation, see Appendix B Figure B-8
11	Metal pipe arch culvert with added corrugated metal pipes at each end	CTH NN	- -[a]	South Branch	High–metal obstruction at culvert junction is obstructing flow and reducing depths and increasing velocities	Moderate–metal obstruction at culvert junction may induce woody debris accumulation within culvert
12	Four 10-inch-diameter, 12-foot-long steel culvert and one 10-inch-diameter, 12-foot-long, concrete pipe culvert	Private drive	4.79	North Branch	High–narrow width, increased velocity, and segregated flows among pipes	High–woody debris accumulation observed near inlet
13	21-inch-diameter, 14-foot-long corrugated metal pipe culvert	Private drive	5.22	North Branch	Low	High–narrow width may induce woody debris accumulation

[a]*These culverts were located in tributaries to the main channel of Quaas Creek, and so river miles were not designated.*

[b]*This culvert was recommended for replacement under the intermediate-Priority Projects. See SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend, Washington County, Wisconsin*, Volume Four,* Alternatives and Recommended Plan for the Quaas Creek Subwatershed*, July 1996.*

Source: SEWRPC.

watershed, their combined impact on stream fish communities could potentially be greater than generally recognized.[21] Culverts tend to have a destabilizing influence on stream morphology that can create selective barriers to fish migration because swimming abilities vary substantially among species and size-classes of fish affecting their ability to traverse the altered hydrological regime within the culverts.[22] Fish of all ages require freedom of movement to fulfill needs for feeding, growth, and spawning which generally cannot be found in only one particular area of a stream system. These movements may be upstream or downstream and occur over an extended period of time, especially in regard to feeding. In addition, before winter freeze-up, fish tend to move downstream to deeper pools for overwintering. Fry and juvenile fish also require access up and down the stream system while seeking rearing habitat for feeding and protection from predators. The recognition that fish populations are often adversely affected by culverts has resulted in numerous designs and guidelines that have been developed to allow for better fish passage and to help ensure a healthy sustainable fisheries community.[23]

FISHERIES

Review of the fishery data collected in the Quaas Creek watershed between 1924 and 2001 indicates an apparent loss of 12 species since 1983 as shown in Table 9. Most notable were losses of intolerant species such as the blackchin shiner, smallmouth bass, and the Iowa darter. Additional species that have not been observed since 1983 include the banded killifish which is a species of special concern in the State of Wisconsin, bluntnose darter, bullhead minnow, largescale stoneroller, northern redbelly dace, sand shiner, as well as gamefish species largemouth bass, and northern pike. The tolerant common carp species has also not been observed since 1983, but this exotic species is always considered a potential threatening invader. Despite the declines in the occurrence of certain species as noted above, recent fish population surveys of the Quaas Creek watershed, demonstrated a fairly diverse fish community, as shown in Table 9, indicative of warmwater lowland stream systems in Southeastern Wisconsin.[24] Nonetheless, native brook trout species were collected by the Wisconsin Department of Natural Resources in 1984. This coldwater species was found in the headwater areas upstream and immediately downstream of old USH 45 at River Mile 4.3, at the confluence of the North and South Branches near River Mile 4.5, and on the South Branch upstream of CTH NN. The second and only other record of the presence of brook trout within Quaas Creek watershed was in 1994, by Dr. Timothy Ehlinger at the University of Wisconsin-Milwaukee, at the confluence of the North and South Branches. Although there were no reports on the condition of the brook trout collected in 1984, observations of the brook trout caught in 1994 showed evidence of discoloring and fin rot, which are indicators of stress. There has never been a record of brook trout spawning anywhere within this system. During reconnaissance of the recent bank stability survey in the late fall of 2001 within which nearly six miles of stream were surveyed, there was neither a single observation of a trout nor evidence of a spawning redd within any of the high-quality riffle habitats. Consequently, this would bring the total apparent fish species loss to 13 within the Quaas Creek watershed.

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[21] *Thomas M. Slawski and Timothy J. Ehlinger, "Fish Habitat Improvement in Box Culverts: Management in the Dark?"* North American Journal of Fisheries Management*, Vol. 18, 1998, pp. 676-685.*

[22] *Stream Enhancement Research Committee, "Stream Enhancement Guide", Province of British of Columbia and the British Columbia Ministry of Environment. Vancouver, 1980.*

[23] *B.G. Dane, "A Review and Resolution of Fish Passage Problems at Culvert Sites in British Columbia", Canada Fisheries and Marine Sciences Technical Report 810, 1978. Chris Katopodis, "Introduction to Fishway Design", Freshwater Institute Central and Arctic Region Department of Fisheries and Oceans, January, 1992.*

[24] *John Lyons, "Correspondence Between the Distribution of Fish Assemblages in Wisconsin Streams and Omernik's Ecoregions,"* American Midland Naturalist*, Vol. 122, 1989, pp. 163-182.*

Table 9

SUMMARY OF HISTORICAL REPORTS OF FISHES COLLECTED IN THE QUAAS CREEK WATERSHED: 1924-2001

Species According to Their Relative Tolerance to Pollution	Date of Survey								
	1924	1978	1983	1984	1994	1998	1999	2000	2001
Intolerant									
Blackchin Shiner	- -	X	- -	- -	- -	- -	- -	- -	- -
Blacknose Shiner	- -	X	- -	- -	- -	- -	- -	X	X
Brook Trout	- -	- -	- -	X[a]	X[b]	- -	- -	- -	- -
Iowa Darter	- -	X	X	- -	- -	- -	- -	- -	- -
Mottled Sculpin	- -	X	- -	- -	- -	X	X	X	X
Smallmouth Bass	X	- -	- -	- -	- -	- -	- -	- -	- -
Tolerant									
Blacknose Dace	- -	X	- -	- -	- -	- -	X	X	X
Bluntnose Minnow	X	X	X	- -	- -	- -	X	X	X
Central Minnow	- -	X	X	- -	- -	X	X	X	X
Common Carp	- -	X	X	- -	- -	- -	- -	- -	- -
Creek Chub	X	X	- -	- -	- -	X	X	X	X
Fathead Minnow	- -	- -	- -	- -	- -	- -	- -	X	X
Golden Shiner	- -	X	X	- -	- -	- -	- -	- -	X
Green Sunfish	X	X	X	- -	- -	- -	X	X	X
White Sucker	X	X	- -	- -	- -	- -	X	X	X
No Tolerance Classification									
Banded Killifish	- -	X	- -	- -	- -	- -	- -	- -	- -
Black Bullhead	- -	- -	- -	- -	- -	- -	- -	X	X
Bluegill	- -	- -	X	- -	- -	- -	- -	X	X
Bluntnose Darter	X	- -	X	- -	- -	- -	- -	- -	- -
Brook Stickleback	- -	X	- -	- -	- -	- -	- -	X	X
Brown Bullhead	- -	- -	X	- -	- -	- -	X	- -	X
Bullhead Minnow	- -	- -	X	- -	- -	- -	- -	- -	- -
Central Stoneroller	- -	X	X	- -	- -	X	X	X	X
Common Shiner	- -	X	X	- -	- -	- -	X	X	X
Fantail Darter	X	X	- -	- -	- -	- -	X	X	X
Finescale Dace	- -	- -	- -	- -	- -	- -	- -	X	- -
Grass Pickerel	- -	- -	- -	- -	- -	- -	- -	- -	X
Hornyhead Chub	- -	X	X	- -	- -	- -	- -	X	- -
Johnny Darter	X	X	- -	- -	- -	- -	- -	X	X
Largemouth Bass	- -	X	- -	- -	- -	- -	- -	- -	- -
Largescale Stoneroller	X	- -	X	- -	- -	- -	- -	- -	- -
Northern Pike	- -	X	X	- -	- -	- -	- -	- -	- -
Northern Redbelly Dace	- -	X	X	- -	- -	- -	- -	- -	- -
Pearl Dace	- -	X	X	- -	- -	- -	- -	- -	X
Pumpkinseed	- -	- -	- -	- -	- -	- -	X	- -	X
Sand Shiner	- -	- -	X	- -	- -	- -	- -	- -	- -
Southern Redbelly Dace	- -	X	- -	- -	- -	- -	X	- -	X
Total Number of Species	9	24	19	- -	- -	4	13	18	20

[a]*Reported by Wisconsin Department of Natural Resources staff.*

[b]*Reported by University of Wisconsin-Milwaukee staff.*

Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Recent electrofishing and habitat surveys conducted from 1999 through 2001 by Dr. Timothy Ehlinger at the University of Wisconsin-Milwaukee as part of the Great Lakes Protection Fund Project indicate that some portions of the Quaas Creek watershed indicate an improved fishery, in terms of overall fish abundance and diversity. In order to compare current versus historical fisheries records, data from 1924 to 1983 were combined to represent the historical fisheries conditions and current data from 1998 to 2001 were combined and considered to represent the existing fishery.

An Index of Biotic Integrity (IBI) was used to classify the historic and existing fishery and environmental quality in this stream system using fish survey data from various sampling locations of the Quaas Creek watershed.[25] The IBI consists of a series of fish community attributes that reflect basic structural and functional characteristics of biotic assemblages: species richness and composition, trophic and reproductive function, and individual abundance and condition.[26]

In Wisconsin, high-quality warmwater streams are characterized by many native species, darters, suckers, sunfish, and intolerant species (species that are particularly sensitive to water pollution and habitat degradation). Tolerant fish species are capable of persisting under a wide range of degraded conditions and are also typically present within high-quality warmwater streams, but do not dominate. Insectivores (fish that feed primarily on small invertebrate bugs) and top carnivores (fish that feed on other fish, vertebrates, or large invertebrate bugs) are generally common. Omnivores (fish that feed on both plant and animal material) are also generally common, but do not dominate. Simple lithophilous spawners which are species that lay their eggs directly on large substrate, such as clean gravel or cobble, without building a nest or providing parental care for the eggs are also generally common. In addition, deformities, eroded fins, lesions, or tumors on fish species in high-quality streams are generally few to none.

IBI results indicate an overall improvement in the quality of the fishery of the Quaas Creek watershed compared to the historic conditions as shown in Figure 11. Results also show that the upstream areas in the past and present generally contain higher scores than the downstream reaches, except for the South Branch. The downstream reaches show an improvement from a very poor-poor score to poor-fair IBI scores. The upstream reaches indicate an improvement from poor-fair scores to fair-excellent scores. The current poor-fair score in the South Branch is comparable to the mid- and downstream areas of the watershed, but substantially less than the fair-excellent classification of the North Branch. Results also indicate that recent surveys generally show an increase in the total number of native species in the upstream and downstream reaches of the watershed compared to historic records (Figure 12).

Despite the increase in IBI scores and native fish species as noted above, there has also been a general increase in the proportion of tolerant fish species throughout the watershed compared to historic fish species records in this watershed, except for the North Branch (Figure 13). The South Branch currently contains the highest proportion of tolerant species compared to the rest of the watershed. Conversely, the North Branch contains the lowest

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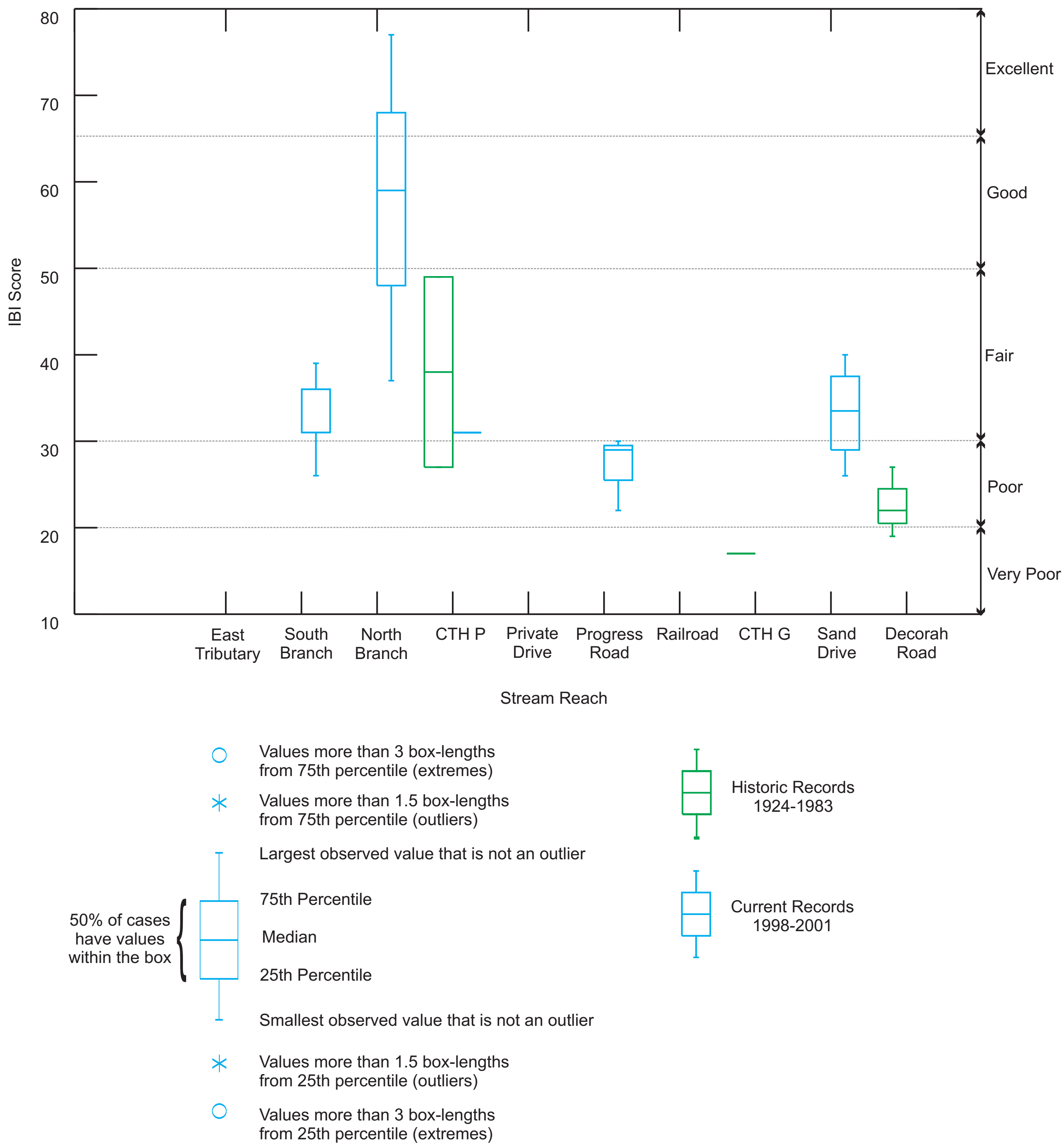
[25] *John Lyons, "Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin," United States Department of Agriculture,* General Technical Report NC-149*, 1992.*

[26] *John Lyons,* General Technical Report NC-149, op. cit*. The Wisconsin IBI described here consists of 10 basic metrics, plus two additional metrics (termed "correction factors") that affect the index only when they have extreme values. These 12 metrics are: Species Richness and Composition—total number of native species, darter species, sucker species, sunfish species, intolerant species, and percent (by number of individuals) that are tolerant species; Trophic and Reproductive Function—Percent that are omnivores, insectivores, top carnivores, and simple lithophilous spawners; and Fish Abundance and Condition—number of individuals (excluding tolerant species) per 300 meters sampled and percent with deformities, eroded fins, lesions, or tumors (DELT). The last two metrics are not normally included in the calculation of the IBI, but they can lower the overall IBI score if they have extreme values (very low number of individuals or high percent DELT fish).*

Figure 11

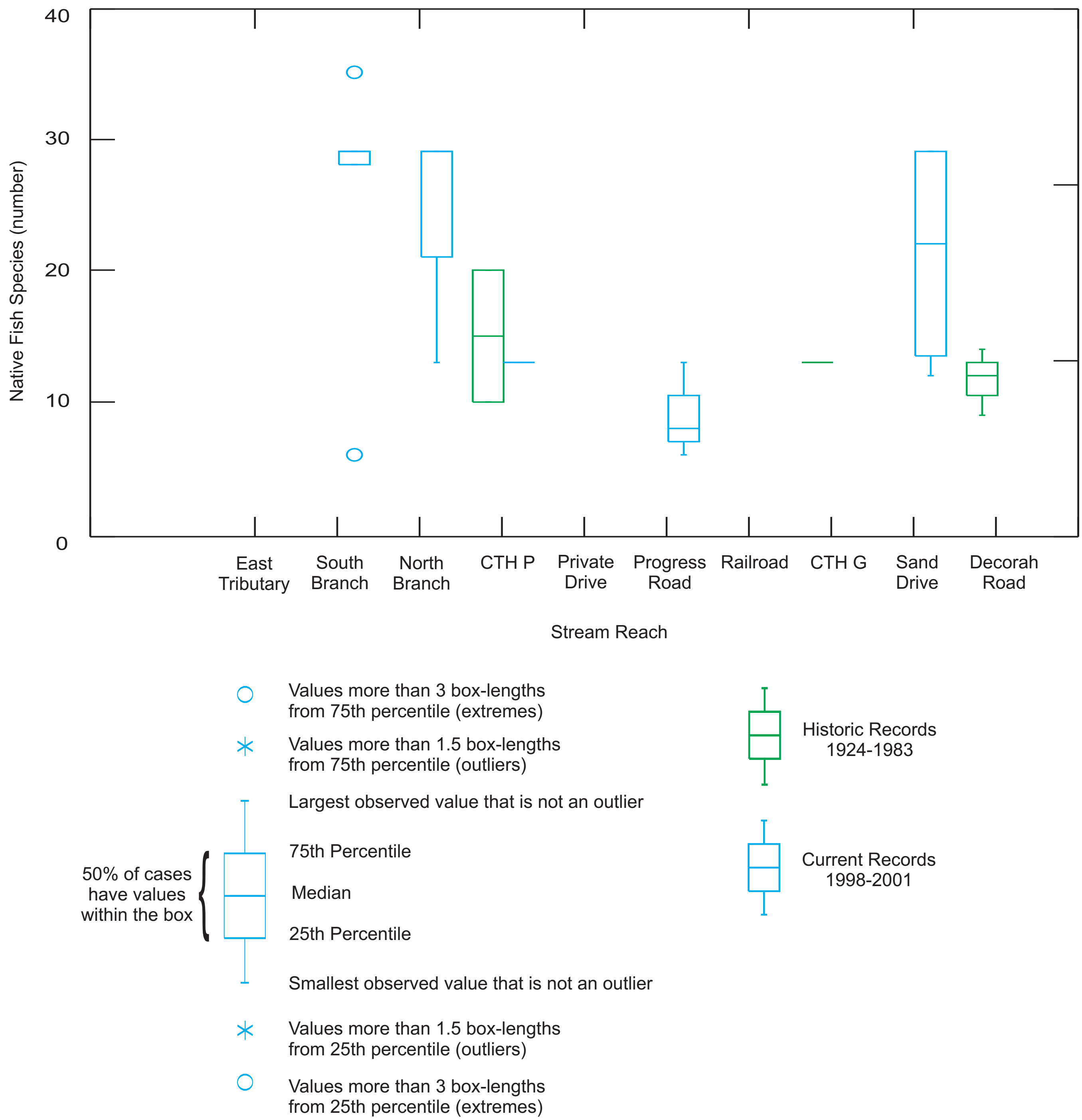
HISTORIC AND CURRENT FISHERIES INDEX OF BIOTIC INTEGRITY (IBI) CLASSIFICATION AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 12

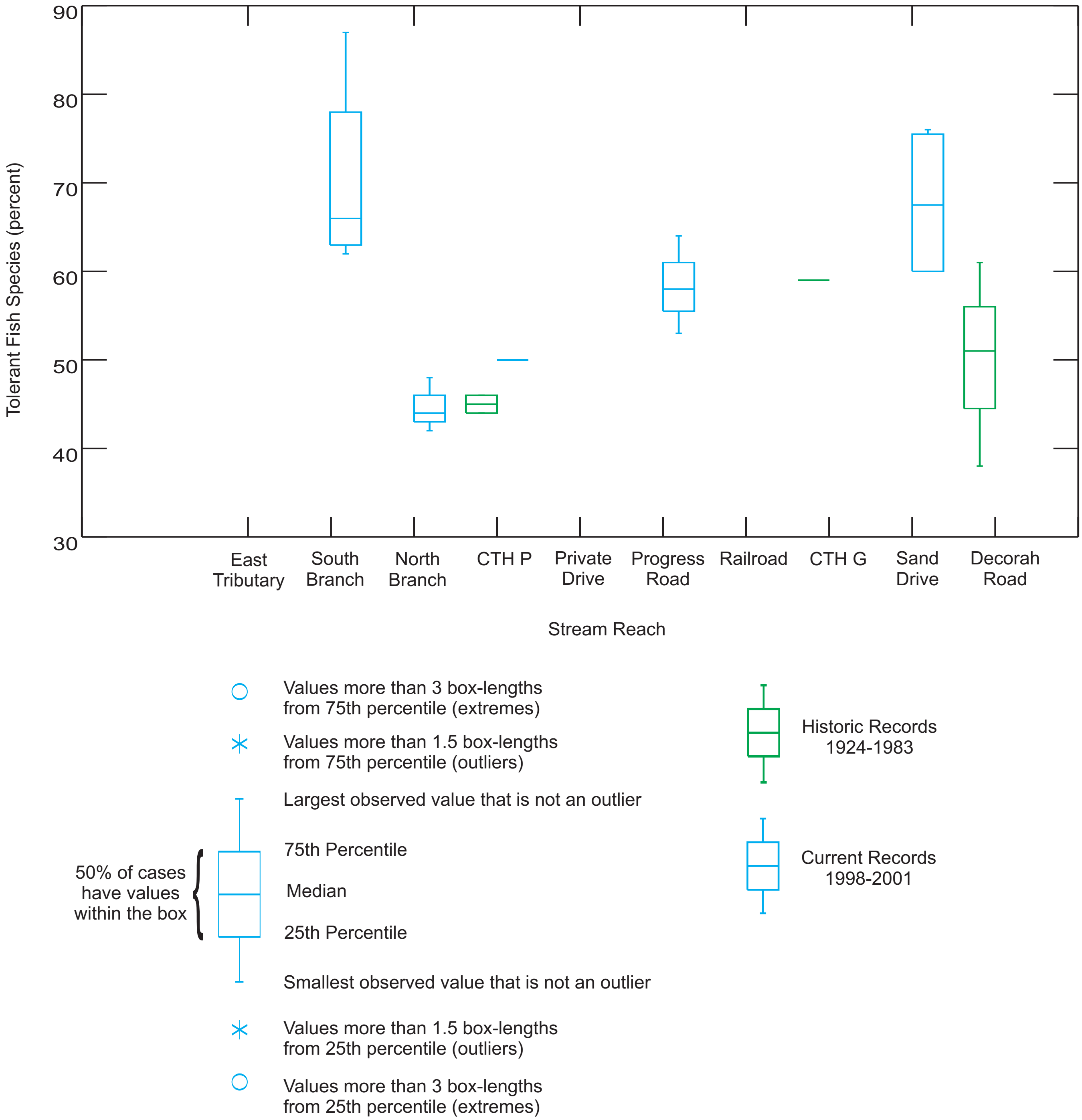
HISTORIC AND CURRENT NUMBER OF NATIVE FISH SPECIES AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 13

HISTORIC AND CURRENT PERCENT OF TOLERANT FISH SPECIES AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

proportion of tolerant species, and it seems that both the amount and variance in the proportion of tolerant species increases from upstream to the downstream reaches. In addition, Figure 14 also shows a general increase in the number of simple lithophilic spawners, which tend to decrease in abundance with disturbance. There appears to be a continuum of low proportions of simple lithophiles in the upstream reaches, with the greatest proportions in the furthest downstream reach. The South Branch contains the lowest proportion of simple lithophiles compared to the rest of the watershed. This apparent trend in simple lithophiles, which require clean gravel or cobble substrates for successful spawning, is consistent with the increased proportion, or availability, of riffle habitats in the downstream areas compared to the upstream portions of this watershed.

The proportions of omnivorous species as shown in Figure 15 tended to be greatest in the downstream reaches both in the past and existing fisheries. Proportions of insectivorous fishes in the historic records did not demonstrate a pattern. In contrast, proportion of the current distribution of insectivorous fishes demonstrates relatively high amounts in the upstream area, except for the South Branch, and decrease in proportion to the downstream reaches (Figure 16). The proportion of top carnivores has been very low (1 percent) to nonexistent in both the historic and existing fishery survey records. Although sportfish, such as largemouth bass, have been recorded, large predator species have not been recorded to be a significant component of the fisheries community in this watershed.

Based upon the results presented above, the Quaas Creek watershed seems to have maintained a healthy and diverse fishery, which is a manifestation of the relatively good water quality conditions that have generally existed. However, the sportfish component of this system seems to have been and continues to be limited. Of the 37 species of fish captured over the period of 1924 to 2001, the following 10 species are considered to be of sport fishing value: brook trout, northern pike, grass pickerel, black and brown bullhead, largemouth and smallmouth bass, green sunfish, bluegill, and pumpkinseed. Brook trout, northern pike, largemouth bass, and smallmouth bass have not been recorded in nearly 10, 20, 25, and 80 years, respectively, as shown in Table 9. The apparent loss of these species could be due to a variety of reasons. For example, the loss of brook trout from this system may be related to elevated water temperatures throughout the watershed (see discussion on water quality below). Northern pike have been observed to be spawning by local residents in this system in both the East Tributary and South Branch of this watershed. It is possible that northern pike continue to spawn in areas of the watershed in the spring, but then migrate back to the larger Milwaukee River. Therefore, these species are not found in the mid summer and late fall fish surveys that have been taken recently. Brown bullhead, bluegill, and green sunfish have been found since 1983 and continue to be a component of the existing fishery, although a very small component with limited abundance. Notwithstanding, recent occurrences of both the black bullhead, and, especially, the grass pickerel species may be indicative that this system contains great potential for enhancement in terms of the sportfish recreational opportunities.

Although the fish IBI is useful for assessing environmental quality and biotic integrity in warmwater streams, it is most effective when used in combination with additional data on physical habitat, water quality, macro-invertebrates, and other biota when evaluating a site.[27] Hence, supplemental data for macroinvertebrates surveys conducted by the Wisconsin Department of Natural Resources and University of Wisconsin-Milwaukee are summarized below.

MACROINVERTEBRATES

The Hilsenhoff Biotic Index[28] (Family Biotic Index or FBI) and percent EPT (percent of families comprised of Ephemeroptera, Plecoptera, and Trichoptera) were used to classify the historic and existing macroinvertebrate and

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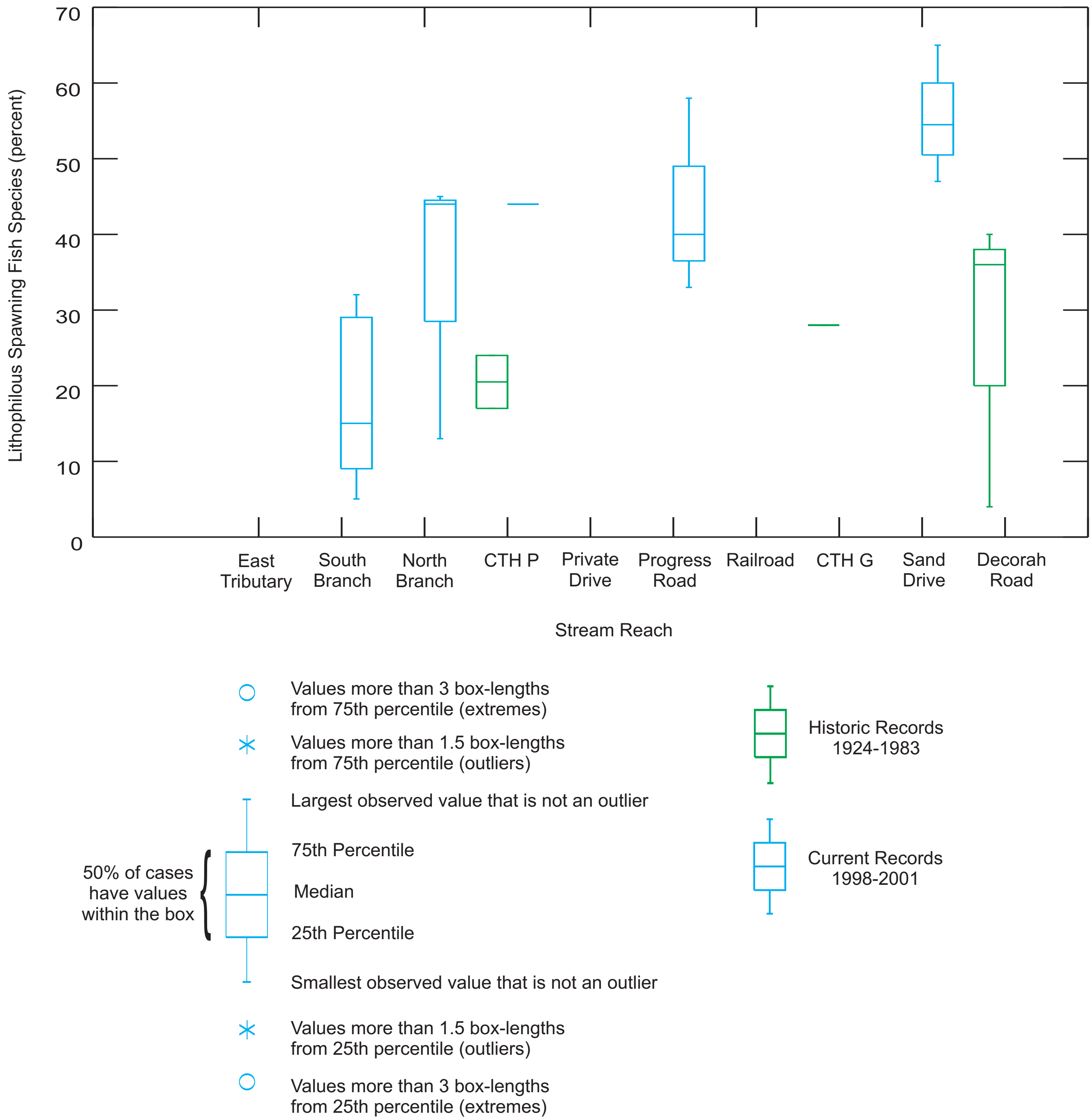
[27]*John Lyons,* General Technical Report NC-149, op. cit.

[28]*William L. Hilsenhoff, "Rapid Field Assessment of Organic Pollution with Family-Level Biotic Index," University of Wisconsin, Madison, 1988.*

Figure 14

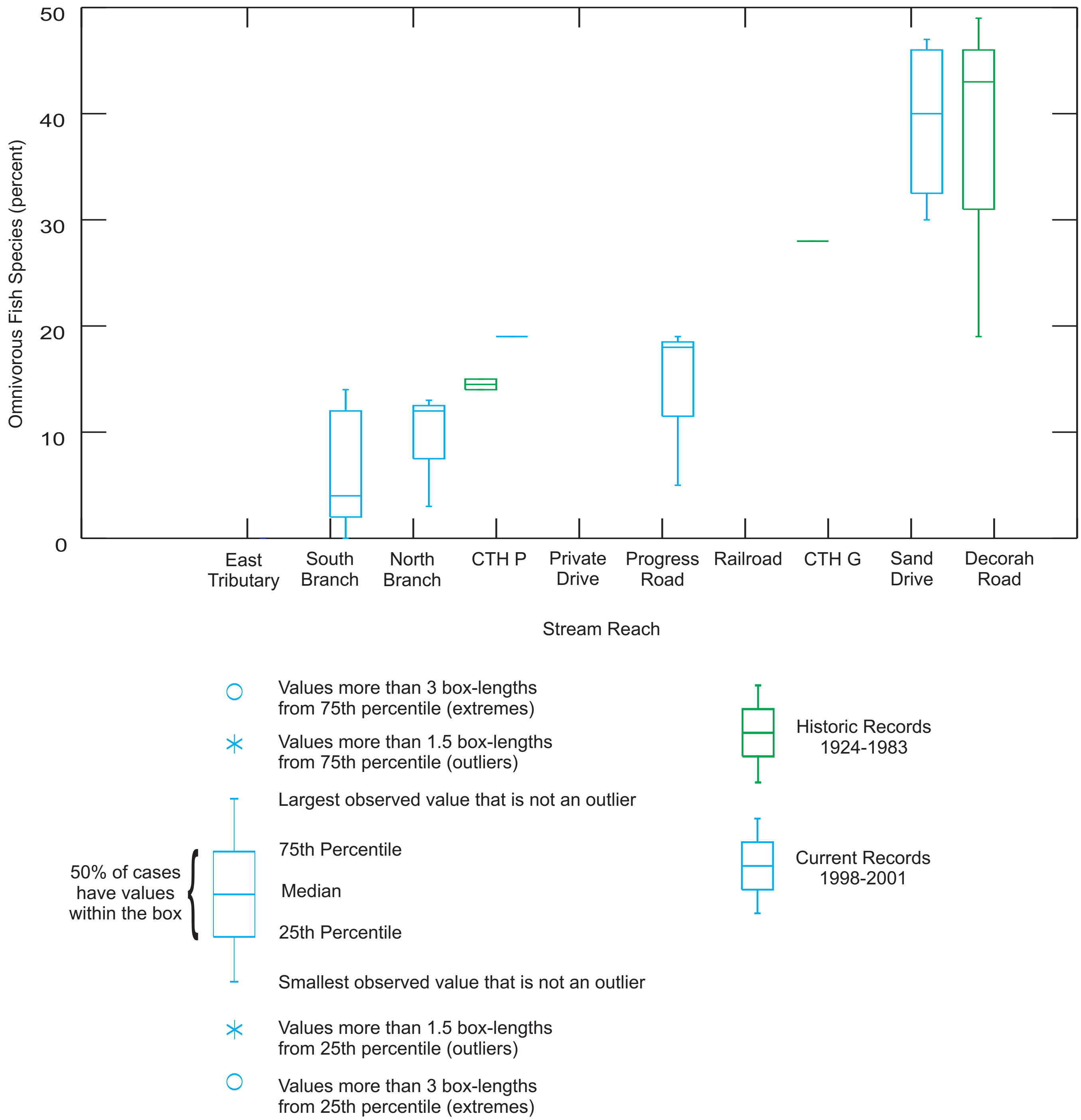
HISTORIC AND CURRENT PERCENT OF SIMPLE LITHOPHILOUS SPAWNING FISH SPECIES AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 15

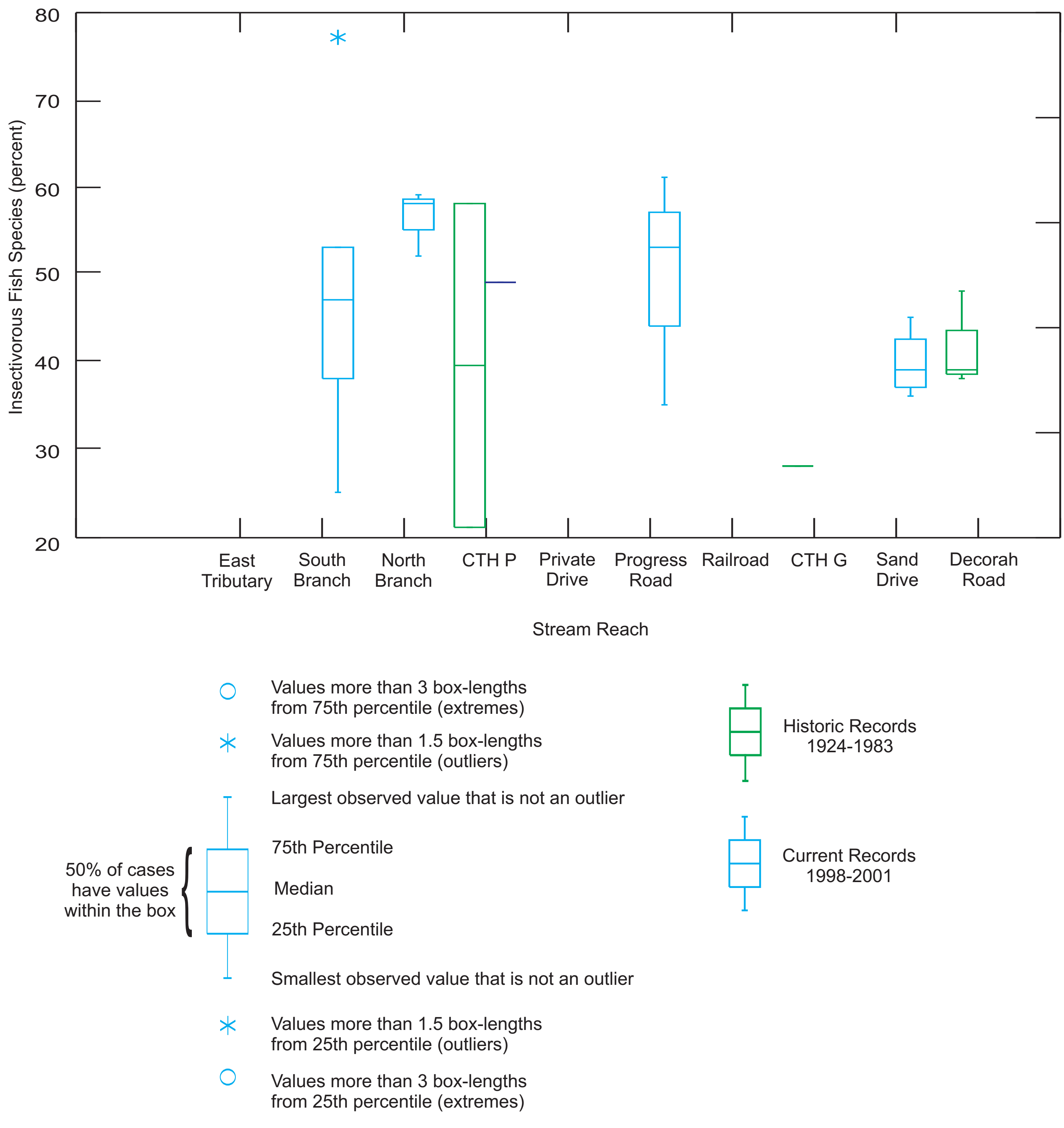
HISTORIC AND CURRENT PERCENT OF OMNIVOROUS FISH SPECIES AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 16

HISTORIC AND CURRENT PERCENT OF INSECTIVOROUS FISH SPECIES AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 1924-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

environmental quality in this stream system using survey data from various sampling locations of the Quaas Creek watershed.

Macroinvertebrate surveys conducted from 1985 through 2001 by the Wisconsin Department of Natural Resources and Dr. Timothy Ehlinger from the University of Wisconsin-Milwaukee show that FBI scores generally range from fairly poor to excellent throughout the Quaas Creek watershed, except for one severely impaired site on the South Branch (Figure 17). Figure 17 also shows that FBI scores are variable from year to year both within and among reaches, with the best scores for year 1985, 1986, and 2001 ranging from good to excellent. These same years with the best FBI scores are also associated with the highest percent EPT as shown in Figure 18. Conversely, the very poor classification for the South Branch in 2000 was also associated with the lowest percent EPT throughout the watershed, which is also consistent with fisheries warmwater IBI results (see fisheries section above). Notwithstanding, results generally indicate that historic and current macroinvertebrate diversity and abundances are indicative of good to excellent water quality throughout the Quaas Creek watershed, with the exception of the South Branch.

SUMMARY

The Quaas Creek watershed contains four major subwatersheds designated as the East Tributary, South Branch, North Branch, and Main Stem. Quaas Creek has been determined to be capable of meeting the warmwater sport fish and full recreation water use objectives, and has been designated as a Class II within the Washington County Lake and Stream Classification System. Between 2000 and 2020, urban land uses in the watershed are expected to more than double with concomitant impacts on the stream system in terms of hydrology, water quality, habitat, and fisheries.

Hydrology

Ten unique stream reaches were defined within the Quaas Creek watershed, as shown on Map 4, that reflect specific hydrological characteristics of the system. These reaches were based upon the following characteristics as outlined in Table 6: slope, sinuosity, width, depth, entrenchment ratio, and dominant channel material. These characteristics integrated within the Rosgen Stream Classification System indicated a Rosgen Type “C” and “E” stream system between its confluence with the Milwaukee River and its headwaters. Based upon these classifications, the Rosgen methodology would suggest that Quaas Creek is very sensitive to disturbances within the drainage area, with a fair to good recovery potential. These classifications also suggest that the potential for streambank erosion within this system is moderate to very high, with streambank vegetation having a very high controlling influence on moderating this erosion potential. This was confirmed by the field survey which indicated that there were more than 130 sites totaling about 1.5 miles of streambank where active erosion was found as shown on Maps 5 and 6. The average length of these actively eroding sites was about 65 feet and ranged from 20 to 550 feet.

Water Quality

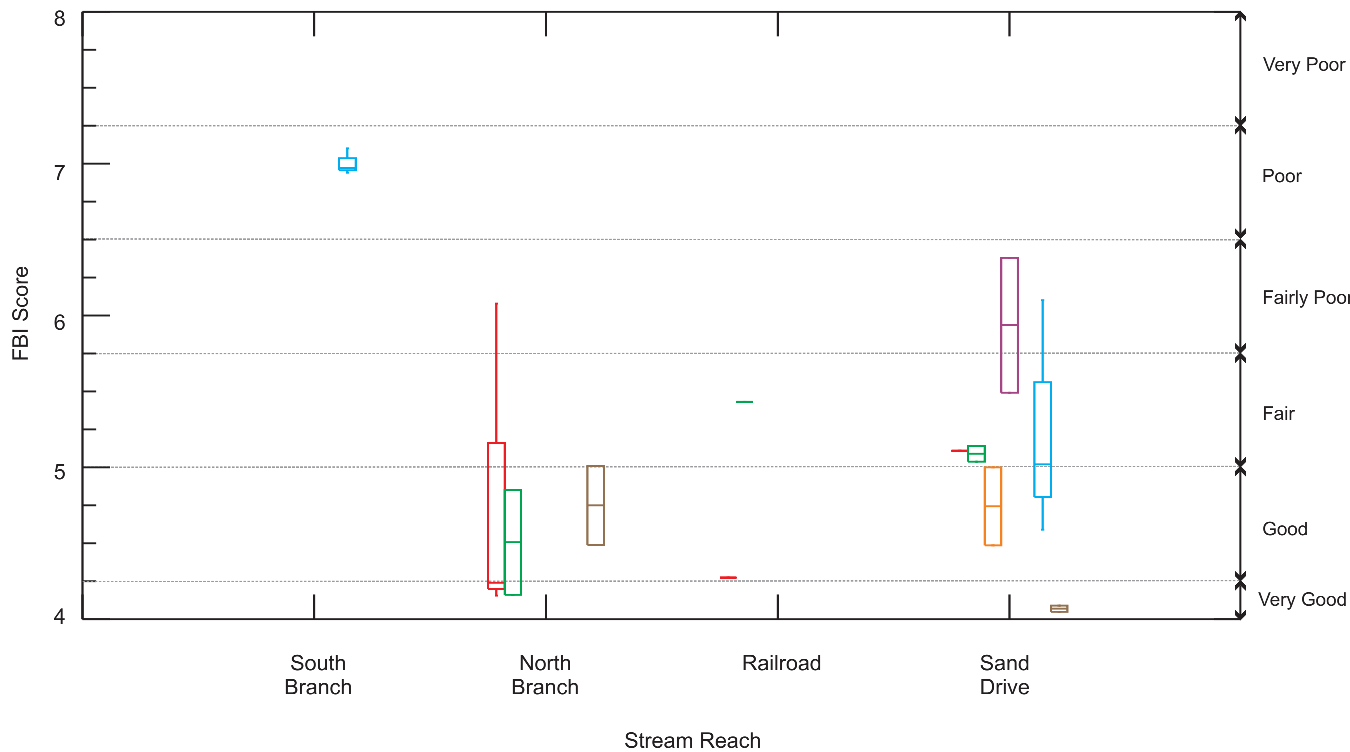
Quaas Creek is a perennial stream with a water quality varying from poor to excellent, depending upon the indicators considered. From 1983 to 2001, the Wisconsin Department of Natural Resources and University of Wisconsin-Milwaukee collected various instantaneous dissolved oxygen and temperature measurements, among others, for specific areas within Quaas Creek that were consistent with full fish and aquatic life standards supporting a warmwater sportfish community. These data also suggested a thermal regime that would not support a coldwater sportfish community.

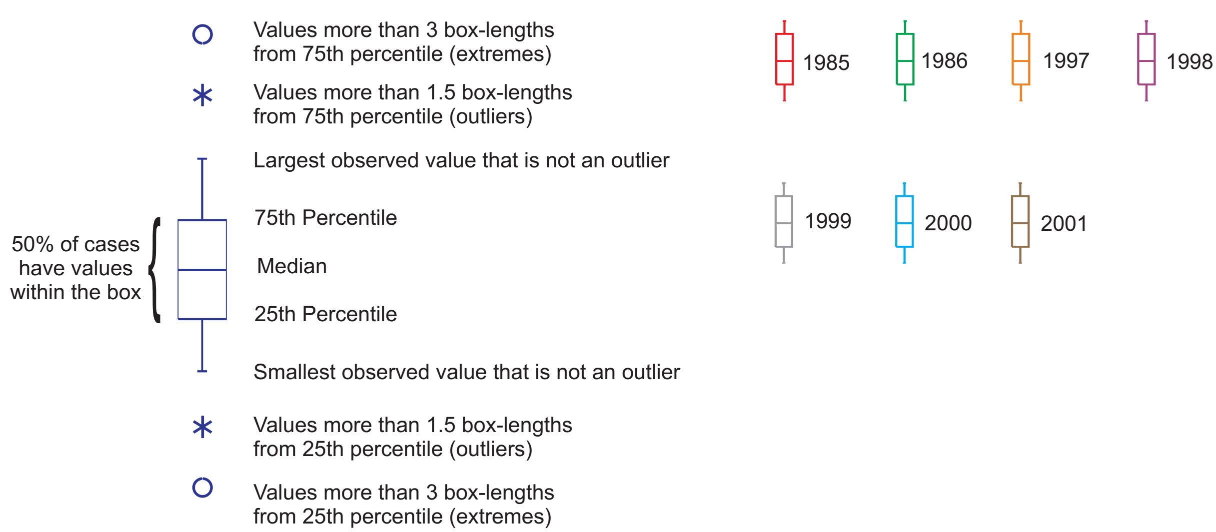
Habitat

The amount, quality, and diversity of available instream fisheries and macroinvertebrate habitat are generally very good within the Quaas Creek watershed. The Quaas Creek watershed also generally contained a high amount of in-stream cover for fish and macroinvertebrates in terms of undercut banks, woody debris, as well as large boulders. The presence and diversity of woody debris within the system is excellent, however, woody debris has been observed to accumulate excessively causing debris jams. These debris jams function much like a beaver

Figure 17

FAMILY-LEVEL BIOTIC INDEX (FBI) FOR MACROINVERTEBRATES AMONG REACHES AND YEAR WITHIN THE QUAAS CREEK WATERSHED: 1985-2001

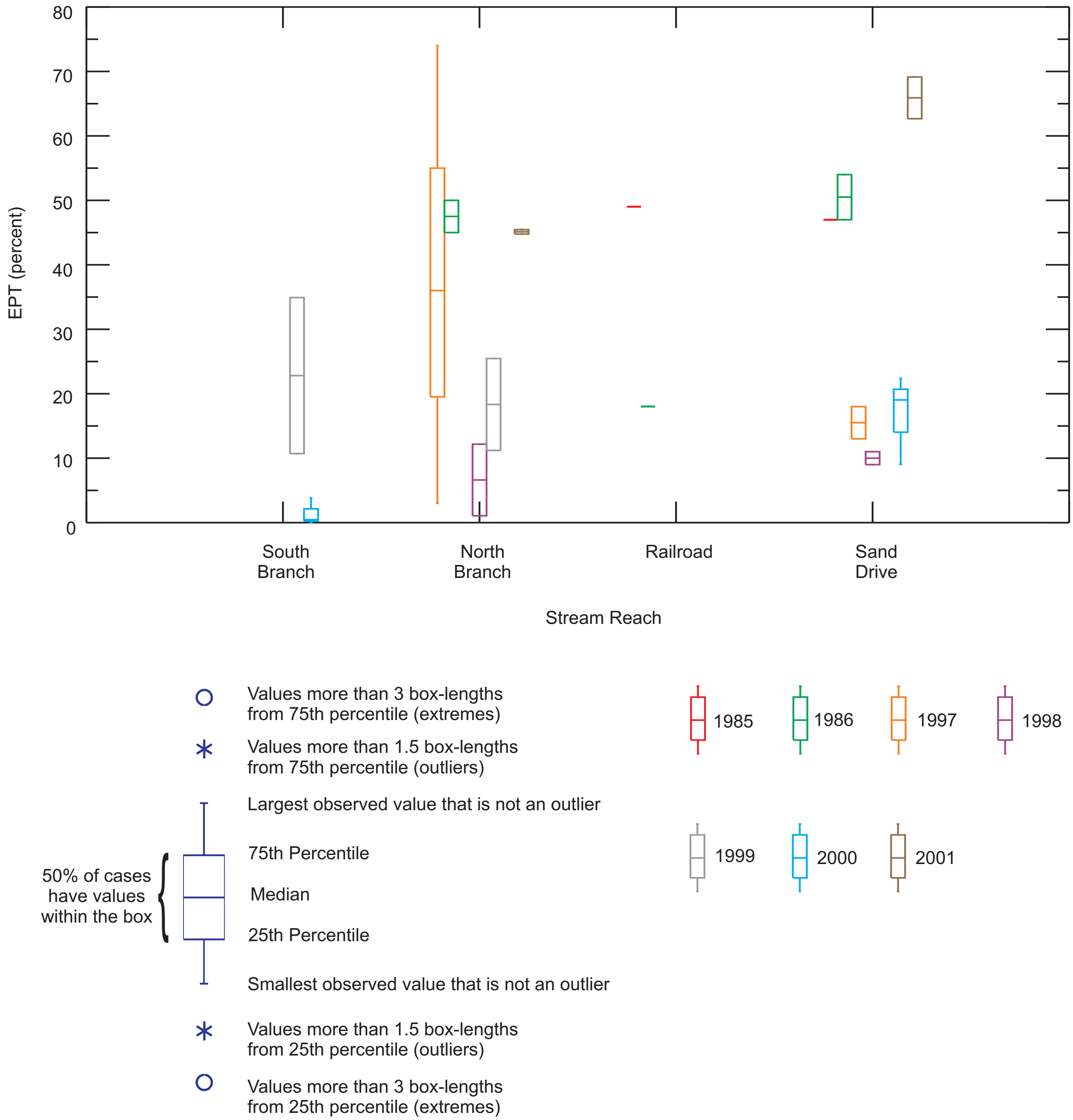




Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

Figure 18

PERCENT EPHEMEROPTERA, TRICHOPTERA, AND EPHEMEROPTERA (EPT) MACROINVERTEBRATE GENERA AMONG REACHES AND YEAR WITHIN THE QUAAS CREEK WATERSHED: 1985-2001



Source: Wisconsin Department of Natural Resources, University of Wisconsin-Milwaukee, and SEWRPC.

dam, which can cause a significant disruption in sediment dynamics, cause localized flooding, and localized bank stability problems. Debris jams as well as culverts within the stream system may inhibit movement of fishes to feeding and spawning areas.

Fisheries

Review of the fishery data collected in the Quaas Creek watershed between 1924 and 2001 indicates an apparent loss of 13 species since the mid-1980s. Most notable were losses of intolerant species such as the brook trout, blackchin shiner, smallmouth bass, and the Iowa darter. Notwithstanding, IBI results indicate an overall improvement in the quality of the fishery of the Quaas Creek watershed compared to the historic conditions. FBI results generally support this improvement in that historic and current macroinvertebrate diversity and abundances are indicative of good to excellent water quality throughout the majority of the Quaas Creek watershed. Based upon these results, the Quaas Creek watershed seems to have maintained a healthy and diverse fishery, which is a manifestation of the relatively good water quality conditions that have generally existed.

In conclusion, the hydrological, water quality, physical habitat, and biological characteristics were indicative of potentially supporting a high-quality warmwater sportfish community throughout the Quaas Creek watershed.

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Chapter III

SUMMARY OF ISSUES, FINDINGS, AND CONCLUSIONS

INTRODUCTION

Quaas Creek is in relatively good condition and is capable of supporting a warmwater sportfish community and full recreational uses. However, there are a number of issues that should be addressed to ensure the continued maintenance and future protection of this high-quality fishery resource. These issues of concern are related to the predicted developmental changes in land use and the associated potential effects on hydrology, water quality, habitat quality, bank stability, and fisheries. In addition, the potential of the stream system to fully support a coldwater fishery, even with the implementation of practical management measures, is an issue to be considered.

HYDROLOGY

Ten stream reaches were defined within the Quaas Creek stream system, as shown on Map 4 in Chapter II. These reaches reflect specific hydrological characteristics of the system, as well as defining discrete habitat areas. Each of these reaches can be characterized by a series of pools, riffles, and runs, increasing in depth and width with distance from the headwaters of the Creek to its confluence with the Milwaukee River. Concerns relative to the hydrological regime of the Creek reflect the increasing density of impervious surface related to urban development in the watershed. Urban development increases the area of rooftops, roadways, and other surfaces relative to the amount of open space wherein infiltration of a portion of the precipitation into the surficial groundwater system occurs. This increasing urbanization, therefore, has two potential impacts on the hydrology of Quaas Creek:

1. Surface water volumes increase due to the greater area of impervious surface increasing the proportion of the precipitation that runs off the land surface instead of infiltrating—the greater volumes of surface run off, in turn, create higher flows that are generally more likely to peak sooner and diminish more rapidly than flows occurring under current conditions, and to the increased erosivity of the flows that occur, and

2. Reduced infiltration that limits the volume of groundwater recharge that occurs within the watershed—although groundwater recharge occurs over a significantly greater area of land surface than is directly affected by surface runoff, localized reductions in infiltration can reduce the amount of groundwater inflow to the stream during periods of reduced rainfall, effectively reducing baseflow conditions and potentially negatively affecting the temperature regime in the stream.

Of these concerns, the former has a more direct impact on the stability and water quality of the stream. Surface runoff is more likely to transfer nonpoint source contaminants to the stream system, and nonpoint source contaminants are more likely to be available for transport to the stream system as a result of increased urban development. Deposition of nutrients from gasoline powered motor vehicle exhausts, urban residential lawn care practices, and other urban activities, among other forms of contaminants, are more readily washed off impervious surfaces. Likewise, the higher volumes of flow generally relate to higher flow velocities that can further destabilize eroding streambanks, contribute to undercutting of streambanks, and impair fisheries habitat in the system.

The hydrological concerns for the City of West Bend and environs are addressed in the adopted stormwater management plan.[1] The major water quality management recommendations of that plan include the following actions to be implemented in the Quaas Creek watershed:

- Provision of 11 detention-infiltration basins that would control runoff from about 650 acres of the planned urban area,
- The infiltration of runoff from parking lots serving commercial facilities with a total area of about 28 acres,
- The provision of low-cost measures to promote infiltration of precipitation in areas of planned medium-density residential development, and
- The preservation of the riparian buffer for natural infiltration and storage of runoff within the primary environmental corridor.

With regard to the third component of the stormwater management plan noted above, the groundwater-surface water relationship in the Quaas Creek watershed is of particular importance. Accordingly, the application of innovative source control stormwater management measures would be an important component of the watershed protection plan. Such measures, often called "low impact development" stormwater measures, are intended to maintain and restore the natural hydrology of the watershed. These measures include:

- Conserving existing natural areas.
- Minimizing development impacts:
  - Cluster buildings,
  - Reduce roadway widths and other impervious surfaces,
  - Limit lot disturbance, and
  - Preserve recharge areas.
- Maintain natural runoff rates:
  - Use open drainage,
  - Maintain natural flow paths, and
  - Incorporate integrated stormwater management practices, such as bio-retention (rain gardens), infiltration systems, and related landscaping measures.

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[1]*See SEWRPC Community Assistance Planning Report No. 173,* A Stormwater Management Plan for the City of West Bend, Washington County, Wisconsin, *Volume Four*, Alternatives and Recommended Plan for the Quaas Creek Subwatershed, *July 1996.*

Such measures could be applied in new developing areas and could be considered for retrofitting in existing developed areas, where practical. If the watershed plan is to attempt to restore portions of Quaas Creek to a coldwater fishery, the data set forth herein indicate that there will be a need to establish a high level of the types of stormwater management noted above in both new and existing development. To a somewhat lesser extent, this is also true for maintaining the Quaas Creek system as a high-quality warmwater fishery stream.

WATER QUALITY

Nonpoint Source Pollution

Runoff and erosion from agricultural and urban land uses has been an important issue both historically and currently within the Quaas Creek watershed.[2] The City stormwater management plan included recommendations designed to meet the nonpoint source pollution control levels identified as needed for the Quaas Creek watershed in the regional water quality management plan and the Wisconsin Department of Natural Resources nonpoint source priority watershed plan. Those recommendations included those noted above under the section on hydrology coupled with treatment of selected lands by sweeping of industrial and commercial parking and storage areas and adjacent streets and the continued enforcement of the applicable construction erosion control ordinances. Most importantly, there will be a need to implement stormwater source controls designed to infiltrate stormwater and maintain the natural hydrology as noted in the previous section. Maintenance of the historic and existing diverse warmwater fish and aquatic life community and recreational use potential of Quaas Creek is likely to be dependent upon the development and implementation of these measures throughout the watershed. Furthermore, to establish a coldwater fishery in portions of the stream system will require a very high level of implementation of such practices in both newly developed and possible existing developed areas, depending upon the stream reaches being considered.

The Washington County land and water resources management plan[3] includes recommendations for nonpoint source pollution control in the Quaas Creek watershed. That plan notes that improved agricultural best management practices and land use regulations related to general zoning, floodplain zoning, shoreland or shoreland wetland zoning, subdivision control, as well as construction site erosion control, among the relevant municipalities have contributed to the maintenance of relatively good water quality throughout the Quaas Creek watershed. As an example, many of the potential erosion and runoff problems, typically associated with such a large construction project as the industrial park near Progress Road in the late 1980s and early 1990s, have been reduced through implementation of construction site erosion control and stormwater management practices.[4] Implementation of nonpoint source pollution abatement practices and stormwater management measures constitute basic fishery enhancement measures at the larger watershed scale and are a necessary precursor to the implementation of more localized or site-specific management measures that were the focus of this report and outlined below. Hence, the larger-scale management measures to address the nonpoint source pollution abatement have been and continue to be important issues for the Quaas Creek watershed to be developed as part of the broader Quaas Creek watershed protection plan by the Washington County Land Conservation Department under the guidance of the Quaas Creek Watershed Protection Committee. Notwithstanding, instream water quality does affect the fishery and fishery habitat. Two issues of concern identified during this planning project were temperature and sedimentation, which are discussed in further detail below.

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[2]*Wisconsin Department of Natural Resources, Publication No. PUBL-WR-255-90,* A Non-point Source Control Plan for East and West Branches of the Milwaukee River Priority Watershed Project*, March 1992.*

[3]*Washington County,* Washington County Land and Water Resources Management Plan: 2000-2005*, August 2000.*

[4]*Wisconsin Department of Natural Resources, Water Resource Appraisal Report and Stream Classification for the Quas Creek Subwatershed, File No. Quascr.rev, Milwaukee River East-West Watershed, Milwaukee River Basin, December 1991.*

Temperature
Current summer water temperatures within the North Branch and South Branch are a substantial limitation to the potential of Quaas Creek to support a coldwater trout fishery. Based on the historic available data, the entire North and South Branches to CTH G were previously found to be potentially capable of supporting a coldwater trout fishery by the Wisconsin Department of Natural Resources in 1991.[5] However, recent intensive fishery surveys from 1998 through 2001 indicate that no trout were found in either the North or South Branches or anywhere else in the watershed. This result may be due to both historic and recent changes to the upper reaches of the Quaas Creek watershed. Historic filling and dredging of the headwater wetlands and springs within the North and South Branches of Quaas Creek may have had significantly impacted ambient stream flows and water temperatures in these areas.[6] It should also be noted that more than a mile of the upper most portions of the North Branch were channelized for agricultural purposes. More recently in the North Branch, Dr. Timothy Ehlinger from the University of Wisconsin-Milwaukee has demonstrated a relationship between increased water temperatures and recent construction of wet detention stormwater basins, as well as increased impervious surface within an area that historically discharged via groundwater to Quaas Creek. However, the South Branch, which contains extensive wetland buffers adjacent to the channel, compared to the North Branch, also demonstrated that summer water temperatures could reach stressful and potentially lethal levels to trout prior to the confluence with the North Branch of Quaas Creek. These water temperatures within the upper portions of the watershed influence and determine to a large extent the temperatures within the downstream reaches of the watershed. In addition, the impervious area throughout the entire watershed is projected to increase with increased urban development in terms of roof tops, streets, and parking lots. Ultimately, this trend of increased water temperatures coupled with increased impervious surface area have the potential to ultimately limit the potential of Quaas Creek to support a warmwater sport fishery. Thus, management of surface water temperature through implementation of other stormwater technologies, such as the development practices and stormwater source controls designed to maintain and restore the natural hydrology discussed above, as well as increased riparian buffers, remains an important issue to be considered throughout the entire watershed of Quaas Creek, especially in the upstream reaches if the warmwater sport fishery is to be maintained. Any efforts to restore portions of the stream system to support a coldwater fishery would need to be particularly cognizant of this temperature consideration.

Sedimentation
The effects of erosion from upland areas due to runoff from construction projects on the habitat of Quaas Creek has been identified as a major limiting factor by the Wisconsin Department of Natural Resources.[7] Likewise, concerns over sedimentation have been identified in the nonpoint source plan and County land and water resource management plan. Sedimentation is a major cause of the decreased quality of fisheries throughout the United States.[8] It can threaten the survival of fish by covering essential feeding areas, essential spawning grounds, and eggs, and preventing emergence of recently hatched fish. Sedimentation associated with the construction of USH 45 from the mid to late 1980s has primarily impacted the upper one-half of the Quaas Creek watershed. More recently, significant sedimentation was documented by the Wisconsin Department of Natural Resources to have occurred during commercial land use development construction within the upper areas of the North Branch of Quaas Creek during 1998. Sedimentation primarily of sand-sized particles from these aforementioned incidences has filled productive riffle, run, and pool habitats in the upper reaches of the watershed. Sand transported to the Creek continues to be one of the most dominant substrates throughout the entire Quaas Creek

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[5]Ibid.

[6]Ibid.

[7]Ibid.

[8]*U.S. Department of Agriculture Forest Service,* Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*, Roxanne S. Palone and Albert H. Todd, editors, Radnor, Pennsylvania, 1997.*

system as shown in Tables 6 and 7 in Chapter II. Sedimentation of sand and silt continues to be a major limiting factor of fisheries habitat in the upper North Branch, South Branch, and CTH P reaches, as well as in the lower CTH G and Sand Drive reaches of Quaas Creek as shown in Table 10. It should be noted that this excessive sedimentation is primarily within the channelized portions of these reaches.

HABITAT QUALITY

Channelization

The Wisconsin Department of Natural Resources identified channelization as one of the important limiting factors of fisheries habitat within the Quaas Creek watershed.[9] Approximately three miles of Quaas Creek were documented to have been channelized in order to primarily accommodate agricultural drainage. The majority of channelization throughout the watershed for agricultural drainage purposes occurred prior to 1963. To a lesser extent, the construction of a sewerage system in the lower reaches of the watershed, and the construction of USH 45 in the upper reaches of the watershed, have resulted in additional disturbances to the stream channel and adjacent wetland areas. Significant, but fairly localized, channel realignment, widening, and riparian vegetation removal from the mid- to late-1960s, and in the 1980s, respectively, was documented by the Wisconsin Department of Natural Resources as a result of these activities. The more recent development of the industrial park near the Progress Road culvert crossing has not resulted in any apparent channel disturbance.

The detrimental effects of this channelization appear to be extensive and long lasting, based on recent observations by SEWRPC and County Land Conservation Department staffs during the bank stability survey. More than 40 years after channelization, the areas channelized for agricultural purposes were generally associated with the following characteristics, compared to nonchannelized areas within the Quaas Creek watershed: reduced stream velocities during low-flow periods; increased siltation and inundation of sand substrates; reduced amounts of productive riffle areas and coarse substrate; reduced amounts of habitat cover attributed to undercut banks and pools; and, increased bank erosion and scour in specific areas. In contrast, however, Quaas Creek seems to have largely recovered from the more localized instream and riparian corridor disturbances associated with construction projects in the watershed. Notwithstanding, one sewer crossing near River Mile 0.2 was observed during the 2001 field survey to be partially exposed and appears to be affecting flow within the stream channel. This may be contributing to accelerated, but localized, bank erosion.

As shown in Table 10, channelization is primarily limiting habitat quality within the East Tributary, South Branch, and North Branch reaches, as well as in the CTH G reach on the main channel of Quaas Creek, when compared to the rest of the watershed. Channelization is moderately limiting in the Progress Road, Wisconsin Central Railroad, and Sand Drive reaches of this watershed. Channelization impacts are lowest, or least limiting, within the CTH P, Private Drive, and Decorah Road reaches of the watershed.

Streambank Stability

Streambank stability is currently an important issue of concern throughout the Quaas Creek watershed, even though bank scour and failure historically was not considered to be greatly limiting to the potential recreational use of Quaas Creek.[10] Results of the streambank stability survey conducted during fall 2001 indicated that there were more than 1.5 miles, or about 130 sites, where active streambank erosion was found within the 7.69 miles of stream surveyed. About 20 percent of the streambanks could be considered as failing within the study area. Maps 5 and 6 in Chapter II indicate that the location and extent of erosion differed among and within reaches within the Quaas Creek watershed. The relative differences in bank stability among reaches were based upon field observations of a number of actively eroding sites, the linear extent of erosion, the undercut depth, and the bank slope at the site where erosion was observed. Rates of streambank erosion, were estimated for purposes of this

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[9]*Wisconsin Department of Natural Resources, File No. Quascr.rev,* op. cit.

[10]Ibid.

Table 10

COMPARISON OF POTENTIAL HABITAT LIMITATIONS TO FISHERIES HABITAT AMONG REACHES WITHIN THE QUAAS CREEK WATERSHED: 2002

River Reach	Potential Habitat Limitations[a]			
	Sedimentation[a]	Channelization[b]	Bank Stability[c]	Obstructions[d]
East Tributary	Low	High	Low	Low
South Branch	High	High	Low	Moderate
North Branch	High	High	Moderate	Low
CTH P	Moderate	Low	Moderate	High
Private Drive	Low	Low	High	Low
Progress Road	Low	Moderate	Moderate	Low
Wisconsin Central Railroad	Low	Moderate	Low	Low
CTH G	High	High	High	High
Sand Drive	High	Moderate	High	Moderate
Decorah Road	Low	Low	High	Low

[a]*Low, moderate, and high category limitations to habitat due to sedimentation were defined as follows:*

High = Total accumulated sediment depth greater than 20 feet and average sediment depth greater than 0.5 foot
Moderate = Total accumulated sediment depth greater than ten and less than 20 feet and average sediment depth greater than 0.5 foot
Low = Total accumulated sediment depth less than three feet and average sediment depth less than 0.5 foot

[b]*Low, moderate, and high category limitations to habitat due to channelization were defined as follows:*

High = more than 0.5 mile of channelization
Moderate = between 0.2 and 0.5 mile of channelization
Low = less than 0.2 mile of channelization

[c]*Low, moderate, and high category limitations to habitat due to bank stability were defined as follows:*

High = greater than 20 actively eroding sites
Moderate = between five and 20 actively eroding sites
Low = less than five actively eroding sites

[d]*Low, moderate, and high category limitations to habitat due to obstructions were defined as follows:*

High = more than 10 woody debris jams
Moderate = between five and 10 woody debris jams
Low = less than five woody debris jams

Source: SEWRPC.

study from field observations and comparison of the Commission's one-inch equals 400-feet scale aerial photographs over an approximately 40-year period. The bank stability analyses generally indicated that downstream reaches were much more unstable compared to the rest of watershed. This instability also seems to be associated with a shift in channel morphology, or stream type, from an "E" to "C" based upon the Rosgen system of stream classification.[11] More specifically, due to this streambank instability, these downstream reaches were significantly wider and apparently subjected to an increase in bank erosion rate compared to the rest of the watershed. Table 10 presents the predicted level or state of stability among reaches throughout the Quaas Creek watershed, and indicates that these downstream reaches, extending over a linear distance of nearly 2.5 miles, contain over 80 actively eroding sites. Given the potential impact and ecological significance of bank failures and

[11]*D.L. Rosgen, "A Classification of Natural Rivers,"* Catena*, Vol. 22, 1994, pp. 169-199.*

instream erosion, quantification of the rates of streambank erosion is an important consideration. Such quantification is consistent with Level IV of the Rosgen system of stream classification. Identifying the causes of streambank erosion within the Quaas Creek watershed is equally as important an issue as identifying the consequences of actively eroding sites as described above.

The results of the bank stability analyses further indicated that the loss of bank stability was most limiting to fish habitat within the CTH G, Sand Drive, and Decorah Road reaches in the downstream area of watershed, as well as in the Private Drive reach in the middle of the watershed as shown in Table 10. The North Branch, CTH P, and Progress Road reaches demonstrated moderate levels of bank stability compared to the rest of the watershed, whereas, the East Branch, South Branch, and Wisconsin Central Railroad reaches appeared to contain fairly stable streambanks compared to the rest of the watershed.

Obstructions

Woody debris jam obstructions are an important consideration within the Quaas Creek watershed. The presence and diversity of woody debris within the Quaas Creek watershed is excellent and offers good-quality habitat for fish and macroinvertebrates. However, woody debris has been observed to accumulate excessively creating large physical obstructions that create streambank instability and reduces habitat quality in localized areas. The debris jams function much like a beaver dam, which can cause a significant disruption in sediment dynamics, cause localized flooding, and localized bank stability problems, and may inhibit movement of fishes to feeding and spawning areas. The CTH P and CTH G reaches contain two to 15 times more woody debris jams than the rest of the watershed, which indicates a potential problem in these areas compared to the rest of the watershed.

In addition to woody debris jams, culverts and bridges created hydrological obstructions within Quaas Creek that resulted in reduced water depths and increased velocities. In addition, excessive woody debris accumulations at the inlets of several culverts were also observed. Because of the relatively high number of culverts within the Quaas Creek watershed, their combined impact on stream fish communities is in the form of selective barriers to fish.[12] These observations indicate a potential problem at several culvert crossings throughout the Quaas Creek watershed as set forth in Table 8 (Chapter II) and locations are shown on Maps 5 and 6 (Chapter II). In cases where both hydrological and physical impacts are moderate to high such as structure numbers 2, 5, 6, 10, 11, and 12, these culvert related impacts may be adversely affecting the short-term and long-term maintenance of a healthy sustainable fisheries community in this river system.

FISHERIES

Warmwater Versus Coldwater Fishery[13]

The issue of whether or not Quaas Creek and its tributaries should be managed as a warmwater sport or a coldwater trout fishery is an important consideration when planning for the future of this system. Overall habitat

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[12] *Stream Enhancement Research Committee, "Stream Enhancement Guide," Province of British of Columbia and the British Columbia Ministry of Environment. Vancouver, 1980.*

[13] *Recently, the concept of cool water fisheries has been proposed by John Lyons, Lizhu Wang and Timothy D. Simonson in their paper, "Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin," which appeared in the* North American Journal of Fisheries Management*, Volume 16, No. 2, pages 241-256, May 1996. This concept is intended to distinguish cool water habitats that include waters having a maximum daily mean water temperature of between 22 and 24°C; waters with temperatures in excess of 24°C have been identified as warm water habitat, while waters having a maximum daily mean water temperature of less than 22°C have been identified as cold water habitat. Currently, however, coolwater fisheries are not recognized for regulatory purposes pursuant to Chapters NR 102 and NR 104 of the* Wisconsin Administrative Code. *Lyons and his co-authors also note that, "at present, no IBI* [Index of Biotic Integrity] *version exists for Wisconsin coolwater streams, which are common in many parts of Wisconsin…."*

and water quality conditions which currently exist in Quaas Creek are capable of sustaining a diverse and abundant warmwater sportfish community. Nonetheless, the entire North and South Branches to CTH G were previously indicated to be capable of supporting a coldwater trout fishery by the Wisconsin Department of Natural Resources as recently as 1991.[14] However, recent fisheries surveys from 1998 through 2001 indicate that both the North and South Branches do not currently support trout, although the Wisconsin Department of Natural Resources historically reported at least one record in 1984 of brook trout being present in this system. This apparent loss of brook trout within this system is most likely due to an increase in water temperatures and to a lesser extent habitat availability and quality. Therefore, there are two important questions related to the water use objectives of Quaas Creek:

1. Should the upper portions of the watershed be managed to support a coldwater trout fishery or warmwater sport fishery (which it currently supports)?

2. If the upper portions of the Quaas Creek watershed are managed as a coldwater trout fishery, can management measures be implemented to mitigate the effects of temperatures to allow Quaas Creek to be capable of supporting a coldwater trout fishery?

Although many aspects of warmwater versus coldwater fisheries management are not necessarily mutually exclusive in terms of bank stability, habitat quality, riparian cover, the effort in time and monies spent in developing and enforcing technologies designed to maintain the thermal conditions necessary for a coldwater sport fishery could be significant. Current water quality, physical habitat, and biological characteristics were indicative to potentially support a high-quality warmwater sportfish community throughout the Quaas Creek watershed. As previously noted, this issue relates to the type and level of development and stormwater management measures which would have to be implemented within the watershed. In any case, it will be important to institute land development and stormwater management measures, including source controls, to maintain and restore the natural hydrology in both developed and developing areas.

Warmwater Sport Fishery

The warmwater sport fishery is somewhat limited throughout the entire Quaas Creek watershed. Notwithstanding, the white sucker has been, and continues to be, the dominant sportfish species with adequate numbers and sizes to be considered fishable in Quaas Creek. Northern pike from the Milwaukee River may use the lower reaches of the stream for spawning purposes and, thus, provide a spring sport fishery, but this has not been recently verified. According to one local resident, northern pike were historically observed to be spawning in the lower portion of the East Tributary just downstream of Paradise Road to the confluence with the main channel, but have not been seen spawning recently. According to another local resident, northern pike were commonly caught within the South Branch of the Quaas Creek watershed approximately 20 years ago, but have not been seen recently. The Quaas Creek system has historically and currently been limited by the lack of numbers of large carnivorous sportfish, such as northern pike, largemouth bass, or bullhead species, which may indicate it contains a high potential for the enhancement of one or more of these species.

Exotic Species

Exotic, invasive species, such as common carp, have not been observed within the Quaas Creek system since 1983, but are considered a threat to the Quaas Creek system due to their presence within the Milwaukee River. The downstream reaches, including Decorah Road, Sand Drive, and CTH G, contain the highest potential risk for invasion by carp due to their proximity to the Milwaukee River and their greater depths compared to the rest of the watershed. The middle reaches from the Wisconsin Central Railroad through CTH P has a moderate level of potential risk of invasion by carp. The shallowest upstream East Tributary, North Branch, and South Branch reaches have the lowest potential for establishment of carp species compared to the rest of the watershed given the less favorable habitat conditions.

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[14]*Wisconsin Department of Natural Resources, File No. Quascr.rev,* op. cit.

POTENTIAL STREAM CHANNEL MANAGEMENT MEASURES

Measures adjacent to, and within, the stream channel could potentially be taken in Quaas Creek watershed in order to maintain the high quality of this resource. These measures would also prevent the decline of the fishery in the watershed and, to the extent practicable, be able to enhance the sport fishery. These measures outlined below complement the adopted land use, park and open space plans, and the stormwater management measures previously noted. The measures include potential habitat rehabilitation measures for reaches within the Quaas Creek watershed, which are discussed below and outlined in Table 11.

The measures that would be required to maintain and potentially enhance the fishery in the Quaas Creek watershed as a warmwater sport fishery include implementation of measures to address the principal issues of concern identified above and Table 10. A number of factors were considered in identifying and prioritizing stream reaches for the maintenance and enhancement of the fishery in the Quaas Creek basin. These factors include environmental considerations such as fisheries assessments and macroinvertebrate assessments, as well as physical habitat and water quality considerations. Specifically, these measures would seek to address recommendations by the Wisconsin Department of Natural Resources for habitat improvement of warmwater stream systems.[15] These recommended actions include: 1) enhanced streambank stability, 2) limitation of instream sediment deposition, 3) implementation of mitigation techniques to moderate the effects of channelization, and 4) restoration of in-stream and riparian habitat. Inherent in these priority actions is the improvement of water quality, including water clarity, and improvement of the quality and availability of food organisms for fish species.

Table 11 provides management measures for potential habitat improvements for streambank stability and instream treatments among reaches within the Quaas Creek watershed. It should be noted that management measures could be implemented in several reaches simultaneously among this watershed, and many of the treatments could be used in combination. However, any bank stabilization treatment or instream structure must be biologically suitable, to be both hydrologically and structurally stable within the constraints imposed by the specific physical conditions at that site. Inappropriate structures can lead to undesirable consequences, such as accelerated erosion or deposition, displacement or replacement of beneficial species, and physical structure failure. Stream channels operate in a consistent and predictable manner, and the knowledge of such channel responses to artificially placed structures must be applied in the selection, design, and placement of improvement structures.

Table 11 provides a list of commonly used structural enhancement designs that can be applied to a wide range of stream types and indicates their potential application within specific reaches within the Quaas Creek watershed. The notes on the potential application and effectiveness of given structure types set forth within Table 11, are intended to provide general information to address known problems, and the potential effectiveness of specific, recommended fishery habitat measures should be further refined through detailed, site-specific-analysis prior to their selection.

ANCILLARY FISHERIES MANAGEMENT MEASURES

Development and implementation of an appropriate, ongoing monitoring and evaluation strategy to establish baseline conditions and to assess progress toward the maintenance or enhancement of the stream fishery within the Quaas Creek watershed is recommended as a component of the watershed protection plan. This strategy should include not only fisheries and fish habitat surveys, but also water quality and physical habitat assessments

[15]*Wisconsin Department of Natural Resources Technical Bulletin No. 169,* A Review of Fisheries Habitat Improvement Projects in Warmwater Streams, with Recommendations for Wisconsin*, 1990.*

Table 11

RECOMMENDED POTENTIAL CHANNEL STABILITY AND FISHERIES HABITAT MANAGEMENT MEASURES FOR STREAM REACHES WITHIN THE QUAAS CREEK WATERSHED: 2002

Management Elements	Description	Potential Application and Effectiveness[a]	River Reach									
			East Tributary	South Branch	North Branch	CTH P	Private Drive	Progress Road	Wisconsin Central Railroad	CTH G	Sand Drive	Decorah Road
Streambank Treatment[b]												
Riprap	Appropriately sized rock placed at the toe of the slope to height needed to stabilize the slope and promote sediment deposition	Utilized in areas where the streambank or shoreline is being undermined by toe scour, and where vegetation cannot be used	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tree Revetments and Brush Bundles	Single or multiple interconnected trees or bundles of tree branches attached at the toe of the streambank or shoreline to reduce flow velocities along eroding banks, trap sediment, and provide substrate for plant establishment	Within streams it is more appropriate in areas where streambank heights are less than 12 feet and bankfull velocities under six feet per second	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Log, Rootwad, Brush and Boulder Revetments	Logs, rootwads, brush, and boulders are placed in various combinations adjacent to a streambank or shoreline to stabilize the bank, increase scour, and improve habitat	Has been used to enhance fisheries habitat availability and diversity	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cribwalls	Box like interconnected logs that are anchored to the bank. Usually filled with rocks and/or with dirt and planted with live stakes or cuttings	Provides protection along streambank or shorelines in areas with near vertical banks and options to sloping the banks are limited	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]
Gabions	A rectangular wire cage or basket filled with rocks and soil attached together to form a wall of protection. Live branch cuttings or other vegetation can be placed in the soil layer of each basket to take root and bind the structure to the slope	Useful for protecting steep slopes with active scouring and undercutting occurring	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]	Limited[c]

Table 11 (continued)

Management Elements	Description	Potential Application and Effectiveness[a]	River Reach									
			East Tributary	South Branch	North Branch	CTH P	Private Drive	Progress Road	Wisconsin Central Railroad	CTH G	Sand Drive	Decorah Road
Streambank Treatment[b] (continued)												
Coconut Fiber Roll	Cylindrical structures comprised of coconut husk fibers wrapped with twine woven from coconut material, which are 100 percent biodegradable, to protect banks from erosion while trapping sediment and encouraging plant growth	Appropriate where moderate toe stabilization is required in conjunction with restoration of the streambank or shoreline, which allows for minimal disturbance of the area	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Branch Packing, Brush Mattresses	Variable combinations of live stakes, fascines, and branch cuttings, and backfill that stabilize and revegetate the bank	Forms immediate protective cover that can also be used to repair patches of scoured voids in banks. Reinforcement with some type of additional toe protection is often needed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank Shaping and Revegetation	Regrading streambanks or shorelines to a stable slope, placing topsoil and other materials needed for sustaining plant growth, and selecting, installing and establishing appropriate plant species	Most appropriate in areas where moderate erosion and channel migration are anticipated. Reinforcement with some type of additional toe protection is often needed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Live Stakes, Post Plantings	Live woody cuttings that are tamped or planted into the soil to root and grow to stabilize the soil, trap sediment, and provide shade	Appropriate where site conditions contain moderate slopes and minor bank sloughing is occurring	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Live Fascines	Live branch cuttings bound together into cylindrical bundles and place along shallow trenches on slopes to reduce longitudinal erosion	Utilized to trap and hold soil on streambank or shoreline by reducing the slope length into a parallel series of shorter slopes along the bank acting as dam-like structures	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instream Treatment[b,d]												
Boulder Clusters	Individual or groups of boulder clusters placed in random areas of the stream base flow channel to provide cover, create scour holes, and heterogeneity of flow	Can be used in a variety of riffle, run, and pool habitat types to create instream cover. Best results are found in areas with average flows exceeding two feet per second and in streams with a low bed material load	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 11 (continued)

Management Elements	Description	Potential Application and Effectiveness[a]	River Reach									
			East Tributary	South Branch	North Branch	CTH P	Private Drive	Progress Road	Wisconsin Central Railroad	CTH G	Sand Drive	Decorah Road
Instream Treatment[b,d] (continued)												
Weirs or Sills, Grade Stabilization Structure, Low Head Dam, Check Dam, K-Dams, Wedge Dam	Structure that completely spans the channel and causes a sudden drop in channel elevation of less than five feet. Built of logs, rock, gabions, concrete, or sheet metal. May be notched to concentrate flow	Appropriate in stabilizing stream gradient and reducing headcutting. Effective in changing scour and deposition patterns within the stream and creating downstream pool habitat, however, these may become migratory barriers to some fish species	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]	Limited[e]
Channel Constrictor	Log structures that are built suspended above the stream bottom at the water surface parallel to each other along opposite sides of each bank. This constriction of the flow increases velocity and scouring action that creates a narrow, deep channel with overhead cover	Appropriate in straight reaches of stream channel to increase habitat availability and diversity. Often necessary to reinforce structure with riprap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cross Channel Log/ Bank Revetment	Log and rock structure constructed to protect the outside bank of a stream meander and create pool habitat with cover	Appropriate at natural bends that lack stream cover and/or just at the downstream end of obvious breaks in stream gradient such as at the end of riffle habitats. Often necessary to reinforce structure with riprap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Revetments	See Log, Rootwad, Brush and Boulder Revetments above	See Log, Rootwad, Brush and Boulder Revetments above	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Half and Whole Log Cover	A log split lengthwise or whole log that is anchored to the substrate so that there is a narrow gap between the log and the substrate	Appropriate use to increase instream cover, but not recommended in streams with high bed load material	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wing Deflectors	A structure composed of logs, rocks, gabions, or other structures that protrude from the streambank and are used to force the current away from the bank. Can be a single wing (one side of channel only) or double wing (both sides of the channel)	Appropriate in channels with low physical habitat diversity, especially those with limited stable pool habitats	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 11 (continued)

Management Elements	Description	Potential Application and Effectiveness[a]	River Reach									
			East Tributary	South Branch	North Branch	CTH P	Private Drive	Progress Road	Wisconsin Central Railroad	CTH G	Sand Drive	Decorah Road
Instream Treatment[b,d] (continued)												
Sediment Traps	A large hole dug in the stream channel to catch fine sediment, which is periodically cleaned out	Appropriate to use in reducing instream sedimentation by changing scour and deposition patterns through removal of sediments from the system	No	No	No	No	No	No	No	No	No	No
Obstruction Removal[f]	Removal of major blockages of large accumulations of lodged trees, sediment, and other debris that span the entire stream width causing unacceptable flow problems	No stream work, including bank clearing, repositioning, or removal of material, should be allowed except at specific locations where unacceptable flow problems occur or may occur in the near future	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lunker Structures	A plank and log, free-standing, box-like structure with open sides that is installed just below the water at the toe of the bank, and is covered with riprap, soil, and vegetation to protect the bank and provide cover	Appropriate along outside bends of streams where water depths can be maintained at or above the top of the structure. Not recommended in streams with heavy bed loads	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[a]*For additional information consult the Stream Corridor Restoration: Principles, Processes, and Practices FISRWG (10/1998). By the Federal Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the U.S. government). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. http://www.usda.gov/stream_restoration/Water.*

[b]*Department of Natural Resources Technical Bulletin No. 169, "A Review of Fisheries Habitat Improvement Projects in Warmwater Streams, with Recommendations for Wisconsin," Madison, Wisconsin, 1990.*

[c]*These structures can be a cost-effective solution where some form of structural solution is needed, but tend to be more costly in terms of materials, equipment, and hours to install and replace compared to other treatments. These treatments should also, where appropriate, be used with soil bioengineering systems and vegetative plantings to stabilize the upper bank and ensure a regenerative source of streambank vegetation.*

[d]*Waushara County Land Conservation Department, "Fluvial Geomorphology Workshop," Wautoma, Wisconsin, September 13-17, 1999; C. J. Hunter, "Better Trout Habitat: A Guide to Stream Restoration and Management," Island Press, Washington D.C., 1991; Department of Natural Resources Technical Bulletin No. 179, "Evaluation of Trout Habitat Structures in Three High-Gradient Stream in Wisconsin," Madison, Wisconsin, 1992; Bureau of Fisheries Management Department of Natural Resources Administrative Report NO. 27, "Unit habitat Construction of Habitat Improvement Structures for Wisconsin Coulee Streams," Madison, Wisconsin, August 1988; Ann L. Riley, "Restoring Streams in Cities: A Guide for Planners, Policy Makers, and Citizens," Island Press, 1998; State of California Resources Agency Department of Fish and Game, "California Salmonid Stream Habitat Restoration Manual," Second Edition, October 1994.*

[e]*These structures are recommended to be utilized at culvert and bridge crossings where fish passage is limited due to low water depths, especially during low flow periods. Upstream pool areas created by these structures can provide improved fish passage and aquatic habitat. Ann Riley, Restoring Streams in Cities: A Guide for Planners, Policymakers, and Citizens, Island Press, Washington, D.C., 1998.*

[f]*Stream Renovation Guidelines Committee, The Wildlife Society, American Fisheries Society, and International Association of Fish and Wildlife Agencies, "Stream Obstruction Removal Guidelines," Bethesda, Maryland, 1983.*

Source: SEWRPC.

in accordance with Wisconsin Department of Natural Resources monitoring protocols.[16] This evaluation strategy should also include establishment of specific fisheries goals and objectives in order to implement appropriate management actions among reaches of the Quaas Creek watershed. As of 2002, both the Wisconsin Department of Natural Resources and University of Wisconsin-Milwaukee had ongoing fisheries and habitat monitoring programs on Quaas Creek.

Promotion of local support for fisheries management and environmentally sensitive and sustainable measures through targeted informational programming and creation of opportunities for public participation in monitoring, as well as decision-making processes, is also recommended. Such opportunities for shared decision-making include the creation of citizen advisory committees, completion of memoranda of understanding with river organizations within the basin, and participation in programs such as Project WET (Water Education for Teachers) and related school-based programming. A sound and vocal base of public support for a fisheries rehabilitation project will benefit all aspects of watershed management, and complement the Wisconsin Department of Natural Resources Basin Team approach.

[16] *See Wisconsin Department of Natural Resources,* Guidelines for Assessing Fish Communities of Wadable Streams in Wisconsin*, June 2000; Wisconsin Department of Natural Resources,* Guidelines for Evaluating Habitat of Wadable Streams*, June 2000.*

APPENDICES

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Appendix A

STANDARDS, GUIDELINES, AND REFERENCE CONDITIONS FOR LAKES AND STREAMS WITHIN SOUTHEASTERN WISCONSIN

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Table A-1

APPLICABLE WATER USE OBJECTIVES AND WATER QUALITY STANDARDS AND GUIDELINES FOR LAKES AND STREAMS WITHIN THE SOUTHEASTERN WISCONSIN REGION

Water Quality Parameters	Combinations of Water Use Objectives Adopted for Southeastern Wisconsin Inland Lakes and Streams[a,b]				
	Coldwater Community and Full Recreation Use	Warmwater Sportfish Community and Full Recreation Use	Warmwater Forage Fish Community and Limited Recreational Use	Limited Aquatic Life and Limited Recreational Use	Source
Temperature (°F)[c]	Background	89.0 maximum	89.0 maximum	- -	NR 102.04 (4)[d]
Dissolved Oxygen (mg/l)[c]	6.0 minimum 7.0 minimum during spawning	5.0 minimum	3.0 minimum	1.0 minimum	NR 102.04 (4) NR 104.02 (3)
pH Range (S.U.)	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0	NR 102.04 (4)[e] NR 104.02 (3)
Fecal Coliform (MFFCC)	200 mean 400 maximum	200 mean 400 maximum	1,000 mean 2,000 maximum	1,000 mean 2,000 maximum	NR 102.04 (5) NR 104.06 (2)
Ammonia Nitrogen (mg/l)	- -	- -	3.0-6.0	- -	NR 104.02 (3)
Total Phosphorus (mg/l)	0.1 maximum for streams 0.02 maximum during spring turnover for lakes	0.1 maximum for streams 0.02 maximum during spring turnover for lakes	- -	- -	Regional water quality management plan[f]
Chloride (mg/l)	1,000 maximum	1,000 maximum	1,000 maximum	- -	Regional water quality management plan[g]

[a]*NR102.04(1) All waters shall meet the following minimum standards at all times and under all flow conditions: substances that will cause objectionable deposits on the shore or in the bed of a body of water, floating or submerged debris, oil, scum, or other material, and material producing color, odor, taste or unsightliness shall not be present in amounts found to be of public health significance, nor shall substances be present in amounts which are acutely harmful to animal, plant or aquatic life.*

[b]*It is recognized that under both extremely high and extremely low flow conditions, instream water quality levels can be expected to violate the established water quality standards for short periods of time without significantly damaging the overall health of the stream. It is important to note the critical differences in the application of standards for regulatory versus planning purposes. For this purpose, the standards are often applied using a probabilistic approach, whereby the percent of time a given standard is violated is considered to allow assessment and resolution of water quality problems during high flow, as well as low flow conditions. This approach is considered appropriate for planning purposes, as opposed to regulation. The U.S. Environmental Protection Agency and the Wisconsin Department of Natural Resources, being regulatory agencies, utilize water quality standards as a basis for enforcement actions and compliance monitoring. This requires that the standards have a rigid basis in research findings and in field experience. The Southeastern Wisconsin Regional Planning Commission and others use water quality standards as criteria to measure the relative merits of alternative plans.*

[c]*Dissolved oxygen and temperature standards apply to continuous streams and the upper layers of stratified lakes and to the unstratified lakes; the dissolved oxygen standard does not apply to the hypolimnion of stratified inland lakes. However, trends in the period of anaerobic conditions in the hypolimnion of deep inland lakes should be considered important to the maintenance of their natural water quality.*

[d]*NR 102.04(4) There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained. The maximum temperature rise at the edge of the mixing zone above the natural temperature shall not exceed 5°F for streams. There shall be no significant artificial increases in temperature where natural trout reproduction is to be maintained.*

[e]*The pH shall be within the stated range with no change greater than 0.5 unit outside the estimated natural seasonal maximum and minimum.*

[f]*U.S. Environmental Protection Agency, Quality Criteria for Water, EPA-440/9-76-023, 1976.*

[g]*J.E. McKee and M.W. Wolf, Water Quality Criteria 2nd edition, California State Water Quality Control Board, Sacramento, California, 1963.*

Source: Wisconsin Department of Natural Resources and SEWRPC.

Table A-2

POTENTIAL REFERENCE NUTRIENT WATER QUALITY CONDITIONS FOR LAKES AND RESERVOIRS AND RIVERS AND STREAMS WITHIN EPA ECO-REGION 53 OF THE MOSTLY GLACIATED DAIRY REGION VII: 1990-1998

Parameter[c,d]	Lakes and Reservoirs[a]				Streams and Rivers[b]			
	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer
Physical Properties								
Dissolved Oxygen								
Interquartile Range (P25, P75)	5.0-9.95	5.05-10.4	10.0-11.7	5.25-8.5	8.5-10.2	10.5-12.4	10.2-12.4	6.4-8.7
Median	8.13	7.9	11.1	7.58	9.4	11.3	11.2	7.7
Less Than 5 Percent (P5)	- -	- -	- -	- -	5.5	7.8	8.7	4.2
Number of Samples	62	53	83	94	78	74	90	118
Secchi Depth (feet)								
Interquartile Range (P25, P75)	3.3-9.4	6.6-15.4	3.9-11.5	3.9-9.5	- -	- -	- -	- -
Median	5.7	10.8	6.9	6.6	- -	- -	- -	- -
Less Than 5 Percent (P5)	19.7	20.0	15.6	14.4	- -	- -	- -	- -
Number of Samples	79	47	97	108	- -	- -	- -	- -
Turbidity (FTU)								
Interquartile Range (P25, P75)	- -	- -	- -	- -	3.0-8.2	2.49-6.09	2.05-5.45	4.5-16.8
Median	- -	- -	- -	- -	5.20	3.95	3.33	9.45
Less Than 5 Percent (P5)	- -	- -	- -	- -	1.1	1.9	1.05	1.46
Number of Samples	- -	- -	- -	- -	29	24	42	40
Nutrients								
Total Kjeldahl Nitrogen								
Interquartile Range (P25, P75)	0.54-1.40	0.50-1.25	0.55-1.15	0.60-1.60	0.36-1.11	0.70-1.35	0.75-1.35	0.60-1.4
Median	1.02	0.90	0.80	1.02	0.85	1.05	1.0	0.93
Less Than 5 Percent (P5)	0.19	0.18	0.20	0.15	0.13	0.21	0.40	0.25
Number of Samples	44	37	91	62	64	63	63	98
Dissolved Nitrogen, NO_2+NO_3								
Interquartile Range (P25, P75)	0.01-0.16	0.38-3.24	0.06-0.67	0.00-0.21	1.28-4.08	1.45-4.30	0.59-4.5	0.33-4.18
Median	0.03	1.13	0.45	0.01	1.43	3.65	1.86	0.80
Less Than 5 Percent (P5)	0.00	0.00	0.00	0.00	0.50	1.20	0.24	0.21
Number of Samples	16	4	15	15	9	11	11	10
Total Phosphorus (μg/L)								
Interquartile Range (P25, P75)	11.9-95.0	12.5-100	10.0-70.0	12.5-115	90.0-240	70.0-240	60.0-175	100-298
Median	45.0	40.0	25.0	45.0	140	115	100	155
Less Than 5 Percent (P5)	5.0	4.5	6.25	5.63	40.0	40.0	20.0	20.0
Number of Samples	87	71	114	125	89	97	105	136
Biological								
Chlorophyll-*a* (μg/l)								
Interquartile Range (P25, P75)	5.14-28.9	4.10-16.3	5.41-21.3	4.39-18.1	5.24-35.0	4.48-12.2	7.92-18.0	7.24-29.4
Median	10.7	6.0	11.2	7.3	12.1	7.93	15.2	10.7
Less Than 5 Percent (P5)	3.00	2.29	1.98	2.52	3.87	2.94	4.0	4.56
Number of Samples	76	43	96	106	23	22	26	24

[a]*Information derived from USEPA Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Rivers and Streams in Nutrient Ecoregion VII, EPA 822-B-00-018, December 2000. Apparently values include data from both surface and bottom waters, which complicates interpretation of certain parameters such as the nutrients which commonly exhibit surface to bottom gradients in concentration during periods of stratification.*

[b]*Information derived from USEPA Ambient Water Quality Criteria Recommendations, Information Supporting the Development of State and Tribal Nutrient Criteria, Lakes and Reservoirs in Nutrient Ecoregion VII, EPA 822-B-00-009, December 2000.*

[c]*Milligrams per liter unless otherwise indicated.*

[d]*P5 is equal to the 5th percentile of all data, P25 is equal to the 25th percentile of all data, and P75 is equal to the 75th percentile of all data.*

Source: US Environmental Protection Agency and SEWRPC.

Appendix B

QUAAS CREEK BANK STABILITY SURVEY IN FALL 2001: DESCRIPTION OF FIELD MEASUREMENTS AND STATISTICAL ANALYSIS RESULTS

STREAMBANK CHARACTERISTICS

Bank Height: Height of the bank from the streambed to the top edge of the lateral scour line as shown in Figure B-1.

Undercut Depth: A bank that has had its toe of slope, or base, cut away by the water action creating overhangs in the stream as shown in Figure B-1.

Length of Erosion: Total linear distance of active erosion along the streambank as shown in Figure B-2.

Slope: Ratio of horizontal distance divided by the vertical height of the streambank as shown in Figure B-2.

INSTREAM HABITAT CHARACTERISTICS

Width: The width of the existing water surface measured at right angles to the direction of flow from shore to shore.

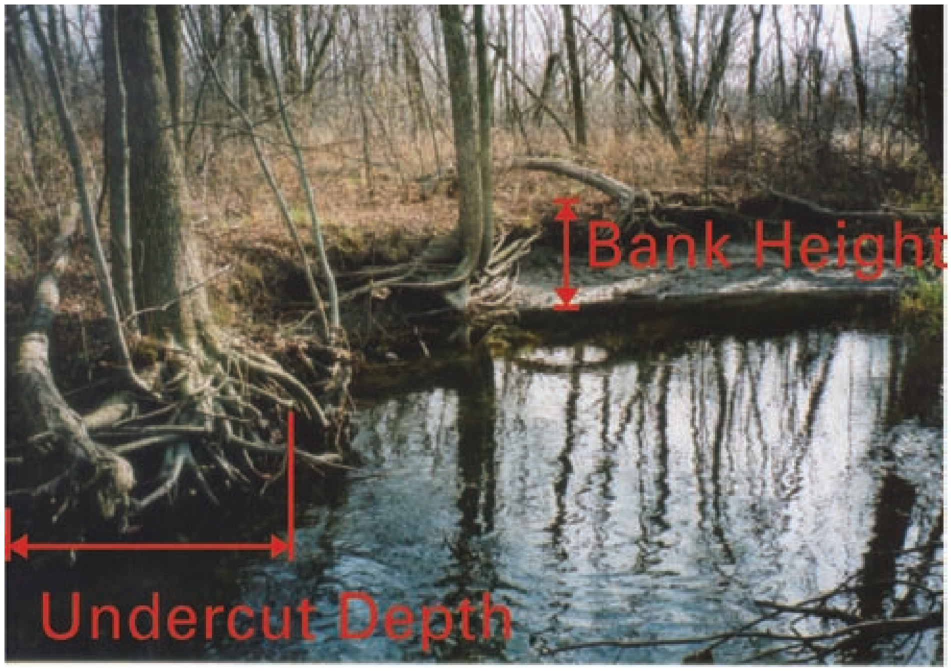
Maximum Depth: The vertical height of the water column from the existing water surface level to the deepest point of the channel bottom.

Habitat Type: An aquatic unit, consisting of an aggregation of habitats having equivalent structure, function, and responses to disturbance. Pool, riffle, and run habitat types were observed in the Quaas Creek watershed.

- A pool is that area of the water column that has slow water velocity and is usually deeper than a riffle or run (Figure B-3). Pools usually form around bends or around large-scale obstructions that laterally constrict the channel or cause a sharp drop in the water surface profile.
- Riffles are portions of the water column where water velocity is fast, stream depths are relatively shallow, and the water surface gradient is relatively steep (Figure B-4).
- A run is that area of the column that does not form distinguishable pools or riffles, but has a rapid nonturbulent flow. A run is usually too deep to be a riffle and too fast to be a pool.

Figure B-1

EXAMPLE OF BANK HEIGHT AND UNDERCUT DEPTH MEASURED AT AN ACTIVELY ERODING SITE WITHIN THE DECORAH ROAD REACH: FALL 2001



Source: SEWRPC.

Substrates: Refers to the materials that make up the streambed. Substrate composition was determined visually by recording the dominant substrate types within the area of the actively eroding streambank site (Figure B-3). The following categories of substrate type were used.

- Boulder: Rocks with a maximum length of 256-512 millimeters.
- Cobble: Rocks with a maximum length of 64-256 millimeters.
- Gravel: Rocks with a maximum length of 2-64 millimeters.
- Sand: Inorganic particles smaller than gravel, but coarser than silt with a maximum length of 0.062-2 millimeters.
- Silt: Fine inorganic particles, typically dark brown in color. Feels greasy and muddy in hands. The material is loose and does not retain shape when compacted into a ball and will not support a person's weight when it makes up the stream bottom. Silt particles have a maximum length of less than 0.004 millimeters.
- Clay: Very fine, inorganic, dark brown or gray particles. Individual particles are barely or not visible to the unaided eye. The particles feel gummy and sticky in hands and slippery underfoot. Clay particles retain shape when compacted and partially or completely supports a person's weight when it makes up the stream bottom. Clay particles have a maximum length of less than 0.004 millimeters.

Sediment Depth: Is the depth of fine sediments (usually sand and silt) that overlay or comprise the streambed. Sediment depth is an indicator of sediment deposition and was measured to the nearest 10th of a foot.

Figure B-2

EXAMPLE OF LENGTH OF EROSION AND BANK SLOPE MEASURED AT AN ACTIVELY ERODING SITE WITHIN THE CTH G REACH: FALL 2001

Source: SEWRPC.

Woody Debris: Large pieces or aggregations of smaller pieces of wood (e.g. logs, large tree branches, root tangles) located in or in contact with the water surface.

Woody Debris Jams: A group of three or more large diameter (greater than 20 centimeters) intermingled logs partially or completely submerged in the channel that substantially alter stream flow and sedimentation patterns (Figures B-5 and B-6).

FISHERIES PASSAGE BARRIERS

Culverts can create hydrological and physical obstructions within a river system that result in reduced water depths and increased velocities that can limit fisheries passage as shown in Figures B-7 and B-8.

Depth: In order to provide adequate fish passage a depth of at least nine inches at any point in the culvert is recommended.[1]

Velocity: In order to provide adequate fish passage velocities are recommended not to exceed three feet per second. In addition, a culvert should be designed so that the average stream bank full width, depth, and slope of the existing stream are maintained.[2]

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[1] *SERC Stream Enhancement Research Committee,* Stream Enhancement Guide*, Province of British Columbia and the British Columbia Ministry of the Environment, Vancouver, 1980.*

[2] *Washington Department of Fish and Wildlife, Habitat and Lands Program, Environmental Engineering Division,* Fish Passage at Road Culverts: A Design Manual for Fish Passage at Road Crossings*, Washington, March 3, 1999.*

Figure B-3

TYPICAL POOL HABITAT AND DIVERSITY OF SUBSTRATE OBSERVED WITHIN THE WISCONSIN CENTRAL RAILROAD REACH: FALL 2001

Source: SEWRPC.

Figure B-4

TYPICAL RIFFLE HABITAT AND HETEROGENEITY OF FLOW OBSERVED WITHIN THE CTH G REACH: FALL 2001

Source: SEWRPC.

Figure B-5

EXAMPLE OF WOODY DEBRIS JAM CHANNEL OBSTRUCTION AND ASSOCIATED LOCALIZED BANK EROSION LOCATED WITHIN THE CTH G REACH: FALL 2001

Source: SEWRPC.

Figure B-6

EXAMPLE OF WOODY DEBRIS JAM CHANNEL OBSTRUCTION AND ASSOCIATED LOCALIZED BANK EROSION LOCATED WITHIN THE SAND DRIVE REACH: FALL 2001

Source: SEWRPC.

Figure B-7

HYDROLOGICAL AND PHYSICAL OBSTRUCTIONS WITHIN THE STRUCTURAL PLATE PIPE ARCH CULVERT AT THE CTH G ROAD CROSSING OF THE MAIN CHANNEL OF QUAAS CREEK

Source: SEWRPC.

Figure B-8

POTENTIAL HYDROLOGICAL OBSTRUCTION WITHIN THE CULVERT STRUCTURE AT THE CTH P ROAD CROSSING OF THE MAIN CHANNEL OF QUAAS CREEK

Source: SEWRPC.

BANK STABILITY STATISTICAL ANALYSIS RESULTS

Table B-1

ANALYSIS OF VARIANCE OF THE PROPORTION OF FAILURE AMONG HABITAT VARIABLES, STREAM REACH, AND RIVER MILES: 2002

Parameters	Analysis of Variance[a]				
	Sum of Squared Deviations	Degrees of Freedom	Variance Estimate	F-Ratio	P-Value
Width	0.485	1	0.485	4.898	0.029
Depth	0.173	1	0.173	1.744	0.189
Bank Height	0.008	1	0.008	0.079	0.779
Reach	1.767	7	0.252	2.551	0.017
River Mile.............................	0.331	1	0.331	3.343	0.070
Error.....................................	13.164	133	0.099	- -	- -

[a]*The dependant variable was proportion of failure. There were 145 cases analyzed which generated a multiple R of 0.414 and squared multiple R of 0.171. The Durbin-Watson D Statistic and First Order Autocorrelation were 1.679 and 0.150, respectively.*

Source: SEWRPC.

Table B-2

ANALYSIS OF VARIANCE OF STREAM WIDTH AMONG STABLE AND UNSTABLE POOL, RIFFLE, AND RUN HABITATS: 2002

Parameters	Analysis of Variance[a]				
	Sum of Squared Deviations	Degrees of Freedom	Variance Estimate	F-Ratio	P-Value
Failure Code[b]	7.309	1	7.309	51.976	0.000
Habitat	1.105	2	0.552	3.928	0.020
Error..................................	61.773	439	0.141	- -	- -

[a]*The dependant variable was stream width. There were 443 cases analyzed which generated a multiple R of 0.327 and squared multiple R of 0.107. The Durbin-Watson D Statistic and First Order Autocorrelation were 0.538 and 0.718, respectively.*

[b]*This was a categorical variable separating the stable from the unstable sites as observed within the Quaas Creek watershed.*

Source: SEWRPC.