Incorporating Aquatic Ecological Classification Units As Elements Of Biodiversity In The Biotics Database

Prepared by:
Amy L. Derosier and Peter J. Badra
Michigan Natural Features Inventory
P.O. Box 30444
Lansing, MI 48909-7944

For:
Michigan Department of Natural Resources
Wildlife Division

September 30, 2007
MNFI Report Number 2007-12

Cover photos by A.L. Derosier, and M.S. Weber

Citation: Derosier, A.L. and P.J. Badra. 2007. Incorporating aquatic ecological classification units as elements of biodiversity in the Biotics database. Report number MNFI 2007-12. Report to Michigan Department of Natural Resources, Lansing, MI. 69pp.

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Abstract

In the United States, freshwater aquatic species are at greater risk of imperilment than terrestrial species. To keep species common, the identification of representative high-quality or unique ecosystems is crucial. Terrestrial natural communities have proved beneficial to the protection and management of terrestrial ecosystems, and species, by tracking them in Biotics and including them in environmental reviews, as well as in land use and conservation planning. However, Michigan currently does not have aquatic natural communities. In this report we: 1) propose a draft hierarchical framework and EO specifications for riverine natural communities; 2) propose draft natural community types for the finest level of the framework; 3) propose draft criteria for ranking riverine natural communities; and 4) provide field survey results collected at potentially high quality river reaches. In addition, we describe future efforts needed to complete this work. Our proposed framework has three levels. The first level, or Ecological Drainage Units, creates a regional framework based on watersheds. This is the over-arching framework that considers climate, physiography, and zoogeographic history. The second level or intermediate level would be used to capture processes such as nutrient and energy dynamics and hydrologic regimes. The size of these intermediate units would likely range from 100 to 600 mi^2. The finest level would be based on river valley segments or VSECs. These have been defined in Michigan and are stretches of river based on parameters such as surficial geology, catchment slope, valley width, channel sinuosity, and groundwater input. Mean lengths for VSECs range from 6 to 12 km. Our proposed river natural community types for Level 3- VSECs are based on size, water temperature, and gradient. Our proposed EO rank specifications are based on five factors of condition and three factors of landscape context. Condition is based on in-stream cover, water temperature, substrate quality, stream bank erosion, and exotic species. Landscape context is based on composition of riparian areas, level of impervious surfaces in watershed, and number of dams in watershed. We performed field surveys at 24 sites in the Lower Peninsula of Michigan to begin detailing site-specific habitat and species data for the Level 3 riverine natural community. Using this data we were able to test the proposed draft of EO rank specifications.

Introduction

Michigan is in many ways defined by its vast aquatic natural resources, including over 36,500 miles of rivers and streams. These ecosystems are intricately tied to the landscape and provide a variety of ecosystem services. They provide municipal and industrial water supplies, energy production, irrigation, flood control, and transportation. They also provide critical habitats for significant populations of many fish, mussel, and macroinvertebrate taxa. Many of Michigan's endangered, threatened, special concern, and species of greatest conservation need (SGCN) rely on these ecosystems for at least a portion of their life cycles. These ecosystems are also critical to many important common species, such as many of Michigan's trout and bass populations. Despite the vastness of these resources, they are under great pressure from human activities.

In the United States, freshwater species are at greater risk of imperilment than terrestrial species (Wilcove and Master 2005). Seven to nine percent of mammals, birds, reptiles, and turtles are imperiled. Where as, 20% of freshwater fish, 48% of freshwater mussels, 61% of freshwater snails, 33% of crayfish, 21% of stoneflies, 22% of mayflies, and 8% of dragonflies and damselflies are imperiled. Because of the pervasiveness of this imperilment, larger scale efforts need to occur. We are realizing an increased focus on preserving ecosystem functions as well as managing individual threatened or endangered species (Franklin 1993, Grumbine 1994). To maintain Michigan's aquatic biodiversity into the foreseeable future, we need to identify and protect representative and unique habitats and ecosystems (or aquatic community types) across the state (WAP 2005).

Despite the considerable progress and success of terrestrial classification of natural communities and the inclusion of these as elements of biodiversity in Biotics (the state's rare species and natural community database), aquatic systems-level elements remain undeveloped. The classification of terrestrial and wetland natural communities has significantly aided efforts to protect high quality ecosystems through environmental review, and it has also provided a means for predicting occurrences of specific listed species that has helped to prioritize survey and monitoring efforts. The lack of development and tracking of comparable aquatic ecological units therefore reflects a significant gap in the management of Michigan's biodiversity. Preserving the full range of Michigan's biodiversity, including aquatic resources, requires that we be able to classify, track, and manage systems-level aquatics elements to protect ecosystem function, representative natural aquatic communities, and rare and common species. Tracking aquatic ecological and community units would provide a vehicle for much more effective habitat conservation to help keep common species common and rare species viable.

The primary objective of this work was to begin defining and incorporating aquatic ecosystem EOs into the Biotics database. An EO or Element Occurrence is an area of land and/or water that a species or natural community is, or was, present (NatureServe 2002). An EO for a community represents 'a stand or patch of a natural community or a cluster of stands or patches of a natural community' (NatureServe 2002). They also should have practical conservation value.

This report details the basis for and suggests a plan to delineate, define, and rank river ecosystems as natural communities. It proposes a framework and future work needed for defining riverine natural communities, specifically this report:

1. Provides a review of what other states and groups have used as aquatic ecosystem or conservation units (or EOs);
2. Proposes a draft hierarchical framework and future efforts needed to detail EO specifications for river natural communities;
3. Proposes a draft for river natural community types for one level of the propose hierarchical framework and future efforts needed to complete classification;
4. Proposes draft criteria and future efforts needed for ranking riverine natural communities;
5. Provides field survey data collected at potentially high quality river reaches to begin to look at the utility of the proposed frameworks for natural community types and EO ranks.

Selection Of Aquatic Conservation Units In Other States

Only a few states have targeted aquatic ecosystems for conservation and they vary quite a bit on the conservation unit used. Some groups have used watersheds (Olivero et al. 2003) or subwatersheds (6-code hydrologic units, HUC-6, Oechsli and Frissel 2002). Where as, others have used individual lakes and specific stretches of rivers (FNAI 2005, NH&ESP 2003). Florida Forever used 2 km stretches of river for their river conservation unit (FNAI 2005). Massachusetts mapped sections of river according to species movements as well as critical watersheds (NH&ESP 2003). Missouri's GAP program created an eight-level classification hierarchy (Sowa et al. 2005). Missouri's analysis is the most comprehensive aquatic assessment to date and is a good model of how to approach classifying riverine aquatic ecosystems. More detail about this assessment will be described below.

Missouri's riverine conservation units were based on the concept that ecosystems are made up of structural, functional, and compositional factors (Sowa et al. 2005). Structural factors include depth, velocity, and substrate of the river ecosystem. Functional factors are more process oriented and include flow regime, temperature regime, sediment budgets, and energy budgets. Compositional factors can be both biotic (e.g. species) or abiotic (e.g. habitat types), and all of these factors are dependent upon the geographic location of an ecosystem. Hence, Missouri's hierarchical framework has eight levels (see Table 3.1 in Sowa et al. 2005). The First three levels are based on evolutionary history and zoogeographic zones. Level 4 or Subregions are based on regional climate, physiography, and physiognomy of vegetation. Level 5 is Ecological Drainage Units (EDU), which are "aggregates of drainages within a distinct physiographic setting that share a common evolutionary history". This level helps explain species distribution patterns. Level 6 or Aquatic Ecological System Types (AES-Types) are based on watershed boundaries, the position within the larger drainage, local and watershed physiography, local climate, and basin morphometry. AES-Types are hydrologic units that are between ~100 and 600 mi^2 in size. Level 7 are Valley Segment Types (VSTs), which are "aggregates of stream reaches with broad similarities in fluvial processes, sediment transport, riparian vegetation, and thermal regime". The last and finest level is Habitat Unit Types, which are more macrohabitat types based on depth, velocity, substrate, position within the channel, and other physical features. In the end, Missouri's conservation strategy: 1) had different conservation plans for each EDU, 2) represented two distinct spatial occurrences of target species in each EDU, 3) represented at least 1 of each AES-Type in an EDU, 3) within each selected AES, represented at least 1 km of the dominant VSTs for each size class, and lastly, 4) represented at least three separate headwater VSTs within each conservation area. Using their hierarchical framework, Missouri was able to choose conservation units (AES-Types or VSTs) to capture multiple scales of ecological processes important for river ecosystems.

Determining how to represent river ecosystems as distinct units is difficult. There are often conflicts between the scale of the processes that create a specific ecosystem or habitat and the level of control practical conservation can have. Functional processes happen at a watershed level, however for medium and large rivers this can be an unmanageable conservation target because of its large size. Finding a balance is important.

Proposed Draft Framework for EO Specifications

Element Occurrences are essential for Natural Heritage methodology and are used as the basis for conservation planning. EOs are added to the Biotics database to track and gather information on important species and natural communities in each state. "EO specifications are used to delineate and differentiate EOs" (NatureServe 2002). Essentially, EO specifications for natural communities define where the boundaries are for a specific ecosystem. Criteria of what constitutes an EO are often based on the minimum size needed for an ecosystem to function, the processes or quality needed for a functioning ecosystem, and the distances or factors that separate one EO from another. EO specifications provide the standard for how a natural community is defined.

One of the initial challenges to describing riverine natural communities is defining boundaries of the natural community or ecosystem. Rivers and streams are linear ecosystems that are a part of a continuum. Any particular point along a river is greatly influenced by the local area as well as the upstream watershed area. Water chemistry, substrates, and water flows are heavily influenced by the underlying geology, surrounding landscape, and the regional climate (Wiley and Seelbach 1997). Rivers often cross over a variety of physiography and geology types.

Three-level hierarchical framework

The size of a river ecosystem unit, needs to be large enough that ecological processes are captured within the unit, yet small enough to be a useful unit for conservation (Dovciak and Perry 2002, Fausch et al. 2002). Often, being able to picture what a natural community looks like helps people have a sense of place and connection, thereby more easily promoting conservation. Watersheds are quite variable in terms of habitat and can be difficult to determine management or conservation practices (Hawkins and Norris 2000). We propose a hierarchical framework for delineating river natural communities. Missouri's GAP program (Sowa et al. 2005) has put a lot of resources into their classification framework and we think it provides a logical way to describe riverine ecosystem while considering their processes and functions. We propose to follow a similar framework using three of their levels: Ecological Drainage Units, Aquatic Ecological Systems or Some variation of sub-watersheds, and River Valley Segments (VSECs).

Level 1 – Ecological Drainage Units

Ecological Drainage Units (EDUs) for the Great Lakes region have been proposed by Higgins et al. (2005). EDUs are aggregates of watersheds based on hydrologic units that share similar ecological characteristics such as climate, hydrologic regime, physiography, and zoogeographic history. EDUs and terrestrial ecoregions do share similar characteristics but EDUs are based on watersheds and hence provide a more effective framework for aquatic ecosystems and species distributions. EDUs have been shown to be effective in landscape-based classification efforts for both riverine and lake ecosystems (Higgins et al. 2005, Cheruveilil in prep) and have been used in other biodiversity planning efforts (Sowa et al. 2005). This regional framework will allow us to break the state up into meaningful units to ensure representation of ecosystems and populations. There are nine Ecological Drainage Units in Michigan (Figure 24). For more descriptions of EDUs in terms of climate, major landforms, water features, and zoogeography see Appendix H.

Level 2 – Aquatic Ecosystem Types

Sowa et al. (2005) used Aquatic Ecological System Types (AES-Types) to "identify and map hydrologic units that are relatively similar with regard to nutrient and energy sources/dynamics, physical habitat, water chemistry, hydrologic regimes, and also contain functionally similar biological assemblages." We believe an intermediate level in a framework for creating riverine natural community types is important because many of the ecological or functional processes (e.g. flow regime, sediment budgets, energy budgets) of rivers occur at a smaller scale than EDUs and a larger scale than VSECs. We think this level helps provide the context for the finer scaled VSECs and macrohabitat types. No work has been conducted to date in Michigan or the Great Lakes region on this level of classification.

Level 3 – River Valley Segments

Fortunately, there has been extensive work in Michigan on defining river valley segments or VSECs (Seelbach et al. 1997, Baker 2006, Seelbach et al. 2006, Brenden et al. 2007). These segments were determined by modeling available information on landscape data as well as expert review. VSECs are ased on surficial geology, catchment slope, catchment landuse, valley width, valley wetlands, channel sinuosity,

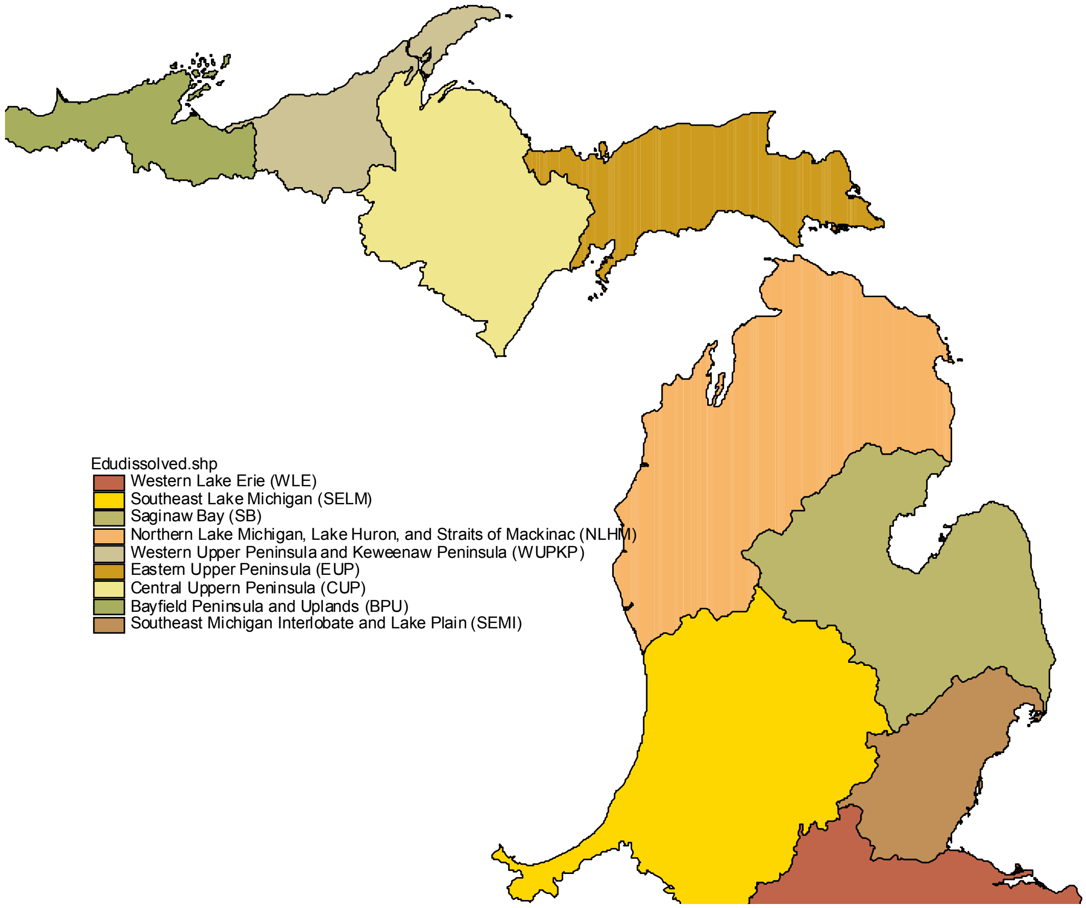

Figure 1. Ecological Drainage Units of Michigan

and potential groundwater influx to river channels (Seelbach et al. 2006). Mean lengths of VSECs range from 6 to 12 km. VSECs provide reasonable boundaries for defining the finest level of river natural communities because they are large enough to capture multiple habitats such that species could complete their life cycles within a single VSEC. This work is on-going, and is expected to be finalized shortly (P. Seelbach personal communication).

Future Directions

River ecosystems are difficult to define and delineate due to their linear and continuous nature. Yet delineation is important to their management and conservation. Both EDUs and VSECs are available and have had some review but more work to refine the frameworks is continuing. However, the mid-level of this proposed framework has not yet been tackled in Michigan. These mid-level units should be hydrologic units that have relatively similar functional processes (e.g. flow regimes, sediment and energy budgets). The following bullets outline the needs for each level of the framework:

- Level 1: Need to ensure that proposed EDUs have gone through a rigorous review to ensure that they represent actual ecological units.
- Level 2: Need to determine available data and data needs to conduct AES-type analysis. Need to determine the approach for this mid-level analysis (review MO GAP, create workgroup, etc). Analysis of AES-types needs to be conducted. Level 2 riverine natural communities need to be described.
- Level 3: VSECs need to be finalized. More detailed descriptions of riverine natural

communities needs to be completed. Determination of distinctness of VSECs within Level 2 needs to be assessed. Natural communities need to be defined based on all three levels. Rare species need to be associated with river natural communities.

Proposed Draft River Natural Community Types – Level 3

Below is a draft framework for defining river natural community types at the finest level, VSECs. This classification will fit into the overall hierarchical framework for riverine natural community types. We cannot propose a classification of natural communities at the Level 2 hierarchy at this time because research is needed to begin to define the important factors and variables at that scale.

Proposed Natural Community Types at the VSEC level

Physical, chemical, and biological changes occur on a longitudinal gradient from the headwaters to the very large rivers (the river continuum concept) (Vannote et al. 1980). Headwater and small tributary streams tend to be shaded and rely on energy inputs from riparian vegetation with macroinvertebrate communities dominated by shredders. Medium rivers tend to be less shaded and rely on energy inputs from primary production with macroinvertebrate communities dominated by grazers. And large rivers tend to rely on energy inputs from upstream with macroinvertebrate communities dominated by collectors. Fish, mussel, and aquatic plant and algae communities all vary from the headwater to large river gradient as well. Rivers do vary from this general model, however it provides insight into how size is an important factor in determining and defining river communities. Water temperature is also an important driver of species grown and reproductive rates and timing as well as species distributions (Wootton 1990, Allan 1995). Aquatic species have specific temperature ranges they thrive in and can tolerate. Stream water temperature is determined by four main factors (Caissie 2006): 1) atmosphere (e.g. solar radiation, air temperature), 2) topography (e.g. riparian vegetation, geology), stream discharge (e.g. water volume, turbulence), and 4) stream bed (e.g. groundwater input, hyporheic exchange). Gradient provides a measure of channel morphology which correlates to valley shape, sinuosity, water velocity, and substrate size (Gordon et al. 1992). All three factors are important in determining species compositions in rivers. Hence, each VSEC was classified using size, water temperature, and gradient.

Four size classes were defined using drainage areas of VSECs, following the Wildlife Action Plan (Eagle et al. 2005): headwaters and small tributaries are less than 40 mi^2, medium rivers are between 40 and 179 mi^2, large rivers are between 180 and 620 mi^2, and very large rivers are greater than 620 mi^2. Four classes of water temperatures were defined for each VSEC: cold (<19°C), cool (19-22°C), and warm (>22°C). And three classes of gradient were defined, where low were those VSECs with an average gradient less than 0.001, moderate was between 0.001 and 0.006, and high was greater than 0.006. Gradient classes were defined using the 25th and 75th percentiles of all stream reach gradients across Michigan, so less than the 25th percentile was low, greater than the 75th percentile was high, and the rest were defined as moderate. VSEC gradient is the average gradient of the reaches that make up a VSEC. This classification is used as Level 3 or the finest level for defining river natural community types. For more information see Appendix J.

Future Directions

Further refinement of the proposed river natural community types is needed. Expert review needs to occur as well as more field sampling and analysis. Alkalinity may prove to be an important factor in determining natural community associations with mussel and macrophyte communities. Macrohabitat (run, riffle, pool composition) make up may also play a role in refining animal and plant community associations.

We propose that one of the next steps in creating detailed riverine natural community types is to examine the variability within types at both the VSEC and AES-type level within EDUs. If variability in habitat and biological communities is low at the VSEC level (both within and among) in an AES within an EDU then an AES may be the appropriate scale for that natural community type. However, if habitat and biological communities are quite variable within VSECs then VSECs or finer maybe the resolution needed for conservation efforts. For the protection and conservation of biodiversity in Michigan, we need to be able to determine what types of natural communities are unique (and why) and which are common so that we can find the high quality common natural communities. Being able to classify natural communities in these terms will allow conservation efforts to be focused on the breadth and quality of river communities in Michigan.

Proposed Draft EO Rank Specifications

Element Occurrence ranks and rank specifications provide an evaluation of estimated viability or probability of persistence of a given EO often based on condition, size, and landscape context (NatureServe 2002). Ranks, typically A through D, provide a succinct measure of whether an EO has excellent estimated viability (i.e. A or high quality) or poor estimated viability (i.e. D or degraded). EO rank specifications provide replicable criteria to determine rank based on knowledge of historical evidence, current status, and threshold values variables that suggest ecological processes are functioning within an ecosystem.

To determine an EO rank for a river natural community, we propose that condition and landscape context be weighted equally. Condition is defined as “an integrated measure of the quality of biotic and abiotic factors, structures, and processes *within* the occurrence, and the degree to which they affect the continued existence of the EO” (NatureServe 2002). Components of this ranking factor include ecological processes, species composition, abiotic physical and chemical parameters. Whereas landscape context is “an integrated measure of the quality of biotic and abiotic factors, structures, and processes *surrounding* the occurrence, and the degree to which they affect the continued existence of the EO” (NatureServe 2002). Components of this ranking factor include landscape structure and extent, and condition of the surrounding landscape. Taken together they reflect the local as well as the watershed influence on a particular natural community. For more information of EO rank specifications see Appendix I.

For condition, six main factors are proposed to rank an EO. (1) In-stream cover is an important component of the local structuring of a river natural community. Abundant and diverse in-stream cover can provide varied habitat for a diverse community of species. (2) Water temperature is an important determinant of a river natural community type. Hence, water temperatures that fall within natural variation are an important quality ranking factor. (3) The amount of siltation in a system is important in determining substrate quality and hence macroinvertebrate (aquatic insects, mussels, snails, etc.) habitat as well as fish rearing habitat. (4) Stream bank erosion provides insight into the hydrology of the natural community. Significant erosion can suggest flashy flows that may not be within the natural variation of that type of river natural community. (5) Exotic species is a critical factor of quality because they can disrupt natural food webs, remove habitat, or directly remove native species from the ecosystem. (6) Dredging, channelization, and streambank armoring can greatly impact abiotic and biotic components of river natural communities.

For landscape context, three main ranking factors are proposed. (1) composition of riparian areas, (2) level of impervious surfaces in watershed, (3) number of dams and size of impoundments in watershed. Riparian areas provide many services to streams and rivers including decreasing and stabilizing water temperatures and flows, and providing in-stream habitat and nutrients. Impervious surfaces can degrade aquatic ecosystems, even at levels of 10%. Impervious surfaces increase the rate that storm waters are inputted into the river thereby increasing water temperatures and changing the natural hydrology of the ecosystem. Dams create a variety of ecosystem changes. They create barriers to species movements and genetic mixing. They can hydrology and nutrient cycling as well as changing a river into a lake habitat.

Future Directions

A more in depth literature search needs to be conducted to support or refute our proposed factors. The following are additional factors that should be examined for inclusion or modification into the EO rank specifications for river natural communities:

Rank Factor – Condition

- Should the amount of time since last dredging or channelization be considered.
- Is in-stream cover component sufficient for all types of rivers?
- Is more evidence of flow regime alteration needed?
- More understanding is needed on the level of natural siltation in different natural community types.
- Should more biological components be added, such as macroinvertebrate community data?
- Other variables that should be considered?

Rank Factor – Landscape context

- Thresholds for the number of dams in the watershed is needed.
- Thresholds for percent impervious surface in the watershed or riparian area is needed.
- Should Wang et al. 2006 disturbance gradient analysis be used as a ranking factor?
- Should type and intensity of land use within the watershed be considered?
- Other variables that should be considered?

Field Surveys

Field Methods

Sites were chosen based on the potential to be of biodiversity significance or higher quality using known rare species locations or Wang et al. (2006) statewide analysis where stream reaches were designated based on a landscape disturbance gradient from reference to severe. Wang et al.'s analysis was based on available GIS data. Landscape variables used for all streams include: active mining sites, percent network watershed agricultural land use, percent network watershed urban land use, MDEQ permitted point source facilities, MDEQ's permitted point source facilities having direct connection with stream, USEPA's toxic release inventory sites, population density, number of road crossings, road density, total nitrogen loading plus (phosphorus *10) loading, watershed area treated with manure from barn yards. Additional variables for coldwater streams include: total nitrogen plus (phosphorus *10) yield. Additional variables for warmwaters streams include: dam density, USEPA's toxic release inventory sites discharging into surface water. For more information see Wang et al. (2006). We targeted stream reaches that were designated as reference or no impact.

At each road crossing site, we randomly chose a sampling reach upstream or downstream of the crossing. The sampling reach was placed outside the influence of the stream/road crossing. The reach length was delineated by multiplying the average width of the stream by 12. This reach was then used for the habitat, fish, and mussel assessments. The type of bridge crossing and whether the road crossing caused issues for fish movements was recorded at each site. We sampled multiple reaches within some VSECs at different road crossings to examine variability in instream-habitat within a single ecosystem unit, i.e. VSECs.

Reach habitat and macrohabitat surveys were performed to determine quality of stream reaches. The overall reach evaluation included the following: average width and depth, reach length, proportions of riffle, run, and pool, percent substrate composition, qualitative measures of embeddedness, siltation, instream cover, cover types, bank stability, vegetated riparian buffer width and extent, dominant riparian cover types, and canopy cover. Additionally, we completed a rapid habitat assessment for the reach which included the following parameters: epifaunal substrate / available cover, pool substrate characterization, pool variability, sediment deposition, channel flow status, channel alteration, channel sinuosity, bank stability, bank vegetative protection, and riparian vegetative zone width. Each parameter was discussed by at least 2 individuals to determine the qualitative value to ensure consistency at all sites sampled. Water quality measures were also collected at each reach including water temperature, dissolved oxygen, specific conductivity, pH, alkalinity, hardess, water color, and turbidity. For each macrohabitat evaluation macrohabitat character was determined (except run, riffle, debris pool), types and number of bars present, maximum wetted width, average thalweg depth, maximum depth, bank erosion, percent of instream cover, and types and amount of instream cover, and a pebble count was conducted.

Mussels were surveyed by wading with glass bottom buckets in a 128 m^2 area within the sampling reach. All live mussels were identified to species, length was measured, and returned back into the substrate anterior end down in the general area they were found in the stream. The presence of dreissenid mussels or Asian clams (*Corbicula fluminea*) was recorded. Empty shells were identified if no live mussels were present.

Fish were surveyed using a backpack electrofisher; the entire reach was sampled. Species were identified, measured, enumerated, and then released back into the stream. A maximum of 30 individuals were measured for each species at each site to describe the age-classes at the reach.

Field Results

A total of twenty-four reaches were sampled in nineteen VSECs (Table 1) in the southern Lower Peninsula of Michgian (Figure 1). Over 20 other sites were visited but not sampled due to poor habitat (including dry stream bed) or inaccessibility. Streams were sampled in 11 counties and 8 watersheds. Stream reaches sampled ranged in stream order from 1 to 4 and in drainage area from less than 1 to 215 square miles (Table 1). Overall, stream reaches sampled were in relatively natural landscapes. For more detail on study sites see Appendix K. Fourteen headwater and small tributary reaches were sampled in moderate gradients in a variety of water temperatures. Nine medium river reaches were sampled in low to moderate gradients and cool or warm water temperatures (Table 1). Only one large river was sampled.

Not all data was collected at all reaches (Table 2). Habitat was sampled in all reaches. Fish were sampled at 11 reaches and the number of species collected ranged from 3 to 12 in headwater and small tributary reaches and 9 to 19 in medium river reaches. Mussels were sampled at 20 reaches but native Unionids were found in only 8 reaches. At those 8 reaches, the number of species ranged from 1 to 4 in headwaters and small tributaries, 1 to 7 in medium rivers, and 6 species were found in the one large river reach sampled. Macroinvertebrates were sampled at all but 2 reaches; however, macroinvertebrate samples have not been processed.

Headwater and small tributary reaches

Fourteen headwater and small tributary stream reaches were sampled, 4 were cold water, 6 were

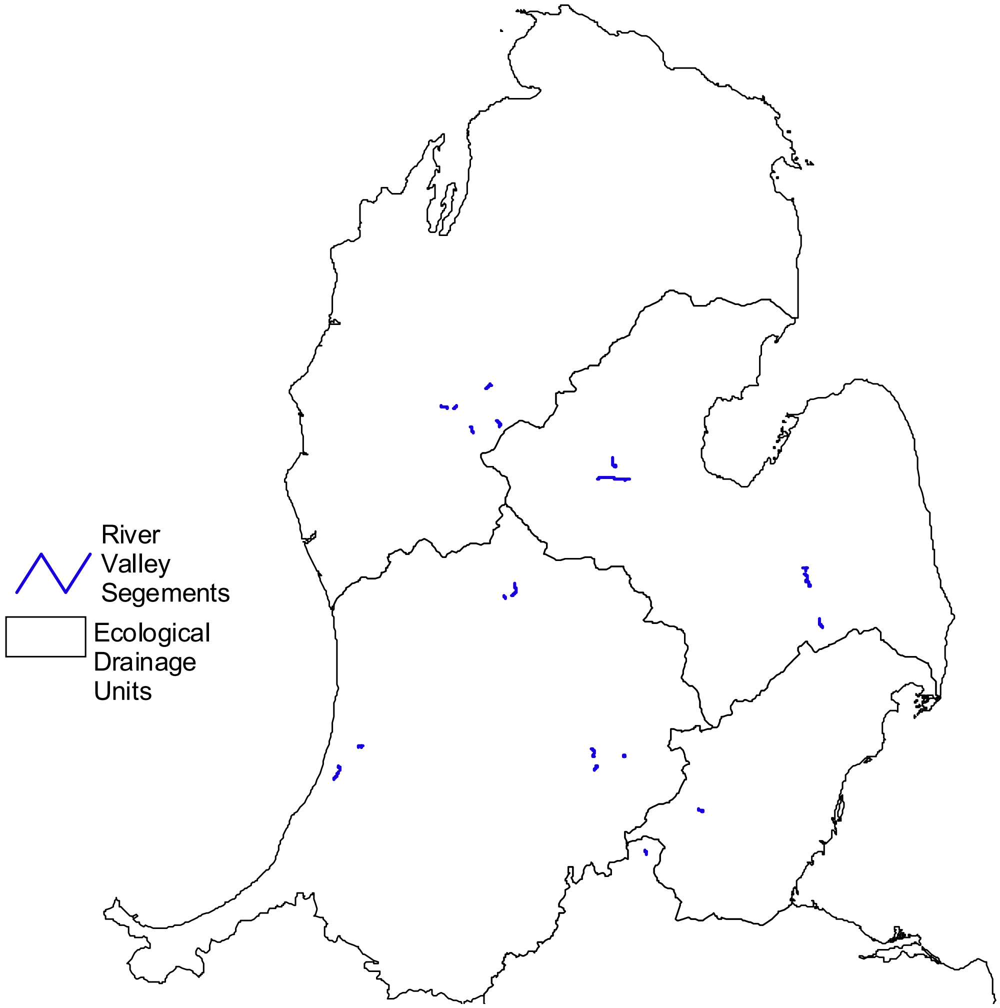

Figure 2. Location of 24 river reaches sampled in southern Lower Peninsula of Michigan. Reaches were sampled in river valley segements.

cool water, and 4 were warm water and all were of moderate gradient (Table 1). These reaches ranged in wetted width from 1.2 to 6.3 m and in average thalweg depth from 0.05 to 0.4 m. Most reaches were scored as sub-optimal using the rapid habitat assessment (RHA) method (Table 3). They were scored lower due to poor pool variability and channel sinuosity. These streams are quite small and it is not surprising that pool variability is relatively low and that the channels are relatively straight. Additionally, some reaches were ranked lower due to unstable substrates. These systems are quite sandy naturally (Table 4) and don't have a lot of rocky substrates. This habitat variable does not provide adequate quality information for sandy ecosystems. All reaches sampled had moderate to extensive in-stream cover. Woody structure was present at all sampled reaches. Overhanging vegetation, shallow water, and root mats or wads occurred at most reaches. Cold and cool headwater and small tributary reaches had very clear water, where as the warm water reaches were a bit more turbid. Alkalinity values ranged from 161 to 400 (Table 5).

Only seven headwater and small tributary reaches were sampled for fish communities, all were cool except two. Common fish species in the cool reaches included johnny darter (*Etheostoma nigrum*), green sunfish (*Lepomis* *cyanellus*), creek chub (*Semotilus atromaculatus*), and central mudminnow (*Umbra limi*). In the warm reaches, mottled sculpin (*Cottus bairdii*), grass pickerel (*Esox americanus*), johnny darter, green sunfish, and central mudminnow were common, all of these species occurred at both cool water reaches (Table 6). All headwater and small tributary reaches were searched for mussels, except site 8 (Table 7). However, mussels were found at only two sites. Five species were collected in these stream reaches including cylindrical papershell (*Anodontoides ferussacianus*), wabash pigtoe (Fusconaia flava), pocketbook (*Lampsilis ovata*), fluted-shell (*Lasmigona costata*), and giant floater (*Pyganodon gradis*).

All cold headwater and small tributary reaches were ranked as reference according to Wang et al. (2006). The cool and warm water reaches were ranked either reference or no impact. Hence, according to the landscape GIS data these streams are relatively high in quality. The field data somewhat corroborated the GIS quality ratings (Table 8). Out of the 14 reaches sampled, only 1 reach ranked less than a B using the proposed EO rank specifications and field data.

Medium reaches

Nine medium river reaches were sampled, five were cool water and 4 were warm water (Table 1). These reaches ranged in wetted width from 3.7 to 12 m and in average thalweg depth from 0.25 to 0.6 m. As for the smaller streams, most of the medium river reaches sampled scored as sub-optimal using the RHA method (Table 3). They were scored lower due to poor pool variability and epifaunal substrates. But again, some of these rivers are naturally sandy systems (Table 4) and hence will not have high amounts of stable substrates. There was more variation in substrates in these medium stream reaches than in the smaller streams. Woody structure again was present at all sampled medium river reaches. The following in-stream cover types were present at all but one medium reach: undercut banks were sparse, overhanging vegetation ranged from sparse to extensive, shallows ranged from sparse to extensive, root mats and wads were sparse. Boulders became more common than in the headwater and small tributary streams. Most medium river reaches sampled also had very clear water. Alkalinity values ranged from 144 to 382 (Table 5).

All five cool water, medium river reaches were sampled for fish communities. Fish species common to all sites were white sucker (*Catostomus commersoni*), johnny darter, and creek chub. Species occurring at all but one site were common shiner (*Luxilus cornutus*), blackside darter (*Percina maculata*), central mudminnow, and mottled sculpin (Table 9). Mussels were found at only 4 medium river reaches (Table 10). Species richness ranged at those medium reaches with mussels, from 1 to 6. No species was present at all reaches, but Spike (*Elliptio dilatata*) and Ellipse (*Venustaconcha ellipsiformis*) were more common.

Almost half of the medium river reaches sampled were designated as having detectable disturbance based on the GIS analysis (Wang et al. 2006). Regardless, most medium river reaches were ranked as a B using the proposed EO rank specifications and field data (Table 8).

Large reaches

The one large river reach sampled had an average wetted width of 9.7 m and an average thalweg depth of 0.35. This reach scored a sub-optimal using the RHA method (Table 3). Channel flow, channel sinuosity, and bank stability were ranked low for this reach. The channel flow and bank stability are not surprising since larger rivers tend to be impacted by their larger watershed, which is often degraded. This reach was dominated by sand and gravel substrates (Table 4). This reach had a variety of in-stream covers but no one component dominated. This reach was also more turbid than many of the other reaches sampled and had an alkalinity value of 235 (Table 5). No mussel species were observed at this reach. This reach was ranked as no impact using the GIS analysis and was ranked as a B quality using the proposed EO rank specifications (Table 8).

Discussion

More field data is needed throughout Michigan We were unable to collect enough data to begin to explore key habitat parameters or threshold values. More field data is needed throughout Michigan. Additionally, more data is need to explore indicator taxa for different types of river natural communities. Macroinvertebrates were collected at all sites, however they were not planned to be processed until the third year of the project. Indicator taxa analysis should also be expanded to include fish, mussels, and macrophytes. Overall, using the GIS analysis (Wang et al. 2006) or presence of rare species to pick potentially high quality sites to sample was successful based on the field data and EO ranks

Acknowledgments

Funding for this project was provided by the Michigan Department of Natural Resources, Wildlife Division. Thank you to Raymond Rustem (MI DNR). Thank you to Melanie Weber, John Matousek, and Brett Alger whose assistance in the field for this project was crucial. I would also like to thank the MNFI administrative staff (Dr. Patrick Brown, Sue Ridge, and Connie Brinson) for providing essential support for this project.

Table 1. Site name, location, year, and data collected of sites surveyed in the lower peninsula of Michigan. Drainage area is in square miles. River type is size_water temperature_gradient. For river size, code 1 = headwater and small tributary streams, code 2 = medium rivers, code 3 = large rivers, and code 4 = very large rivers. For gradient, code 1 = low, code 2 = moderate, code 3 = high. GIS quality ranking is based on Wang et al (2006); reference is considered highest quality, no impact the next, and detectable is the lowest quality.

Site Number	Major Watershed	County	Site Name	Stream Order	Drainage Area	River Type	GIS quality ranking
1	Muskegon	Osceola	Cat Creek at 155th Ave.	2	13.91	1_Cold_2	Reference
2	Muskegon	Osceola	Franz Creek at 90th Ave.	2	9.73	1_Cold_2	Reference
3	Muskegon	Osceola	Hersey Creek at 230th Rd.	1	2.61	1_Cold_2	Reference
4	Muskegon	Osceola	Olson Creek at 200th Ave.	2	24.24	1_Cold_2	Reference
5	Flint	Lapeer	Crystal Creek at Barnes Lake Rd.	1	8.54	1_Cool_2	Reference
6	Flint	Lapeer	Crystal Creek at Dockham Rd.	1	8.54	1_Cool_2	Reference
7	Grand	Jackson	Albrow Creek at Broughwell Rd.	2	6.09	1_Cool_2	No impact
8	Grand	Jackson	Spring Brook at Bangham Rd.	2	33.06	1_Cool_2	Reference
9	Grand	Jackson	Spring Brook at Sibley Rd.	3	33.06	1_Cool_2	No impact
10	Muskegon	Osceola	Thorn Creek at 7 Mile Rd.	2	14.02	1_Cool_2	Reference
11	Black - Macatawa	Van Buren	Cedar Creek at 16th Ave.	2	21.51	1_Warm_2	No impact
12	Black - Macatawa	Van Buren	Cedar Creek at 68th St.	2	21.51	1_Warm_2	Reference
13	Saginaw	Lapeer	Unnamed Stream at Otter Lake Rd.	1	0.94	1_Warm_2	No impact
14	Saginaw	Midland	Salt River at Barden Rd.	1	2.88	1_Warm_2	No impact
15	Black - Macatawa	Allegan	Middle Branch Black River at 54th St.	3	149.24	2_Cool_1	Detectable
16	Grand	Ionia	Dickerson Creek at Long Lake Rd.	4	109.04	2_Cool_1	Detectable
17	Grand	Montcalm	Dickerson Creek at Derby Rd.	4	74.24	2_Cool_1	Detectable
18	Huron	Montcalm	Dickerson Creek at M57	4	74.24	2_Cool_1	Detectable
19	Flint	Lapeer	South Branch Flint River at Hunters Creek Rd.	3	46.49	2_Cool_2	Reference
20	Raisin	Lenawee	Bean Creek at Sorby Rd.	3	68.36	2_Warm_2	No impact
21	Raisin	Washtenaw	River Raisin at Austin Rd.	3	163.80	2_Warm_2	No impact
22	Tittabawassee	Midland	Carrol Creek Drain at 9 Mile Rd.	1	46.74	2_Warm_2	Reference
23	Tittabawassee	Midland	Carrol Creek Drain at Magrudger Rd.	1	46.74	2_Warm_2	Reference
24	Saginaw	Midland	Salt River at Grant Rd.	4	215.13	3_Warm_1	No impact

Table 2. Data collected during surveys and year sampled. Habitat data was collected at all sites.

Site number	Year sampled	Fish collected	Mussel collected	Macro-invertebrates collected
1	2007		X	X
2	2007		X	X
3	2007		X	X
4	2007		X	X
5	2006	X	X	X
6	2006	X	X	X
7	2006	X	X	
8	2006	X	X	X
9	2006	X	X	
10	2007		X	X
11	2006	X	X	X
12	2006	X	X	X
13	2007		X	X
14	2007		X	X
15	2006	X	X	X
16	2006	X		X
17	2006	X		X
18	2006	X		X
19	2006	X	X	X
20	2007		X	X
21	2007		X	X
22	2007		X	X
23	2007		X	X
24	2007		X	X

Table 3. Results of the rapid habitat assessment conducted at each reach. The optimal score for each habitat variable is 20. RHA score is the overall score for each reach and is calculated by added all habitat variables. Values of 200 to 160 are considered optimal, 159 to 110 are sub-optimal, 109 to 60 are marginal, and less than 60 are poor.

site number	Habitat score	RHA score	Epifaunal substrate	Pool substrate	Pool variability	Sediment deposition	Channel flow status	Channel alteration	Channel sinuosity	Bank stability	Bank vegetative protection	Riparian vegetative zone width
1	sub-optimal	152	15	16	0	19	20	20	7	18	20	17
2	sub-optimal	152	17	17	2	19	18	20	5	18	16	20
3	sub-optimal	146	11	12	4	15	15	20	13	18	18	20
4	sub-optimal	136	9	15	7	12	14	20	7	14	18	20
5	sub-optimal	132	13	11	0	19	13	19	6	18	14	19
6	sub-optimal	148	8	14	0	19	15	19	13	20	20	20
7	sub-optimal	139	18	8	0	18	13	20	8	18	16	20
8	sub-optimal	141	1	8	2	20	20	20	10	20	20	20
9	marginal	106	1	15	0	0	19	11	2	18	20	20
10	sub-optimal	143	14	13	10	13	13	20	15	11	14	20
11	marginal	107	7	14	15	12	6	19	14	0	0	20
12	sub-optimal	152	1	13	15	20	15	20	14	20	14	20
13	sub-optimal	112	8	11	0	20	6	18	1	18	16	14
14	sub-optimal	132	4	11	1	19	15	20	12	14	16	20
15	sub-optimal	149	3	8	5	20	19	20	14	20	20	20
16	sub-optimal	140	19	16	0	18	14	20	7	12	14	20
17	sub-optimal	129	1	9	14	9	14	20	14	20	8	20
18	sub-optimal	150	18	16	0	19	15	19	7	20	16	20
19	sub-optimal	159	14	12	13	18	15	19	13	20	16	19
20	sub-optimal	128	17	13	16	11	8	20	9	5	9	20
21	sub-optimal	153	19	17	7	13	14	20	13	16	14	20
22	marginal	102	18	13	1	10	1	18	5	9	9	18
23	sub-optimal	134	15	15	9	12	10	19	6	8	20	20
24	sub-optimal	137	17	16	14	13	10	19	10	7	11	20

Table 4. Percent composition of each substrate size class within reaches, estimated using pebble counts. Substrate categories are as follows: boulders have a diameter greater than 256 mm, cobble 64-256 mm, gravel 2-64 mm, and sand 0.006-2 mm. Marl is grey and often consists of shell fragments, CPOM is coarse particulate organic matter, FPOM is fine particulate organic matter, SWD is small woody structure, and LWD is large woody structure.

Site Number	Boulder	Cobble	Gravel	Sand	Clay	Silt	Muck	Marl	CPOM	FPOM	SWD	LWD	Vegetation
1	4	7	43	40		3			3				
2			3	57		17			17			6	
3			1	44		11	6		22		13	2	
4				67		3			23			7	
5	10	13	43	20		3			3			7	
6				67			33						
7		18	12	20			50						
8				7		3	80					7	3
9	1	8	22	38		4	9		16		1	1	
10	1	8	22	38		4	9		16		1	1	
11			1	74	10	6	1		3			6	
12				69	7	5	5		9			5	
13				33		17	27	3			10	7	3
14				87		7							7
15			8	74	4		8		6				
16	5	8	67	13	7								
17				68		4	23		2		1	2	
18	3	3	33	43		17							
19	1		26	42		24	7						
20	3	4	55	16	1	2	8		8			3	
21	6	24	51	10		1			1		3	2	2
22				23	3	20			17	10	27		
23				20	2	13	24		3	14	14	3	4
24	6	7	31	25	4	9	3		3		3	1	8

Table 5. Water quality parameters measured at each reach.

Site Number	Water Temperature (C°)	Dissolved Oxygen (mg/L)	Specific Conductivity (µS)	pH	Alkalinity	Water Clarity (cm)
1	18.5	8.65	521	8.34	175	>120
2	14.4	8.67	396	8.30	242	>120
3	16.3	8.02	186	8.29	115	>120
4	15.6	9.05	374	8.33	240	>120
5	14.2	8.51	689	8.13	364	>120
6	11.5	6.61	642	7.87	360	>120
7	19.3	7.23	740	8.08	400	>120
8	17.5	7.97	-	7.85	265	>120
9	20.1	8.66	592	8.21	330	>120
10	15.0	10.51	512	8.45	270	>120
11	16.5	8.05	469	8.08	161	107
12	15.2	7.89	371	7.97	180	70
13	18.5	8.63	581	8.37	320	85
14	21.1	8.04	641	8.43	340	-
15	17.2	7.55	377	7.94	144	119
16	15.0	8.72	503	8.36	222	>120
17	17.2	7.86	512	8.24	235	>120
18	15.5	8.83	522	8.28	218	>120
19	13.2	9.73	669	8.45	360	>120
20	14.5	9.20	735	8.47	382	102
21	17.6	9.93	535	8.50	230	>120
22	18.8	6.30	962	8.11	195	-
23	22.4	9.38	580	8.12	220	-
24	20.8	8.06	1134	8.31	235	95

Table 6. Abundance of fish species collected during surveys in headwater and small tributary reaches.

		Cool Water					Warm Water	
Species	Fish Species	5	6	7	8	9	11	12
Ambloplites rupestris	rock bass					1		
Catostomus commersoni	white sucker	1				1	8	
Cottus bairdii	mottled sculpin						24	17
Culaea inconstans	brook stickleback				7			
Esox americanus	grass pickerel					1	1	3
Etheostoma blennioides	greenside darter		7					
Etheostoma nigrum	johnny darter	16		1	18		20	11
Icthyomyzon sp.	Icthyomyzon sp.				1			
Lepomis cyanellus	green sunfish	8	15			2	6	4
Lepomis gibbosus	pumpkinseed					5		
Lepomis macrochirus	bluegill					6		
Luxilus cornutus	common shiner	14					20	
Micropterus salmoides	largemouth bass	1				1		
Nocomis biguttatus	hornyhead chub						2	
Noturus gyrinus	tadpole madtom					10		
Percina maculata	blackside darter	2			1		1	
Pimephales notatus	bluntnose minnow	38			2		2	
Rhinichthys obtusus	blacknose dace			2			4	
Semotilus atromaculatus	creek chub	63	1	6			13	
Umbra limi	central mudminnow	2	3		36		4	2
Total number of fish collected:		145	26	9	65	27	105	37

Table 7. Live native mussel species found during surveys of headwater and small tributary streams. Site number 8 was not surveyed for mussels.

			Cold Water					Cool Water				Warm Water		
Mussel Species	Common Name	1	2	3	4	5	6	7	9	10	11	12	13	14
Alasmidonta viridis	slippershell mussel													
Anodontoides ferussacianus	cylindrical papershell									2				
Elliptio dilatata	spike													
Fusconaia flava	wabash pigtoe								2					
Lampsilis fasciola	wavy-rayed lampmussel													
Lampsilis ovata	pocketbook								2					
Lampsilis siliquoidea	fatmucket													
Lampsilis ventricosa	lamp-mussel													
Lasmigona costata	fluted-shell								1					
Ligumia recta	black sandshell													
Pyganodon gradis	giant floater								3					
Strophitus undulatus	strange floater													
Venustaconcha ellipsiformis	ellipse													
Villosa iris	rainbow													
Total:		0	0	0	0	0	0	0	8	2	0	0	0	0

Table 8. Site quality ratings using GIS and field data. GIS quality based on Wang et al. (2006) and field quality based on proposed EO rank specifications. A is higher quality and C is lesser quality.

Site Number	River Type	GIS Quality	Field Quality
1	1_Cold_2	Reference	A
2	1_Cold_2	Reference	B
3	1_Cold_2	Reference	B
4	1_Cold_2	Reference	A
5	1_Cool_2	Reference	B
6	1_Cool_2	Reference	A
7	1_Cool_2	No impact	B
8	1_Cool_2	Reference	B
9	1_Cool_2	No impact	B?
10	1_Cool_2	Reference	B
11	1_Warm_2	No impact	C?
12	1_Warm_2	Reference	B
13	1_Warm_2	No impact	B?
14	1_Warm_2	No impact	B
15	2_Tran_1	Detectable	B?
16	2_Cool_1	Detectable	B?
17	2_Cool_1	Detectable	C?
18	2_Cool_1	Detectable	B?
19	2_Cool_2	Reference	A
20	2_Warm_2	No impact	B?
21	2_Warm_2	No impact	B
22	2_Warm_2	Reference	B
23	2_Warm_2	Reference	BC?
24	3_Warm_1	No impact	B

Table 9. Abundance of fish species collected during surveys in medium, cool river reaches.

Species	Fish Species	15	16	17	18	19
Ambloplites rupestris	rock bass		23			25
Ameiurus natalis	yellow bullhead		1			
Catostomus commersoni	white sucker	17	1	4	14	3
Cottus bairdii	mottled sculpin	54	9	9	13	
Esox americanus	grass pickerel	1		1		
Esox lucius	northern pike				1	
Etheostoma caeruleum	rainbow darter		95			1
Etheostoma nigrum	johnny darter	41	12	17	26	1
Hypentelium nigricans	northern hog sucker		1			8
Lampetra or Icthyomyzon	lamprey sp.		1		6	
Lepomis gibbosus	pumpkinseed					
Lepomis macrochirus	bluegill	4			1	
Luxilus cornutus	common shiner	1	6		2	19
Micropterus dolomieu	smallmouth bass		1			2
Micropterus salmoides	largemouth bass		2			
Nocomis biguttatus	hornyhead chub		4			34
Noturus gyrinus	tadpole madtom					
Perca flavescens	yellow perch				1	1
Percina maculata	blackside darter	5	4		2	2
Pimephales notatus	bluntnose minnow				2	3
Rhinichthys obtusus	blacknose dace		43	2	8	
Semotilus atromaculatus	creek chub	4	36	13	23	6
Umbra limi	central mudminnow	7	6	9	3	
Total number of fish collected:		134	245	55	102	105

Table 10. Live native mussel species found during surveys of medium and large rivers.

		Medium Rivers									Large Rivers
		Cool Water					Warm Water				
Mussel Species	Common Name	15	16	17	18	19	20	21	22	23	24
Alasmidonta viridis	Slippershell mussel		1		13		1				
Anodontoides ferussacianus	Cylindrical papershell				1						
Elliptio dilatata	Spike		4		17	1	4				
Fusconaia flava	Wabash pigtoe				3		11	2			4
Lampsilis fasciola	Wavy-rayed lampmussel							4			
Lampsilis ovata	Pocketbook										2
Lampsilis siliquoidea	Fatmucket						8				2
Lampsilis ventricosa	Lamp-mussel							9			
Lasmigona costata	Fluted-shell					2					
Ligumia recta	Black sandshell	2									
Pyganodon gradis	Giant floater										
Strophitus undulatus	Strange floater				2			6			7
Venustaconcha ellipsiformis	Ellipse		34		45	3					5
Villosa iris	Rainbow		5			7	1				
Total:		2	44	0	81	13	25	21	0	0	20

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Appendices

Appendix A

Descriptions of Ecological Drainage Units in Michigan

There are nine Ecological Drainage Units in Michigan, the following paragraphs briefly describe each one in terms of climate, major landforms, water features, and zoogeography.

Southeast Michigan Interlobate and Lake Plain (SEMILP) contains most of the Lake Erie drainage in Michigan. Mean annual temperature is 48.6˚F (sd 1.1) and has a mean annual precipitation of 30.5 inches (sd 4.8). This EDU contains many kettle lakes, ponds, and wetland complexes in the interlobate headwaters region. In the lake and till plains, there are few lakes but many low gradient streams. Historically, all streams flow to the Ohio River via the Teays River but today they all flow into western Lake Erie and Lake St. Clair.

Only a small portion of the Western Lake Erie (WLE) EDU is in Michigan, most of the EDU is in Ohio. The mean annual temperature in this EDU is 48.6-50.1˚F (sd 1.0-1.2) and the mean annual precipitation is between 30.5-34.3 (sd 4.6-4.8) inches. This EDU mainly has low gradient, surface water-fed streams except in the interlobate area (along the glacial boundary) where moderate gradient streams occur. Historically, all streams drained to the Ohio River via Teays River but today they all flow into western Lake Erie.

The Saginaw Bay (SB) EDU if found in the lower half of the Huron River Basin. The mean annual temperature is 48.5 to 43.3 (sd 1.08) ˚F and the mean annual precipitation is 29.2 (sd 3.8) to 31.7 (sd 4.56) inches from south to north respectively. Many of the streams in this EDU are intermittent. Those that are perennial are part of the Saginaw River system and are generally low gradient streams. Historically, all streams drained west out to the Grand River into Lake Chicago but today they drain to Saginaw Bay and Lake St. Clair.

The Southeast Lake Michigan (SELM) EDU is the southern portion of the Lake Michigan basin. Mean annual air temperatures range from 48.6 (sd 1.15) to 47.4 (sd 1.11) ˚F and mean annual precipitation is 35.1 (sd 4.9) to 31.7 (sd 4.56) inches with the rain shadow from west to east. This EDU has three major river systems (Grand, Kalamazoo, and St. Joseph) which flow east to west. There are many kettle lakes in the interlobate region to the east, which forms the headwaters of all three river systems. Historically, all waters in this region drained west out the Grand River into Lake Chicago, today all rivers flow west to southern Lake Michigan.

The Northern Lake Michigan, Lake Huron, and Straits of Mackinac (NLMLHSM) EDU encompasses the northern half of the lower peninsula of Michigan. Mean annual air temperatures range from 46.1 (sd 1.16) to 43.3 (sd 1.08) ˚F from west to east and mean annual precipitation ranges from 33.1 (sd 4.38) to 29.5 (sd 3.29) inches from west to each with a rain shadow from southwest to northwest. There are kettle lakes in the outwash plains areas. In the lake plain area there are some large lakes, lakes of many geneses, and intermittent streams. Groundwater streams can be found in the outwash surrounded by coarse moraines and ice contact. Historically, this area likely drained to the St. Lawrence River via the Ottowa River and Champlain Sea but today, rivers drain west to Lake Michigan, east to Lake Huron, and north to the straits. The Lake Michigan and Lake Huron drainage divide roughly bisects this EDU.

In the Eastern Upper Peninsula (EUP) EDU the mean annual temperature is 41.1 (sd 1.06) ˚F and the mean annual precipitation is 32.5 (sd 4.07) inches. This EDU has many small and medium sized low-gradient streams which are underlain by deep sandy outwash deposits or sedimentary rock. They are also often connected to wetlands. Historically, the streams in this area likely drained to the St. Lawrence River via the Ottowa River and Champlain Sea, but today waters drain to the north to Lake Superior and to the south to Lakes Michigan and Huron and to the St. Mary's River.

In the Central Upper Peninsula (CUP) EDU the mean annual temperature is 40.4 (sd 1.22) ˚F and the mean annual precipitation is 32.5 (sd 4.39) inches. Half of this EDU is within the Menominee River drainage. There are many lakes, spring ponds, springs, wetlands, and streams in this EDU. Kettle lakes are common. Streams tend to be low in density and have dendritic drainages and high spring and fall water flows with relatively low flows in the summer. These low gradient streams are underlain by sandy outwash, limestone, or shale. Historically, the waters in this EDU drained south to the Mississippi River via a connection through Green Bay (Wolf/Fox Rivers), but today it drains north to Lake Superior and south to northern Lake Michigan / Green Bay.

The Western Upper Peninsula and Keweenaw Peninsula (WUPKP) EDU has mean annual air temperatures of 40.42 (sd 1.22) ˚F and a mean annual precipitation of 32.5 (sd 4.39) inches. This EDU has many kettle lakes in the outwash plains. Historically, the waters in this EDU drained to the upper Mississippi River via St. Croix River drainage of glacial Lake Duluth with a possible connection to Hudson Bay and Lake Agassiz. Today the waters drain to the southwest into Lake Superior.

A very small portion of Michigan is in the Bayfield Peninsula and Uplands (BPU) EDU. The mean annual temperature in this EDU is 41.41 (sd 1.16) ˚F and the mean annual precipitation is 31.29 (sd 5.39) inches, this precipitation. There are few lakes in this EDU and the streams are low gradient and flow from west to east into Lake Michigan. Historically, this EDU drained to the Mississippi River via the Fox River, but today it drains to western Lake Michigan.

Appendix B

Draft EO and Rank Specifications for Rivers - Level 3 - VSECs

"An Element Occurrence (EO) is an area of land and/or water in which a species or natural community is, or was, present" (NatureServe 2000). Since rivers and streams are linear ecosystems that create a continuum, they are difficult to delineate and differentiate. But the ability to define an EO is important to the heritage inventory method and is the basis for conservation planning (NatureServe 2000). Presented here are Draft EO specifications for River Natural Community Elements Level 3 – VSECs, the finest scale proposed.

SPECS GROUP

Lotic ecosystesm - rivers and streams

NATURAL COMMUNITY MAPPING UNIT

River valley segment (VSEC) (Seelbach et al. 1997, 2007)

NATURAL COMMUNITY MAPPING UNIT JUSTIFICATION

Because rivers and streams are linear and form a continuum, it is difficult to delineate where river ecosystem start and stop. But there has recently been extensive work in Michigan on river valley segments. These VSECs were determined by modeling available information on landscape data as well as expert review. These VSECs are aggregated reaches (a reach is a stream section between confluences) that have similar landscape attributes such as water temperature, geology, valley character type, and water source. The VSECs are large enough such that ecological processes likely function at this scale. These units provide a meaningful way to delineate river ecosystems. This work is on-going (Seelbach et al. 1997, 2007), but is expected to be finalized soon (P. Seelbach, personal communications).

MINIMUM SIZE

500 m

The recommended minimum length for linear communities is 30 m. This is not adequate for aquatic processes, hence a 500 m length is proposed. This is a minimum distance that non-mobile fish may move (see literature cited below). Mussel movements are generally associated with fish, hence by accounting for the largest and most mobile river species we expect this minimum distance is sufficient.

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Storck, T. and W.T. Momot. 1981. Movements of the creek chub in a small Ohio stream. Ohio Journal of Science 81(1): 9-13.

EO Separation

SEPARATION BARRIER

Barriers that would separate river communities include dams, concrete channels, below ground channels, large stretches of channelization, perched culverts, lakes or reservoirs.

SEPARATION DISTANCE – DIFFERENT NATURAL / SEMI-NATURAL COMMUNITIES

SEPARATION JUSTIFICATION

It is difficult to develop separation distance guidelines for different natural or semi-natural communities for rivers and streams due to their linear, complex, and continuum nature. Hence, no separation distance is currently proposed.

Edition

SPECS AUTHOR

Derosier, A.L.

SPECS EDITION DATE

2007-10-05

SPEC NOTES

This is a proposed draft EO Specification for streams and rivers. This draft still needs to go through a review process.

EO Rank Specs

RANK SPECS GROUP

RANK PROCEDURE

Condition and landscape context are weighted equally for this type because linear ecosystems are strongly affected by the surrounding watershed as well as the local conditions.

EO RANK FACTOR *[1st]*

Condition – is an integrated measure of the quality of biotic and abiotic factors, structures, and processes *within* the occurrence, and the degree to which they affect the continued existence of the EO. Components of this factor are: ecological processes, species composition and biological structure, abiotic physical and chemical factors (taken from pg. 45, NatureServe 2002).

A SPECS

a) Instream cover is abundant (>25% of channel) and diverse (more than one type of cover). In-stream cover can include: undercut banks, overhanging vegetation, shallows in slow water, pools greater than 70 cm, root mats or wads, aquatic vegetation, woody structure, boulders. Streams with forested riparian buffers should have large woody structure available as in-stream cover. Streams with grassy riparian buffers should have overhanging vegetation available as in-stream cover.
b) Water temperatures fall within natural variability of temperature regimes of natural community type.
c) Little or no siltation.
d) Stream banks are stable.

B SPECS

a) Instream cover is moderately abundant (>10% of channel) and diverse (more than one type of cover). In-stream cover can include: undercut banks, overhanging vegetation, shallows in slow water, pools greater than 70 cm, root mats or wads, aquatic vegetation, woody structure, boulders. Streams with forested riparian buffers should have large woody structure available as in-stream cover. Streams with grassy riparian buffers should have overhanging vegetation available as in-stream cover.

b) Water temperatures fall within natural variability of temperature regimes of natural community type.
c) Some light to moderate silt is present.
d) Stream banks have some erosion but it is not extensive.
e) Exotic fish, clams, or macrophytes may be present at low densities.

C SPECS

a) Instream cover is present. In-stream cover can include: undercut banks, overhanging vegetation, shallows in slow water, pools greater than 70 cm, root mats or wads, aquatic vegetation, woody structure, boulders.
b) Water temperatures fall within temperature regimes of natural community.
c) Some moderate silt is present.
d) Stream bank erosion is moderate.
e) Some exotic fish, clams, or macrophyte species.
f) Dredging or channelization occurred but vegetation has re-grown and stream starting to meander.

D DPECS

a) Instream cover is absent.
b) Water temperatures are not within temperature regimes of natural community.
c) Siltation is moderate to extensive.
d) Stream bank erosion is moderate to extensive.
e) Exotic species are common. Exotic mussels species are present: zebra mussels, quagga mussels.
f) Dredging or channalization recent.

RANK SPEC JUSTIFICATION

FACTORS TO EXAMINE FOR INCLUSION OR MODIFICATION

- More in depth literature search is needed to back or refute proposed factors.
- Amount of time since last dredging / channalization
- Is in-stream cover factor sufficient for all types of rivers?
- Evidence of flow regime alteration
- How can we distinguish between natural siltation and siltation due to human activities?
- Include more biological components? Macroinvertebrate community data?
- Water quality parameters within normal variation? More details needed.
- Others?

EO RANK FACTOR *[2nd]*

Landscape context – is an integrated measure of the quality of biotic and abiotic factors, structures, and processes *surrounding* the occurrence, and the degree to which they affect the continued existence of the EO. Components of this factor are: landscape structure and extent, including genetic connectivity, condition of the surrounding landscape (taken from pg. 46, NatureServe 2002).

A SPECS

a) Riparian buffer is wide (>50 m).
b) Amount of impervious surfaces in watershed is low.
c) Number of dams in watershed is low.

B SPECS

a) Riparian buffer is wide (>50 m).
b) Local riparian buffer and upstream riparian buffer is wide.
c) Amount of impervious surfaces in watershed is low to moderate.
d) Number of dams in watershed is low to moderate.

C SPECS

a) Riparian buffer is wide (>50 m).
b) Amount of impervious surfaces in watershed is moderate.
c) Number of dams in watershed is moderate.

D DPECS

a) Riparian buffer is wide (>50 m).
b) Amount of impervious surfaces is moderate to high.
c) Number of dams in watershed is high.

RANK SPEC JUSTIFICATION

FACTORS TO EXAMINE FOR INCLUSION OR MODIFICATION

- More in depth literature search is needed to back or refute proposed factors.
- Thresholds for the number of dams in watershed is needed.
- Thresholds for percent impervious surface in watershed or riparian buffer or critical watershed area is needed.
- Use of disturbance gradient (Wang et al. 2006?) analysis as a factor
- Number of point-source facilities in watershed
- Number of active mining operations or farming operations in watershed
- Others?

RANK SPECS AUTHOR

A.L. Derosier

RANK SPECS EDITION DATE

October 5, 2007

RANK SPEC NOTES

This is a proposed draft EO Rank Specification for streams and rivers. This draft still needs to go through a review process.

Appendix C

Draft Natural Community Types of Rivers - Level 3 - VSECs

Drafted by A.L. Derosier
October, 2007

The classification to determine different types of Level 3 or VSEC river natural communities proposed here is based on size, water temperature, and gradient. Physical, chemical, and biological changes occur along a longitudinal gradient from the headwaters to very large rivers (Vannote et al. 1980 – river continuum concept). Rivers do vary from this general model, however it provides a generalized model for determining and defining river communities. The size of a stream or river generally helps determine where the primary energy inputs come from. Water temperature is also important because species have optimum temperature preferences determining associated species. Gradient provides a measure of channel morphology which correlates to valley shape, sinuosity, water velocity, and substrate size. Hence, all three factors are important in determining species compositions in rivers.

Four size classes were defined using drainage areas of VSECs, following the Wildlife Action Plan (Eagle et al. 2005): headwaters and small tributaries are less than 40 mi^2, medium rivers are between 40 and 179 mi^2, large rivers are between 180 and 620 mi^2, and very large rivers are greater than 620 mi^2. Three classes of temperature were defined for each VSEC: cold (<19°C), cool (19-22°C), and warm (>22°C). And three classes of gradient were defined, where low were those VSECs with an average gradient less than 0.001, moderate was between 0.001 and 0.006, and high was greater than 0.006. Gradient classes were defined using the 25^{th} and 75^{th} percentiles of all stream reach gradients, so less than the 25^{th} percentile was low, greater than the 75^{th} percentile was high, and the rest were defined as moderate. VSEC gradient is the average gradient of the reaches that make up a VSEC. A reach is a segment of stream between confluences.

Table 1. Summary of the number of river valley segments (VSECs) for headwater and small tributary streams, medium rivers, large rivers, and very large rivers for each temperature and gradient combination statewide according to the available GIS data. This table does not include VSECs that were not fully classified or classified as transitional water temperature.

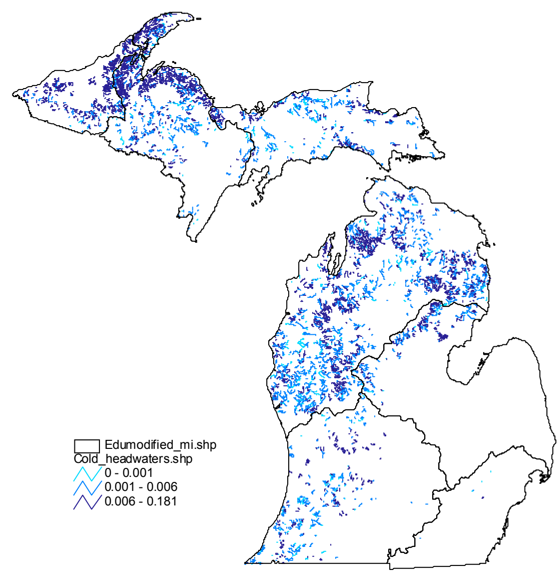
Water Temperature	Gradient	Headwaters and small tributaries	Medium rivers	Large rivers	Very large rivers
Cold	low	139	24	4	0
	moderate	1007	89	10	0
	high	1658	12	1	0
Cool	low	449	131	42	8
	moderate	1793	155	36	17
	high	689	19	6	2
Warm	low	384	135	78	92
	moderate	1317	141	44	44
	high	360	3	4	10

HEADWATER AND SMALL TRIBUTARY STREAMS

Table 2. Summary of the number of VSECs for headwater and small tributary streams for each temperature and gradient combination within each EDU according to available GIS data.

Water Temperature	Gradient	Ecological Drainage Units[1] SELM	SB	NLMH	WUPKP	EUP	CUP	SEMI
Cold	Low	20	3	66	3	19	26	2
	Moderate	145	57	448	51	113	181	12
	High	155	81	623	306	109	383	1
Cool	Low	165	39	59	11	53	47	75
	Moderate	580	231	64	48	225	262	283
	High	139	61	48	226	33	82	100
Warm	Low	59	198	5	2	7	5	108
	Moderate	284	706	33	9	38	44	203
	High	60	211	5	70	2	4	8
Unclassified		161	61	95	113	24	157	106

Cold, Headwater and Small Tributary Streams



Overview: Headwater and small tributary streams tend to be shaded and rely on energy inputs from riparian vegetation. These natural communities or ecosystems are small wadeble streams that have a midpoint catchment area less than 40 square miles. These streams have low Strahler stream orders, often below 2. These small ecosystems typically have mean July temperatures less than 19˚C (66˚F). The water source for these streams is dominated by groundwater flow and have relatively high and stable baseflows. They typically pass through unconfined alluvial valleys.

These small streams heavily influence the ecosystem health and functioning of the stream network of which they are a part of. There are relatively few ecosystems of this type in Michigan (Table 1).

Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.

Moderate gradient: These ecosystems can have a variety of substrates.

[1] Ecological drainage unit codes: SELM – Southeast Lake Michigan, SB – Saginaw Bay, NLMH – Northern Lake Michigan, Lake Huron, and Straits of Mackinac, WUPKP – Western Upper Peninsula and Keweenaw Peninsula, EUP – Eastern Upper Peninsula, CUP – Centeral Upper Peninsula, SEMI – Southeast Michigan Interlobate and Lake Plain

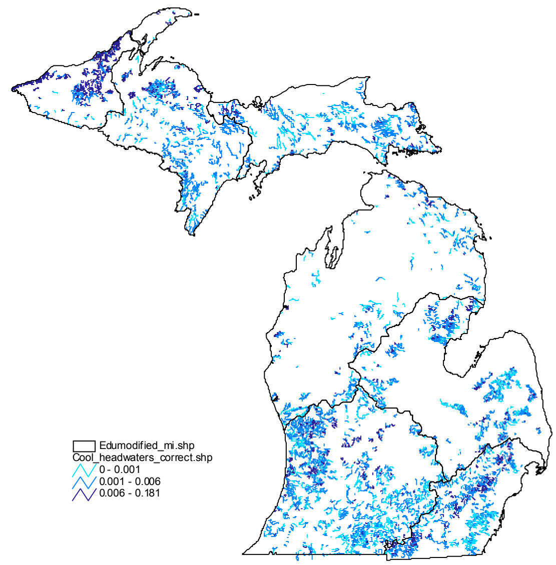
High gradients: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by shredders. The fish communities tend to include trout or salmon species, sculpin species, and blacknose dace.

Characteristic plants or algae:

Cool, Headwater and Small Tributary Streams:

Overview: Headwater and Small Tributary Streams tend to be shaded and rely on energy inputs from riparian vegetation. These natural communities or ecosystems are small wadeble streams that have a midpoint catchment area less than 40 square miles. These streams have low Strahler stream orders, often below 2. These small ecosystems typically have mean July temperatures ranging from 19-22°C (66-X°F). The water source for these streams are dominated by run-off flow and have moderate baseflows and moderate to high peak flows. They typically pass through unconfined alluvial valleys. These small streams heavily influence the ecosystem health and functioning of the stream network of which they are a part of.



Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.

Moderate gradient: These ecosystems can have a variety of substrates.

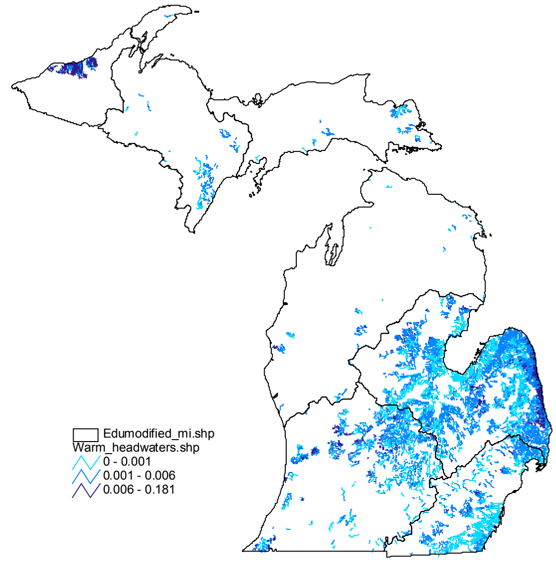
High gradients: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by shredders. Hungerfords crawling water beetle are found in these natural communities. The fish community tends to include hornyhead chub, logperch, white sucker.

Characteristic plants or algae: Aquatic macrophytes are limited, but mosses and periphyton are often present.

Warm, Headwater and Small Tributary Streams:

Overview: Headwater and Small Tributary Streams tend to be shaded and rely on energy inputs from riparian vegetation. These natural communities or ecosystems are small wadeble streams that have a midpoint catchment area less than 40 square miles. These streams have low Strahler stream orders, often below 2. These small ecosystems typically have mean July temperatures greater than 22°C (X°F). The water source for these streams are dominated by run-off flow and have lower baseflows and higher peak flows than cool or cold water headwater systems. They typically pass through unconfined alluvial valleys. These small streams heavily influence the ecosystem health and functioning of the stream network of which they are a part of.



Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.

Moderate gradient: These ecosystems can have a variety of substrates.

High gradients: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by shredders. The fish community tends to include ??.

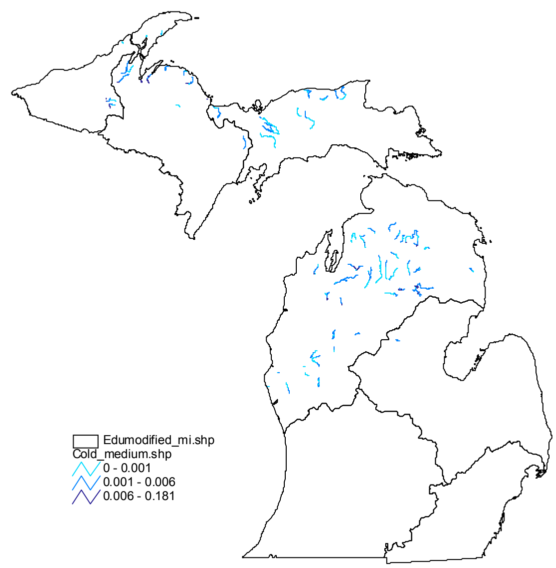
Characteristic plants or algae: Aquatic macrophytes are limited, but mosses and periphyton are often present.

MEDIUM RIVERS

Table 3. Summary of the number of VSECs for medium rivers for each temperature and gradient combination within each EDU according to available GIS data.

		Ecological Drainage Units[1]						
Water Temperature	Gradient	SELM	SB	NLMH	WUPKP	EUP	CUP	SEMI
Cold	Low	1	0	12	2	6	3	0
	Moderate	0	1	54	8	11	15	0
	High	0	0	2	1	0	9	0
Cool	Low	59	15	21	1	13	17	5
	Moderate	35	19	29	13	6	46	7
	High	0	0	0	5	0	14	0
Warm	Low	30	47	11	3	4	2	38
	Moderate	23	61	1	5	5	4	42
	High	0	1	0	0	0	0	2
Unclassified		22	20	62	32	26	33	0

Cold, Medium Rivers:



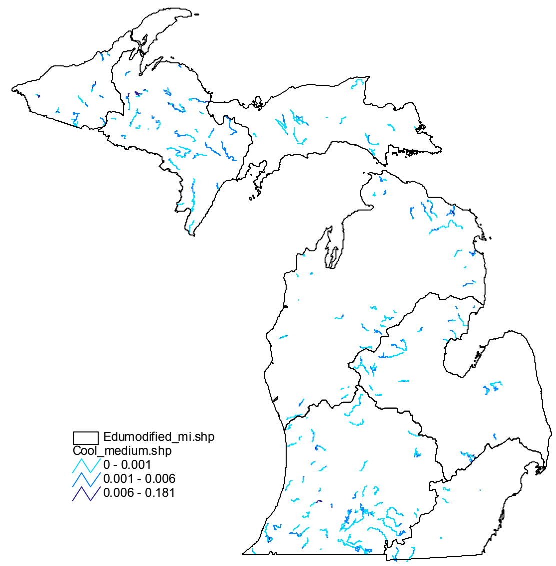
Overview: Medium rivers are wadable streams that have a midpoint catchment area from 40 to 179 square miles. They are of intermediate Strahler stream order (generally 3-5). These ecosystems have more variable and diverse substrates and habitat than headwater ecosystems. These rivers tend to be less shaded and rely on energy inputs from primary production. The source of water for these ecosystems are dominated by ground-water and have relatively high baseflow and peak flows. Most of these ecosystems have low to moderate gradient and flow through unconfined alluvial valleys. The mean July water temperatures in these ecosystems are less than 19°C (66°F).

> Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.
>
> Moderate gradient: These ecosystems can have a variety of substrates.
>
> High gradients: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by grazers. Fish Species of Greatest Conservation Need associated with these natural communities are lake sturgeon, brassy minnow, finescale dace, slimy sculpin.

Characteristic plants or algae: Aquatic macrophytes are more prominent, and periphyton are often present.

Cool, Medium Rivers:



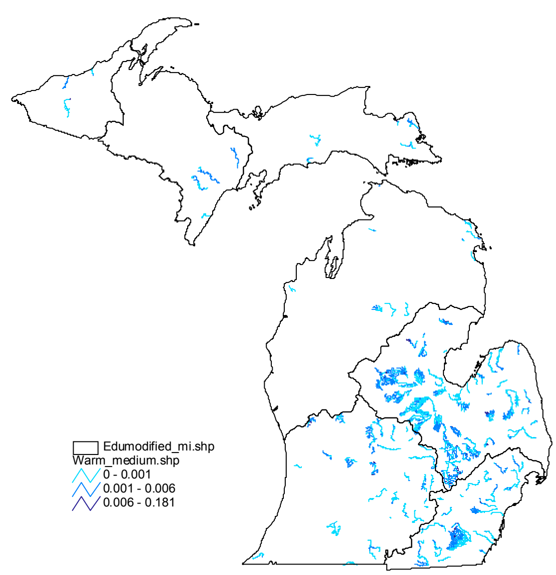
Overview: Cool medium rivers are wadable rivers that have a midpoint catchment areas from 40 to 179 square miles. They are of intermediate Strahler stream order (generally 3-5). These ecosystems have more variable and diverse substrates and habitat than headwater ecosystems. These rivers tend to be less shaded and rely on energy inputs from primary production. The source of water for these ecosystems are dominated by run-off and have low to moderate baseflow and fair to moderate peak flows. The majority of cool, medium river ecosystems have low to moderate gradient and flow through unconfined glacial or alluvial valleys. The mean July water temperatures in these ecosystems range from 19-22°C (66-72°F).

> <u>Low gradient</u>: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.
>
> <u>Moderate gradient</u>: These ecosystems can have a variety of substrates.
>
> <u>High gradients</u>: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by grazers.

Characteristic plants or algae: Aquatic macrophytes are more prominent, and periphyton are often present.

Warm, Medium Rivers:



Overview: Cool medium rivers are wadable rivers that have a midpoint catchment areas from 40 to 179 square miles. They are of intermediate Strahler stream order (generally 3-5). These ecosystems have more variable and diverse substrates and habitat than headwater ecosystems. These rivers tend to be less shaded and rely on energy inputs from primary production. These ecosystems typically have mean July temperatures greater than 22°C (72°F). The water source for these streams are dominated by run-off flow and have lower baseflows and higher peak flows than cool or cold water headwater systems. They typically pass through unconfined alluvial valleys.

Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.

Moderate gradient: These ecosystems can have a variety of substrates.

High gradients: These ecosystems can have a variety of substrates, but hard substrates are more common because the softer substrates are flushed downstream.

Characteristic animals: The macroinvertebrate communities tend to be dominated by shredders. The fish community tends to include ??.

Characteristic plants or algae: Aquatic macrophytes are more prominent, and periphyton are often present.

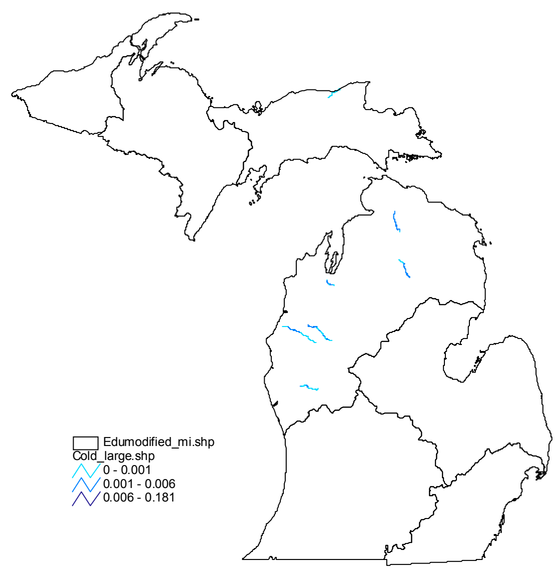
LARGE RIVERS

Table 4. Summary of the number of VSECs for large rivers for each temperature and gradient combination within each EDU according to available GIS data.

		Ecological Drainage Units[1]						
Water Temperature	Gradient	SELM	SB	NLMH	WUPKP	EUP	CUP	SEMI
Cold	Low	0	0	3	0	1	0	0
	Moderate	0	0	10	0	0	0	0
	High	0	0	1	0	0	0	0
Cool	Low	9	11	11	1	4	6	0
	Moderate	7	6	4	11	0	8	0
	High	1	1	0	4	0	0	0
Warm	Low	26	27	10	2	2	1	10
	Moderate	6	18	3	4	1	4	8
	High	1	2	0	1	0	0	0
Unclassified		16	4	45	16	9	31	0

Cold, Large Rivers:

Overview: Large rivers tend to rely on energy inputs from upstream. These ecosystems tend to have pelagic communities. These ecosystems are wadable and non-wadable rivers that have a midpoint catchment areas between 180 to 620 square miles. These rivers are of intermediate to high Strahler stream order and have diverse substrate and habitat. "Cold large rivers in Michigan are typically groundwater-driven with high to very high baseflow and low to moderate peak flow, and pass through several different valley types including unconfined glacial and alluvial valleys, as well as confined and sporadically confined glacial valleys". These ecosystems typically have mean July temperatures less than 19˚C (66˚F). These ecosystems in Michigan are rare.



Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited.

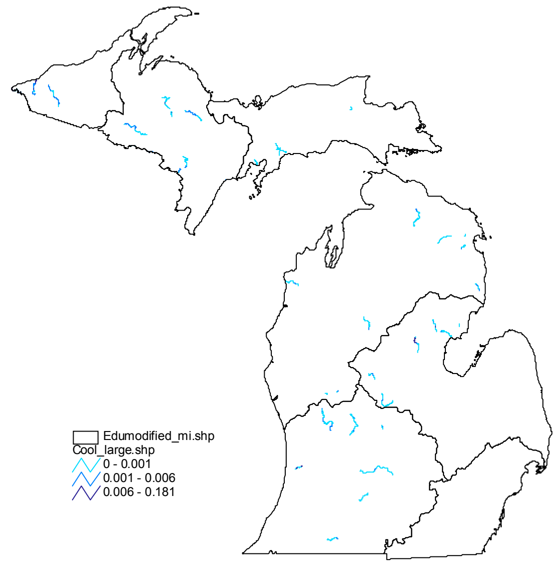
Moderate gradient: These ecosystems can have a variety of substrates. This is the dominant type for cold, large rivers.

High gradients: High gradient, cold large rivers are very rare, only one VSEC in Michigan has been classified this way.

Characteristic animals: The macroinvertebrate communities tend to be dominated by collectors. Zooplankton are a larger component of the community.

Characteristic plants or algae: Aquatic macrophytes may or may not be present, dependent upon water clarity.

Cool, Large Rivers:



Overview: Large rivers tend to rely on energy inputs from upstream. These ecosystems tend to have pelagic communities. These ecosystems are wadable and non-wadable rivers that have a midpoint catchment areas between 180 to 620 square miles. These rivers are of intermediate to high Strahler stream order and have diverse substrate and habitat. "Cool large rivers in Michigan are usually run-off driven systems with fair to moderate baseflow and peak flow". The majority of cool, large rivers flow through confined or unconfined glacial or alluvial valleys. These ecosystems typically have mean July temperatures ranging from 19-22˚C (66-72˚F).

Low gradient: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited. The majority of cool, large rivers are low to moderate in gradient.

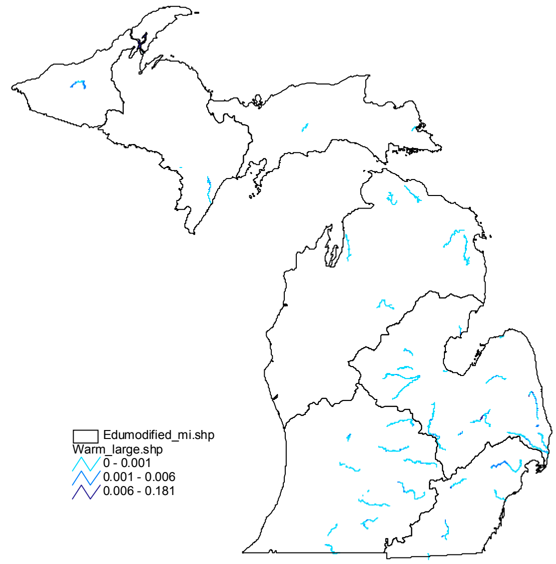
Moderate gradient: These ecosystems can have a variety of substrates. The majority of cool, large rivers are low to moderate in gradient.

High gradients: Cool, high gradient, large rivers are quite rare in Michigan.

Characteristic animals: The macroinvertebrate communities tend to be dominated by collectors. Zooplankton become a larger component of the community.

Characteristic plants or algae: Aquatic macrophytes may or may not be present, dependent upon water clarity.

Warm, Large Rivers:



Overview: Large rivers tend to rely on energy inputs from upstream. These ecosystems tend to have pelagic communities. These ecosystems are wadable and non-wadable rivers that have a midpoint catchment areas between 180 to 620 square miles. These rivers are of intermediate to high Strahler stream order and have diverse substrate and habitat. "Warm large rivers in Michigan are generally runoff-driven systems with low to moderate baseflow, high peak flows, and low gradient". The majority of warm, large rivers are flow through unconfined glacial or alluvial valleys. These ecosystems typically have mean July temperatures are greater than 22˚C (72˚F).

<u>Low gradient</u>: Due to the low gradients, they can have a variety of substrates, but finer substrates (sand, muck) are common due to the slower water velocities allowing sediment to be deposited. The majority of warm, large rivers are low gradient.

<u>Moderate gradient</u>: These ecosystems can have a variety of substrates.

<u>High gradients</u>: There are very few warm, high gradient, large rivers in Michigan.

Characteristic animals: The macroinvertebrate communities tend to be dominated by collectors. Zooplankton play a larger role in the community.

Characteristic plants or algae: Aquatic macrophytes may or may not be present, dependent upon water clarity.

VERY LARGE RIVERS

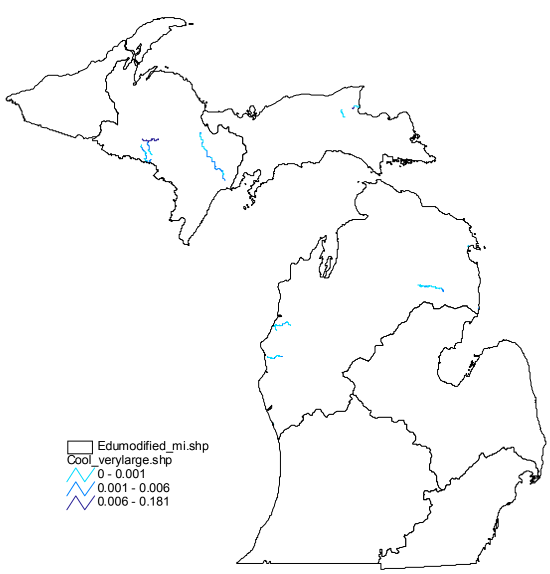
Table 5. Summary of the number of VSECs for very large rivers for each temperature and gradient combination within each EDU according to available GIS data.

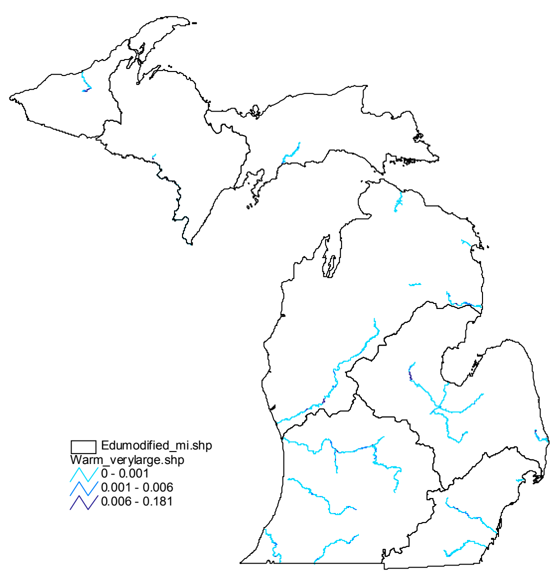
		Ecological Drainage Units						
Water Temperature	Gradient	SELM	SB	NLMH	WUPKP	EUP	CUP	SEMI
Cool	Low	0	0	6	0	2	0	0
	Moderate	0	0	8	0	1	8	0
	High	0	0	0	0	0	2	0
Warm	Low	26	21	21	4	3	9	8
	Moderate	13	10	9	3	0	4	5
	High	0	1	5	1	0	2	1
Unclassified		0	0	14	1	5	5	0

Overview: Very, large rivers rely on energy inputs from upstream. These ecosystems tend to have pelagic communities. These ecosystems are typically non-wadable rivers that have a midpoint catchment areas greater than 620 square miles. These rivers are of high Strahler stream order and have diverse substrate and habitat. "They include runoff and groundwater-driven systems that encompass a variety of thermal regimes from cool to warm. Most are low to moderate gradient, a few are high gradient. Very large rivers flow through a variety of valley types including confined, sporadically confined, and unconfined glacial valleys and unconfined alluvial valleys."

Characteristic animals: The macroinvertebrate communities are dominated by collectors. Zooplankton play a larger role in the community. Fish Species of Greatest Conservation Need found in these ecosystems are sauger, pirate perch, lake herring, river chub, mooneye, lake sturgeon, spotted gar.

Characteristic plants or algae: Aquatic macrophytes may or may not be present, dependent upon water clarity.





Appendix D

Descriptions of Stream Reaches Sampled

Headwaters and small tributaries - Cold

Site:. Cat Creek at 155th Ave. (1)
Draft community type: cold, moderate gradient, headwater or small tributary
Location: Muskegon watershed, Osceola County
GIS Quality: reference
Draft EO Rank: A

Photo:

Site Description:

This shallow stream has an average width of 3.3 m and an average depth of 0.2 m. The sampled reach was 100% run dominated by sand (~68%) and gravel (~15%). The substrate was not embedded and had very little silt. Approximately 50% of the stream channel had in-stream cover that included extensive overhanging vegetation, and sparse undercut banks, root mats or wads, aquatic vegetation, logs or woody structure, and boulders. The stream banks had little to no bank erosion and had a moderate to wide, continuous riparian buffer that consisted forest and shrub. This reach received only a sub-optimal score using the rapid habitat assessment. However, this was mainly due to the lack of pool variability and was scored would have been optimal if this parameter was not considered. The GIS landscape analysis classified this stream as a reference stream.

Table 1. Water quality measurement for Hersey Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.65	pH	8.34
Specific conductivity	521	Alkalinity	175

No live mussel species or empty shell fragments were observed. Macroinvertebrates were collected but have not been processed. Fish composition was not sampled.

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that can often lead to flow restriction and perched.

Site:. Franz Creek at 90th Ave. (2)
Draft community type: cold, moderate gradient, headwater or small tributary
Location: Muskegon watershed, Osceola County
GIS Quality: reference
Draft EO Rank: B (due to moderate silt)

Photo:

Site Description:

This shallow stream has an average width of 3.4 m and an average depth of 0.2 m. The reach sampled was a run dominated by sand (~53%), silt (30%), and detritus (~15). Siltation in this reach was relatively heavy. There was an extensive amount of in-stream cover that included a moderate amount of undercut banks, overhanging vegetation, and logs and woody structure and a sparse amount of shallows and root mats or wads. The stream banks had little erosion and the riparian buffer was wide, continuous, and forested. This reach received only a sub-optimal score using the rapid habitat assessment. However, this was mainly due to the lack of pool variability and was scored would have been optimal if this parameter was not considered. The GIS landscape analysis classified this stream as a reference stream.

Table 2. Water quality measurement for Franz Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.67	pH	8.30
Specific conductivity	396	Alkalinity	242

No live mussel species or empty shell fragments were observed. Macroinvertebrates were collected but have not been processed. Fish composition was not sampled.

The stream / road crossing at this site is a double round culvert that is currently not an issue. However, maintenance and monitoring of the crossing is necessary to ensure this does not become an issue.

Site: Hersey Creek at 230th Rd. (3)
Draft community type: cold, moderate gradient, headwater or small tributary
Location: Muskegon Watershed, Osceola County
GIS Quality: reference
Draft EO Rank: B (due to heavy siltation, but all other ranking factors were an A)

Photo:
No photo available

Site Description:
This shallow, clear water stream has an average width of 2.7 m and an average depth of 0.15 m. The reach sampled was 95% run and 5% debris pool dominated by sand (~55%), detritus (~20%), and silt (~15) substrates. The reach had spare to moderate amount of in-stream cover but it was quite varied and included a moderate amount of undercut banks, shallows, logs and woody structure and a small amount of overhanging vegetation, root mats or wads, and aquatic vegetation. The stream banks had little to no bank erosion and had a wide, continuous riparian buffer that consisted forest and field. This reach received only a sub-optimal score using the rapid habitat assessment. However, this was mainly due to the lack of pool variability and was scored close to optimal if this parameter was not considered. The GIS landscape analysis classified this stream as a reference stream.

Table 3. Water quality measurement for Hersey Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.02	pH	8.29
Specific conductivity	186	Alkalinity	115

No live mussel species or empty shell fragments were observed. Macroinvertebrates were collected but have not been processed. Fish composition was not sampled.

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that is to shallow and restricts the stream flow. This culvert is close to being perched and is likely an issue for sediment and fish movements.

Site:. Olson Creek at 200th Ave. (4)
Draft community type: cold, moderate gradient, headwater or small tributary
Location: Muskegon watershed, Osceola County
GIS Quality: reference
Draft EO Rank: A

Photo:


Site Description:

This shallow stream has an average width of 5.4 m and an average depth of 0.2 m. The reach sampled was 95% run and 5% debris pool dominated by sand (~77%) and detritus (~10%). This stream had very little silt. Approximately 25% of the stream channel had in-stream cover that included undercut banks, overhanging vegetation, shallows, root mats or wads, and logs or woody structure. There is very little stream bank erosion and the forested riparian buffer is wide and continuous. This reach received a sub-optimal score using the rapid habitat assessment. It was low in pool variability and channel sinuosity. The GIS landscape analysis classified this stream as a reference stream.

Table 4. Water quality measurement for Olson Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	9.05	pH	8.33
Specific conductivity	374	Alkalinity	240

No live mussel species were observed. Macroinvertebrates were collected but have not been processed. Fish composition was not sampled.

The stream / road crossing at this site is a double round culvert that is currently not an issue. However, maintenance and monitoring of the crossing is necessary to ensure this does not become an issue.

Headwaters and small tributaries - Cool

Site: Crystal Creek at Barnes Lake Rd. (5)
Draft community type: cool, moderate gradient, headwater or small tributary
Location: Flint Watershed, Lapeer County
GIS Quality: reference
Draft EO Rank: B (due to moderate siltation and some bank erosion)

Photo:

Site Description:
This small stream has an average width of 3 m. The sampled reach was a run dominated by gravel (~40%), cobble (~30%), and sand (~20%). The substrate is between 25 and 50% embedded with moderate silt over top. The channel has moderate in-stream cover that includes overhanging vegetation, shallows, root mats or wads, aquatic vegetation, logs or woody structure, and boulders. There is little to no bank erosion along this reach. The riparian buffer is wide and generally continuous (small sections of residential) and forested. This reach received a sub-optimal score using the rapid habitat assessment. It scored low in pool variability and channel sinuosity. The GIS landscape analysis classified this stream as a reference stream.

Table 5. Water quality measurement for Crystal Creek at Barnes Lake Road taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.51	pH	8.13
Specific conductivity	689	Alkalinity	364

No live mussels were observed. However, spent shells were seen of Giant floater (*Pyganodon gradis*) and Wabash pigtoe (*Fusconaia flava*). This fish community included (starting with the most abundant) creek chub (*Semotilus atromaculatus*), bluntnose minnow (*Pemephales notatus*), johnny darter (*Etheostoma nigrum*), common shiner (*Luxilus cornutus*), green sunfish (*Lepomis cyanellus*), blackside darter (*Percina maculata*), central mudminnow (*Umbra limi*), white sucker (*Catostomus commersonii*), and largemouth bass (*Micropterus salmoides*). Native crayfish were also observed.

Site: Crystal Creek at Dockham Rd. (6)
Draft community type: cool, moderate gradient, headwater or small tributary
Location: Flint Watershed, Lapeer County
GIS Quality: reference
Draft EO Rank: A

Photo:

Site Description:

This small stream has an average width of 1.9 m and an average depth of 0.2 m. The sampled reach was a run with sand (~75%) and mud/muck (~25%) substrates with light silt. In-stream cover in the stream reach was extensive and included extensive overhanging vegetation and logs or woody structure, moderate root mats or wads, and sparse shallows and aquatic vegetation. The stream banks had little to no bank erosion and had a wide, continuous wetland riparian buffer. This reach received only a sub-optimal score using the rapid habitat assessment. However, this was mainly due to the lack of pool variability and stable substrates. The GIS landscape analysis classified this stream as a reference stream.

Table 6. Water quality measurement for Crystal Creek taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	6.61	pH	7.87
Specific conductivity	642	Alkalinity	360

The fish community consisted of green sunfish, greenside darter (*Etheostoma blennioides*), central mudminnow, and creek chub. No live mussel species or empty shell fragments were observed. Macroinvertebrates were collected but have not been processed.

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that can often lead to flow restriction and perched.

Site: Albrow Creek at Broughwell Rd. (7)
Draft community type: cool, moderate gradient, headwater or small tributary
Location: Grand River Watershed, Jackson County
GIS Quality: no impact
Draft EO Rank: B (due to some bank erosion)

Photo:

Site Description:

This small stream is only 1.5 m wide and 0.1 m deep. The reach sampled was a riffle dominated by cobble (~75%) with some gravel and sand mixed in. The substrate was only partly embedded (25-50% embedded) with light silt. The reach had moderate in-stream cover that included sparse overhanging vegetation and boulders, and a moderate amount of logs and woody structure. There is little to moderate bank erosion and the reach had wide, continuous forested riparian buffers. This reach received only a sub-optimal score using the rapid habitat assessment. However this was mainly due to the lack of pools, hence if the reach was longer the score likely would have been optimal. The GIS landscape analysis classified this stream as no impact.

Table 7. Water quality measurement for Albrow Creek taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	7.23	pH	8.08
Specific conductivity	740	Alkalinity	400

Fish species collected include: creek chub, blacknose dace (*Rhinichthys obtusus*), and johnny darter. Native crayfish were also seen. No aquatic invasive species observed.

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that is to shallow and restricts the stream flow. And although the culvert is not currently perched it may become so in the future. This is likely an issue for fish movements as well as stream flow and sediment deposition.

Site: Spring Brook at Bangham Rd. (8)

Draft community type: cool, moderate gradient, headwaters or small tributary

Location: Grand River Watershed, Jackson County

GIS Quality: reference

Draft EO Rank: B (due to heavy siltation, but all other factors are an A)

Photo:

Site Description:

This small stream is only about 2 m in width. The reach sampled was a run with 95% mud/muck and 5% sand with heavy silt. In-stream cover was moderate and included extensive overhanging vegetation, moderate shallows and aquatic vegetation, and sparse undercut banks, root mats or wads, and logs or woody structure. The stream banks had little or no erosion. The left bank is dominated by trees and shrubs and the right bank is a wetland dominated by grasses and forbes. The natural riparian buffer is wide and continuous. This reach received only a sub-optimal score using the rapid habitat assessment. However, this was mainly due to the lack of pool variability, lack of stable substrate, and channel sinuosity. All other parameters were in the optimal condition category. The GIS landscape analysis classified this stream as a reference stream.

Table 8. Water quality measurement for Spring Brook taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	7.97	pH	7.85
Specific conductivity	---	Alkalinity	265

Fish species collected, in order of abundance, include central mudminnow, johnny darter, brook stickleback (*Culaea inconstans*), bluntnose minnow, blackside darter, and Icthyomyzon sp. No live mussel species or empty shell fragments were observed. Macroinvertebrates were collected but have not been processed.

This stream site was very picturesque. The stream / road crossing is a well-constructed box bridge that does not seem to impact the stream channel.

Site: Spring Brook at Sibley Rd. (9)

Draft community type: cool, moderate gradient, headwater or small tributary

Location: Grand River Watershed, Jackson County

GIS Quality: no impact

Draft EO Rank: B? (due to heavy siltation and GIS quality)

Photo:

Site Description:

The stream at this site is quite a bit wider than at the Bangham Road site; it's average width is 6 m and the average depth is 0.2 m. The reach sampled is a run with mud/muck substrates with heavy silt. There is moderate in-stream cover in this reach that includes overhanging vegetation, aquatic vegetation, and sparse shallows and logs or woody structure. The stream banks have little or no erosion and the riparian buffer is wide and continuous with shrub on the left bank and grassy fields on the right bank. This reach received only a marginal score using the rapid habitat assessment. The areas where this reach was low were in epifaunal substrate, pool variability, sediment deposition, and channel sinuosity. The GIS landscape analysis classified this stream as a no impact stream.

Table 9. Water quality measurement for Spring Brook at Sibley Road taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.66	pH	8.21
Specific conductivity	592	Alkalinity	330

Mussel species observed include: Giant floater, Wabash pigtoe, Fluted-shell (*Lasmigona costata*), and Pocketbook (*Lampsilis ovata*). Fish species collected include: tadpole madtom (*Noturus gyrinus*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), rock bass (*Ambloplites rupestris*), green sunfish, largemouth bass, grass pickerel (*Esox americanus*), white sucker. A darter species was observed but not collected. A painted turtle (*Chrysemys picta*) was also observed.

Conservation issues with this site include the stream / road crossing. It is currently a double round culvert. Culverts can become perched and disrupt fish and mussel populations. This stream appears to have been channelized at least 10 year prior.

Site: Thorn Creek at 7 Mile Rd. (10)

Draft community type: cool, moderate gradient, headwater or small tributary

Location: Muskegon Watershed, Osceola County

GIS Quality: reference

Draft EO Rank: B (due to moderate siltation and bank erosion)

Photo:

Site Description:

This reach has an average width of 4.1 m and an average depth of 0.2. The sampled reach was mainly run (~75%) with a debris pool (~25%). The substrate composition was sand (~46%), mud/muck (~25%), detritus (~10), cobble (~10), with the remaining composed of boulder, gravel, and clay. The reach had moderate silt and the substrate was 25-50% embedded. There was a moderate amount of in-stream cover that included a moderate amount of logs or woody structure and undercut banks, shallows, root mats or wads, and boulders sparse. The stream banks had moderate erosion. The channel was moderately sinuous, with the bends in the stream increasing the stream length by 2 to 3 times. The riparian buffer was wide, continuous, and forested. This reach received only a sub-optimal score using the rapid habitat assessment. The scores for the majority of the parameters fell in the sub-optimal category. The GIS landscape analysis classified this stream as a reference stream.

Table 10. Water quality measurement for Thorn Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	10.57	pH	8.45
Specific conductivity	512	Alkalinity	270

Only two individual mussels were observed in this reach and they were Cylindrical papershell (*Anodontoides ferussacianus*).

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that can often lead to flow restriction and perched.

Headwaters and small tributaries - Warm

Site: Cedar Creek at 16th Ave. (11)
Draft community type: warm, moderate gradient, headwater or small tributary
Location: Black – Macatawa Watershed, Van Buren County
GIS Quality: no impact
Draft EO Rank: C? (bank erosion is heavy but all other factors are A-B)

Photo:

Site Description:

This stream reach had an average width of 4.5 m and an average depth of 0.5 m. The sampled reach mainly consisted of a run (~90%) and a lateral pool (~10%). The substrate was primarily sand (~80%) and mud/muck (~10%) with light silt. There was moderate in-stream cover consisting of undercut banks, pools greater than 70 cm, root mats or wads, and logs or woody structure. There was heavy bank erosion in this reach largely due to the steep hillside next to the left bank. The riparian area was wide, continuous, and forested. This reach scored as marginal using the rapid habitat assessment protocol. The following habitat parameters scored low: epifaunal substrate, channel flow status, bank stability, and bank vegetative protection. The GIS landscape analysis classified this stream as a no impact stream.

Table 11. Water quality measurement for Cedar Creek taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.05	pH	8.08
Specific conductivity	469	Alkalinity	161

The fish community consisted of, in decreasing abundance, mottled sculpin (*Cottus bairdii*), johnny darter, common shiner, creek chub, white sucker, green sunfish, central mudminnow, blacknose dace, hornyhead chub (*Nocomis biguttatus*), bluntnose minnow, blackside darter, and grass pickerel. No mussels were observed. Native crayfish were observed.

Site: Cedar Creek at 68th St. (12)
Draft community type: warm, moderate gradient, headwater or small tributary
Location: Black – Macatawa Watershed, Van Buren County
GIS Quality: reference
Draft EO Rank: B (moderate bank erosion)

Photo:

Site Description:
This small stream reach, with an average width of 2.9 m, consisted mainly of run (~95%) and a small lateral pool (~5%). The substrate was dominated by sand (~75%) and clay (~15%) and had light silt. Only about 25% of the stream channel had in-stream cover that included undercut banks, overhanging vegetation, pools greater than 70 cm, root mats or wads, and logs or woody structure. Bank erosion was little or none. The riparian buffer was wide (>50 m), continuous, and forested. This reach scored a sub-optimal using the rapid habitat assessment procedure. The majority of scores on the individual habitat parameters ranged from sub-optimal to optimal. The GIS landscape analysis classified this stream as a reference stream.

Table 12. Water quality measurement for Cedar Creek at 68th Street taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	7.89	pH	7.97
Specific conductivity	371	Alkalinity	180

The fish community consisted of, in decreasing abundance, mottled sculpin, johnny darter, green sunfish, grass pickerel, and central mudminnow. No mussels were observed. Native crayfish were observed.

Site: Unnamed Stream at Otter Lake Rd. (13)

Draft community type: warm, moderate gradient, headwater or small tributary

Location: Saginaw Watershed, Lapeer County

GIS Quality: no impact

Draft EO Rank: B? (siltation is moderate and riparian buffer width is moderate)

Photo:

Site Description:

This small stream reach, average width and depth of 1.2 m and 0.05 m respectively, was a run with mud/muck (~45%) and sand (~40%) substrates. The reach had moderate siltation and moderate in-stream cover that included overhanging vegetation, shallows, and logs or woody structure. The stream banks had little to no erosion and the riparian buffer was moderate, continuous, and mixed forest and shrub. This reach scored as sub-optimal using the rapid habitat assessment. Four condition parameters were scored low: epifaunal substrate, pool variability, channel flow status, and channel sinuosity. The GIS landscape analysis classified this stream as a no impact stream.

Table 13. Water quality measurement for Unnamed Stream taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.63	pH	8.37
Specific conductivity	581	Alkalinity	320

No mussels were observed. Native crayfish were observed.

Site: Salt River at Barden Rd. (14)
Draft community type: warm, moderate gradient, headwater or small tributary
Location: Saginaw Watershed, Midland County
GIS Quality: no impact
Draft EO Rank: B (moderate bank erosion)

Photo:


Site Description:
This stream reach, 1.4 m average width, was a run with sandy (~86%) substrates. The in-stream cover in the stream channel was sparse but included: undercut banks, overhanging vegetation, shallows, and logs or woody structure. There was little to moderate bank erosion and the riparian buffer was wide, continuous, and forested. This reach was scored as sub-optimal using the rapid habitat assessment. Pool variability and epifaunal substrate were both lacking. The GIS landscape analysis classified this stream as a no impact stream.

Table 14. Water quality measurement for Salt River at Barden Road taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.04	pH	8.43
Specific conductivity	641	Alkalinity	340

No mussels were observed, however Asiatic clams (*Corbicula fluminea*) were seen.

Conservation issues with this site include the stream / road crossing. It is currently a round culvert that can often lead to flow restriction and perched.

Medium Rivers – Cool

Site: Middle Branch Black River at 54th St. (15)
Draft community type: cool, low gradient, medium river
Location: Black – Macatawa River Watershed, Allegan County
GIS Quality: detectable disturbance
Draft EO Rank: B? (due to moderate bank erosion and GIS quality – but all other ranking factors are in the A specs)

Photo:

Site Description:

This stream reach was a run with an average width of 9 m. The substrate composition was sand (~75%), mud/muck (~15%), gravel (~5%), with small amounts of cobble and clay. Overall in-stream cover in this reach was about 25% and was dominated by shallows and logs or woody structure, but also had undercut banks, overhanging vegetation, and root mats or wads. The stream banks had little to no erosion. The riparian buffer was wide, continuous, and forested.

The stream reach scored a sub-optimal using the rapid habitat assessment method. Although most habitat parameters scored optimal except for one that scored sub-optimal (channel sinuosity), and two that scored poor (epifaunal substrate and pool variability). The GIS landscape analysis classified this stream as a detectable impact stream.

Table 15. Water quality measurement for Middle Branch of the Black River taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	7.55	pH	7.94
Specific conductivity	377	Alkalinity	144

Only two individual mussels were observed and both were Black sandshell (*Ligumia recta*). This fish community was diverse and included, in decreasing order of abundance: mottled sculpin, johnny darter, white sucker, central mudminnow, blackside darter, creek chub, bluegill, grass pickerel, common shiner. Native crayfish were also observed.

Site: Dickerson Creek at Long Lake Rd. (16)

Draft community type: cool, low gradient, medium river

Location: Grand River Watershed, Ionia County

GIS Quality: detectable disturbance

Draft EO Rank: B? (moderate bank erosion and GIS quality)

Photo:

Site Description:

This medium river reach was on average 10.5 m wide and 0.4 m deep. The sampled reach consisted of riffle (~60%) and run (~40%) with two islands present. The islands were covered in grasses and the larger island had trees growing on it. The substrate composition was gravel (~50%), cobble (~20%), sand (~20%), boulder(~5%), and clay (~5%). The substrate was only moderately embedded and had light silt. The in-stream cover was moderate and consisted of overhanging vegetation, shallows, pools greater thank 70 cm, aquatic vegetation, logs or woody structure, and boulders. There was little or no bank erosion in this reach. The riparian buffer was wide, continuous, and forested. This reach was scored as sub-optimal using the rapid habitat assessment approach. Two habitat parameters were below sub-optimal: pool variability and channel sinuosity. The GIS landscape analysis classified this stream as a detectable impact stream.

Table 16. Water quality measurement for Dickerson Creek at Long Lake Road taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.72	pH	8.36
Specific conductivity	503	Alkalinity	222

Four species and 44 individuals were collected, consisting of Ellipse (*Venustaconcha ellipsiformis*), Rainbow (*Villosa iris*), Spike (*Elliptio dilatata*) and Slippershell mussel (*Alasmidonta viridis*), in order of decreasing abundance.

This river had a diverse fish community that included, in decreasing order of abundance: rainbow darter (*Etheostoma caeruleum*), blacknose dace, creek chub, rock bass, johnny darter, mottled sculpin, central mudminnow, common shiner, blackside darter, hornyhead chub, largemouth bass, yellow bullhead (*Ameiurus natalis*), smallmouth bass (*Microperus dolomieu*), white sucker, northern hog sucker (*Hypentelium nigricans*), and a native lamprey species.

Site: Dickerson Creek at Derby Rd. (17)

Draft community type: cool, low gradient, medium river

Location: Grand River Watershed, Montcalm County

GIS Quality: detectable disturbance

Draft EO Rank: C? (heavy bank erosion and GIS quality, all other specs ranked as an A)

Photo:

Site Description:

At this site the river was wide and shallow with an average width and depth of 12 m and 0.5 m, respectively. Eighty percent of the reach was made up of run habitat and 20% was lateral pool habitat. The substrate composition was mud/muck (~55%) and sand (~45%) with light silt. There was a moderate amount of in-stream cover with more pools greater than 70 cm and logs or woody structure than undercut banks, overhanging vegetation, shallows, and root mats or wads. There was little or no stream bank erosion. The riparian area consisted of wetland and was wide and continuous. Using the rapid habitat assessment, this stream scored as sub-optimal. Four habitat parameters scored marginal or lower including epifaunal substrate, pool substrate characterization, sediment deposition, and bank vegetative protection. The GIS landscape analysis classified this stream as a detectable impact stream.

Table 17. Water quality measurement for Dickerson Creek at Derby Road taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	7.86	pH	8.24
Specific conductivity	512	Alkalinity	235

The fish community composition included, in decrease order of abundance, johnny darter, creek chub, central mudminnow, mottled sculpin, white sucker, blacknose dace, and grass pickerel. No mussel species were observed. Native crayfish were also observed.

Site: Dickerson Creek at M57 (18)

Draft community type: cool, low gradient, medium river

Location: Grand River Watershed, Montcalm County

GIS Quality: detectable disturbance

Draft EO Rank: B? (GIS quality, all other ranking specs are an A)

Photo:

Site Description:

The medium river reach had an average width of 7 m. The sampled reach was a run habitat with sand (~50%), gravel (~30%), and cobble (~10%) as the dominate substrates. The were partly (50-57%) embedded. Light silt covered the substrate. There was a moderate amount of in-stream cover that included moderate amounts of overhanging vegetation and logs or woody structure and sparse amounts of undercut banks, root mats or wads, aquatic vegetation, and boulders. The stream banks had little or no erosion. And the riparian areas were wide, continuous, and forested. Using the rapid habitat assessment, this stream scored as sub-optimal. However, only two habitat parameters scored marginal or lower: pool variability and channel sinuosity. All but two other habitat parameters scored optimal. The GIS landscape analysis classified this stream as a detectable impact stream.

Table 18. Water quality measurement for Dickerson Creek at M-57 taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.83	pH	8.28
Specific conductivity	522	Alkalinity	218

This reach had the most mussel rich community sampled. Six species and 81 individuals were collected consisting of Slippershell mussel, Cylindrical papershell, Spike, Wabash pigtoe, Strange floater (*Strophitus undulatus*), and Ellipse.

This reach had quite a diverse fish community. The following species were collected, in decreasing order of abundance: johnny darter, creek chub, white sucker, mottled sculpin, blacknose dace, native lamprey, central mudminnow, common shiner, bluntnose minnow, blackside darter, yellow perch (*Perca flavescens*), bluegill, and northern pike (*Esox lucius*).

Site: South Branch Flint River at Hunters Creek Rd. (19)

Draft community type: cool, moderate gradient, medium river

Location: Flint River Watershed, Lapeer County

GIS Quality: reference

Draft EO Rank: A

Photo:

Site Description:

This medium river reach has an average width of 8.8 m and an average depth of 0.3 m. The sampled reach was 85% run and 15% lateral pool habitat. The substrate consisted of sand (~40%), gravel (~25%), cobble (~15%), fines (~15%), and boulder (~5%). The substrate was partly embedded and had light silt. This reach had moderate in-stream cover that was dominated by overhanging vegetation but also consisted of undercut banks, shallows, pools greater than 70 cm, root mats or wads, aquatic vegetation, logs or woody structure, and boulders. The stream banks had little or no erosion. The riparian buffer was wide, mostly continuous, and was dominated by wetland. Using the rapid habitat assessment procedure, this reach's score was on the line between the optimal and sub-optimal score. The GIS landscape analysis classified this stream as a reference stream.

Table 19. Water quality measurement for South Branch of the Flint River taken in September, 2006.

Parameter	Value	Parameter	Value
Dissolved oxygen	9.73	pH	8.45
Specific conductivity	669	Alkalinity	360

Six species of mussels were observed in this reach including Spike, Rainbow, Fluted-shell, and Ellipse. They were not abundant in this reach, only 15 individuals were collected.

The fish community was diverse and included in decreasing abundance: hornyhead chub, rock bass, common shiner, northern hog sucker, creek chub, white sucker, bluntnose minnow, smallmouth bass, blackside darter, yellow perch, rainbow darter, and johnny darter.

Medium Rivers - Warm

Site: Bean Creek at Sorby Rd. (20)

Draft community type: warm, moderate gradient, medium river

Location: River Raisin Watershed, Lenawee County

GIS Quality: no impact

Draft EO Rank: B? (moderate bank erosion)

Photo:

Site Description

This reach had an average width and depth of 6.1 m and 0.3 m, respectively. The reach was dominated by run habitat (~75%) but also had lateral, debris, and plunge pool habitat (~25%). One island was present in the channel. The substrate was composed of gravel (~43%), sand (~30%), mud/muck (~20%), cobble (~5%), and clay (~2%). In-stream cover was sparse, but undercut banks, shallows, pools greater than 70 cm, rot mats or wads, and logs or woody structure were present. There was moderate bank erosion in this reach. The riparian buffer was wide, continuous, and forested. This reach was scored as sub-optimal using the rapid habitat assessment method. Five habitat parameters fell into the marginal or poor condition category and they include channel flow status, channel sinuosity, bank stability, and bank vegetative protection. The GIS landscape analysis classified this stream as a no impact stream. This reach was sampled due to the rare fish and mussels present.

Table 20. Water quality measurement for Bean Creek taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.47	pH	8.47
Specific conductivity	735	Alkalinity	382

Five species of mussels were observed including: Slippershell, Rainbow, Fatmucket (*Lampsilis siliquoidea*), Black sandshell, Wabash pigtoe. A total of 25 individuals were collected; Wabash pigtoe was the dominant species. Native crayfish were also observed.

Site: River Raisin at Austin Rd. (21)

Draft community type: warm, moderate gradient, medium river

Location: Raisin River Watershed, Washtenaw County

GIS Quality: no impact

Draft EO Rank: B (moderate silt, GIS quality)

Photo:

Site Description:

This wide river, average width of 13 m, is shallow, with an average depth of 0.5 m, and has a riffle, run, pool macrohabitat composition. About 74% of the reach was run, 14% riffle, and 7% pool. The substrate composition was cobble (~35%), mud/muck (~35%), boulder (~15%), gravel (~8%), sand (~5%), and clay (~2%). One small cobble island was present. There was moderate silt throughout the reach. In-stream cover was extensive with the majority of it comprised of overhanging vegetation, aquatic vegetation, and boulders, and undercut banks, shallows, pools greater than 70 cm, root mats or wads, and logs or woody structure also present in smaller quantities. There was little to no bank erosion. Overall the riparian buffer was wide, continuous, and a mixture of forest and shrub. The reach scored as sub-optimal using the rapid habitat assessment method. Only pool variability feel into the marginal category. The GIS landscape analysis classified this stream as a no impact stream. This reach was sampled due to the rare fish and mussels present.

Table 21. Water quality measurement for River Raisin taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	9.93	pH	8.50
Specific conductivity	535	Alkalinity	230

Four mussel species were observed in the River Raisin reach including Lamp-mussel (*Lampsilis ventricosa*), Strange floater, Wavy-rayed lampmussel (*Lampsilis fasciola*), and Wabash pigtoe in decreasing order of abundance. Only 21 individuals were observed. Mussels were observed displaying lures.

Site: Carrol Creek Drain at 9 Mile Rd. (22)

Draft community type: warm, moderate gradient, medium river

Location: Tittabawassee River Watershed, Midland County

GIS Quality: reference

Draft EO Rank: B (moderate silt and bank erosion)

Photo:

Site Description:

This stream reach has an average width of 2.6 m and was a run habitat. The substrate consisted of sand (~90%), clay (~5%), and detritus (~5%). There was an extensive amount of in-stream cover which was dominated by overhanging vegetation, shallows, and logs or woody structure, but undercut banks and root mats or wads were also present. There was little to moderate erosion along the steep stream banks. The riparian buffer was wide, continuous, and was old field. This reach scored a marginal using the rapid habitat assessment method. The following habitat parameters were scored as optimal or sub-optimal: epifaunal sustrate, pool substrate characterization, channel alteration, and riparian vegetative zone width. The GIS landscape analysis classified this stream as a reference stream.

Table 22. Water quality measurement for Carrol Creek Drain taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	6.30	pH	8.11
Specific conductivity	962	Alkalinity	195

No live mussels or spent shell were observed in this reach.

Site: Carrol Creek Drain at Magrudger Rd. (23)

Draft community type: warm, moderate gradient, medium river

Location: Tittabawassee River Watershed, Midland County

GIS Quality: reference

Draft EO Rank: BC? (moderate to moderate silt and some bank erosion)

Photo:

Site Description:

This reach was small, murky, agriculture drain had an average width of 3 m and an average depth of 0.3 m. The reach was dominated by run (~90%) habitat but also had a debris pool (~10%). The substrate was dominated by sand (~74%) and mud/muck (~15%). There was heavy silt in this reach. The reach had moderate in-stream cover that was dominated by undercut banks, aquatic vegetation, and logs or woody structure, but overhanging vegetation, shallows, pools greater than 70 cm, and root mats or wads were also present. The stream banks had little to moderate erosion. The riparian buffer was wide, continuous, and was old field. The reach scored as sub-optimal using the rapid habitat assessment method. Four habitat parameters were scored as marginal (pool variability, channel flow status, channel sinuosity, bank stability) and only 3 scored as optimal (channel alteration, bank vegetative protection, and riparian vegetative zone width). The GIS landscape analysis classified this stream as a reference stream.

Table 23. Water quality measurement for Carrol Creek Drain taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	9.38	pH	8.12
Specific conductivity	580	Alkalinity	220

No live mussels or spent shells were found in reach. Macroinvertebrates were collected but have not yet been processed.

Large Rivers

Site: Salt River at Grant Rd. (24)
Draft community type: warm, low gradient, large river
Location: Saginaw Watershed, Midland County
GIS Quality: no impact
Draft EO Rank: B (moderate silt and some bank erosion)

Photo:

Site Description:

This large river had an average width of 10 m and an average depth of 0.5 m. The sampled reach had a variety of macrohabitats, approximately 10% of the reach was riffle, 80% was run, and 10% was lateral pool habitat. The substrate was made up mainly of cobble (~30%), gravel (~28%), and sand (~25). The substrate was somewhat embedded, approximately 25-50% embedded and the reach had moderate silt. The reach also had a moderate amount of in-stream cover that consisted of undercut banks, overhanging vegetation, shallows, pools greater than 70 cm, root mats or wads, aquatic vegetation, logs or woody structure, and boulders. The stream banks had little to moderate erosion. The riparian buffers were wide, continuous, and forested with some shrub. This reach scored as sub-optimal using the rapid habitat assessment protocol. Four habitat parameters scored marginal: channel flow status, channel sinuosity, bank stability, bank vegetative protection. The GIS landscape analysis classified this stream as a no impact stream.

Table 24. Water quality measurement for Salt River at Grant Road taken in September, 2007.

Parameter	Value	Parameter	Value
Dissolved oxygen	8.06	pH	8.31
Specific conductivity	1134	Alkalinity	235

Five species of mussels were observed including Strange floater, Ellipse, Wabash pigtoe, Pocketbook, and Fatmucket. Twenty individuals were observed.