RESOURCE ASSESSMENT AND DEVELOPMENT ANALYSIS FOR THE THE UPPER SUGAR RIVER AND BADGER MILL CREEK SOUTHWEST OF VERONA, WI

JUNE 2008

PROJECT NO. 1297

FOR:

THE CITY OF VERONA, WISCONSIN

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1. INTRODUCTION

1.1 Purpose of Study

The purpose of this study was to develop recommendations for urban development standards and environmental corridor boundaries that will provide protection to the identified water resource features of the study area. These recommendations are intended to be "resource-based" and not "policy-based", to provide the basis for an improved approach to protection of water quality and water resources as part of regional water quality management planning. It is expected that the analyses and recommendations contained in this study will be part of the City of Verona's request to the Capital Area Regional Planning Commission and Wisconsin DNR for an extension of the Urban Service Area boundary to include the study area.

This project was conducted for the City of Verona, in response to a resolution adopted by the City in June 2005, "supporting natural resources planning in portions of the Badger Mill Creek and Sugar River watershed". This resolution identified the study area, and committed the City to complete a natural resources planning process to define areas suitable for development that will protect natural resource features and provide compliance with regulations.

1.2 Study Area Description

The study area for this project includes 1702 acres located on the southwest margin of the current urban service area for the City of Verona. The area includes the intersection of Highways 69 and 151. Badger Mill Creek, the Upper Sugar River, the confluence of the Upper Sugar River and Badger Mill Creek, and the Sugar River Wetlands State Natural Area are key resources in the study area (Figure 1).

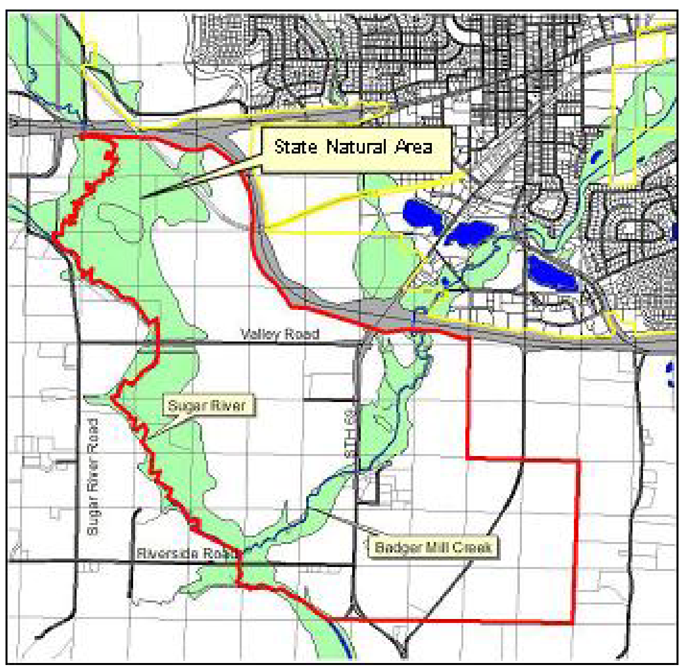


Figure 1. Study Area Map

Land use in the study area is primarily agricultural. Topography is variable, and includes areas of steep slopes in upland areas in the central and eastern portion of the area, contrasting with very flat terrain adjacent to badger Mill Creek and the sugar River.

The study area includes the downstream limit of the Badger Mill Creek watershed, and a small portion of the Sugar River watershed. Upstream of the study area, the Badger Mill Creek watershed includes extensive areas of existing urban development. In contrast, the Sugar River watershed upstream of the study area is relatively undeveloped. Future land use conditions projected by the Capital Area Regional Planning Commission indicates that the Badger Mill Creek watershed will have a substantially higher percentage of impervious area than the Sugar River. Watershed area and projected impervious area percentages are summarized in Table 1.

Table 1. Watershed Development Summary

Characteristic	Upper Sugar River	Badger Mill Creek	Locust Road Dry Tributary
Total watershed area at downstream limit of study area	47.5 mi^2	32.1 mi^2	1.1 mi^2
Watershed area within study area	802 acres	585 acres	315 acres
Fraction of total watershed included in study area	2%	2%	73%
Current impervious cover	10%	20%	NA
Projected impervious cover in 2050, based on land-use projections developed by CARPC	14%	31%	NA

1.3 Background to Key Water Resource Issues

The ability of Badger Mill Creek and the Sugar River to support trout populations has received attention in defining the value of these resources. Both Badger Mill Creek and the Upper Sugar River support brown trout populations, although neither is classified as a trout stream by the Wisconsin Department of Natural Resources. The Upper Sugar River is classified by the State as a Cold Water Community (under NR 102) and an Exceptional Resource Water (under Sec. 281.15). Badger Mill Creek is designated a Cold Water Community in the study area and as far upstream as Bruce Street; upstream of that point it is classified as a Limited Forage Fishery and Warm Water Forage Fishery, as defined in NR 102. Neither stream is on the 303(d) list of impaired waters. The Dane County Water Body Classification study lists both streams as Class 2 streams with management objectives of protection and restoration (Table 2).

An additional significant natural resource feature within the study area is the Sugar River Wetlands State Natural Area, which occupies more than 100 acres in the northernmost part of the study area along the Upper Sugar River. It contains sedge meadows, calcareous fens, emergent aquatics, shrub-carr, and wet-mesic prairie. Numerous rare plant and animal species are also found in the area.

These resources are highly valued and have been the focus of much previous work by the City of Verona, Dane County, the Madison Metropolitan Sewerage District, the Wisconsin Department of

Natural Resources, the U.S. Geological Survey, and the Upper Sugar River Watershed Association. The Dane County Water Quality Plan calls for vigorous enforcement and possible extension of County stormwater and erosion control standards to protect the Sugar River and its tributaries. It also encourages participation between units of government and conservation groups.

Table 2. Watershed Plans and Objectives for the Upper Sugar River and Badger Mill Creek

Plan	Classification & Objectives
Dane Co. Water Body Classification & Objectives	▪ Developing / Impacted ▪ Protection/restoration – reduce runoff & imperviousness
Dane Co. Water Quality Plan (2004) priorities	▪ Enforce & possibly expand minimum Co. ordinance requirements to protect USR & tributaries ▪ Manage USR & BMC in cooperation w/ other units of government & conservation groups ▪ Evaluate road deicer use & adopt salt use management policy
Town of Verona Land Use Plan	▪ Protect and improve the quality of surface water and groundwater ▪ Promote protection of natural areas ▪ Support Dane County Parks and Open Space Plan ▪ Promote environmental restoration and habitat preservation ▪ Protect highly productive soils for agricultural use
Dane County Parks and Open Space Plan	▪ Natural Resource Areas in floodplains. ▪ High priorities for conservation.

1.4 Study Approach

This project was comprised of two phases, with the bulk of the work conducted in 2007.

- Phase 1 included a review of available data and reports, followed by an identification of data gaps that would need to be addressed to understand the critical water resources of the study area, and the hydrologic conditions necessary to maintain these resources. This first phase of the project included several meetings with a project study stakeholder group, and a public meeting to provide an interim description of data collection and resource identification. This public meeting was conducted at the Verona City Hall.

- Phase 2 of the project consisted definition of the sensitivity of identified water resource features to changes in groundwater and surface water quantity and quality. This sensitivity analysis was followed by an analysis of alternative upland development standards and environmental corridor characteristics that would minimize the potential for resource degradation. The recommended development area hydrologic performance standards and environmental corridor criteria were reviewed with the City in an iterative process.

The study report documents the major data collection activities, analyses of resource sensitivity and development impacts, and presents recommendations for development standards and environmental corridor definition. Additional meeting memorandums, technical data summaries, and analysis output have been provided to the City, and will form part of the materials submitted to the Capital Area Regional Planning Commission as part of the urban service area amendment request.

1.5 Study Participants

This study was conducted by Montgomery Associates: Resource Solutions, LLC as prime consultant to the City of Verona. Subconsultants to Montgomery Associates for conduct of this work included Natural Resource Consulting, Inc., and Archaeological Consulting and Services, Inc.

Organizations, municipalities, and agency representatives that participated in the stakeholder discussions and public meetings included the following:

- City of Verona
- Town of Verona
- City of Madison
- Wisconsin DNR, South Central Region
- Madison Metropolitan Sewerage District
- Capital Area Regional Planning Commission
- Upper Sugar River Watershed Association
- Natural Heritage Land Trust

Additionally, a number of interested citizens, primarily residents living within or near to the study area, participated in the public meetings and provided questions and comments.

2 EXISTING DATA REVIEW

The Upper Sugar River and Badger Mill Creek have been the focus of ongoing monitoring efforts by the Madison Metropolitan Sewerage District and the Wisconsin Department of Natural Resources, including several sites in or near the study area (Figure 2).

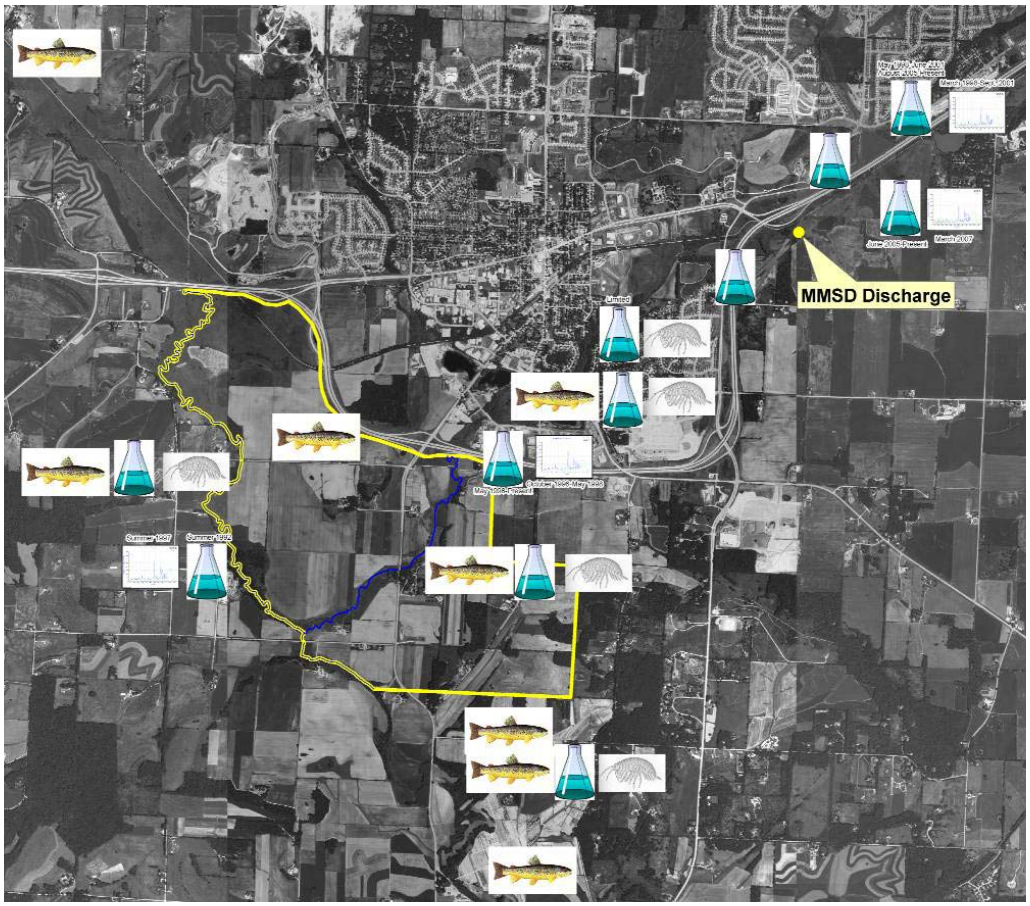


Figure 2. Previous Monitoring Sites.
Data collected by WDNR and MMSD (written communication) include water quality (beaker symbol), macroinvertebrates, fish community composition, and discharge (hydrograph symbol)

2.1 Fisheries

MMSD has been collecting fishery data on the Sugar River and Badger Mill Creek since 1994 (MMSD written communication). Fish shocking has been performed near MARS monitoring stations BM-3, S-3, S-5, and the USGS monitoring station at Bruce Street using a walk-along shocking boat with a pulsed DC generated power shocker in all locations. Each site is approximately 400 yards in length and was shocked in 100 yard segments. Both streams in the study area appear to have naturally reproducing brown trout populations with supplemental stocking, however there is some debate over the occurrence of natural brown trout reproduction in Badger Mill Creek (Jeff Steven, MMSD, written communication). Fish Index of Biotic Integrity (IBI) scores for these streams range from very poor to fair based on Wisconsin's Warmwater Index of Biotic Integrity developed by John Lyons, Wisconsin Department of Natural Resources in 1992 (Figure 3).

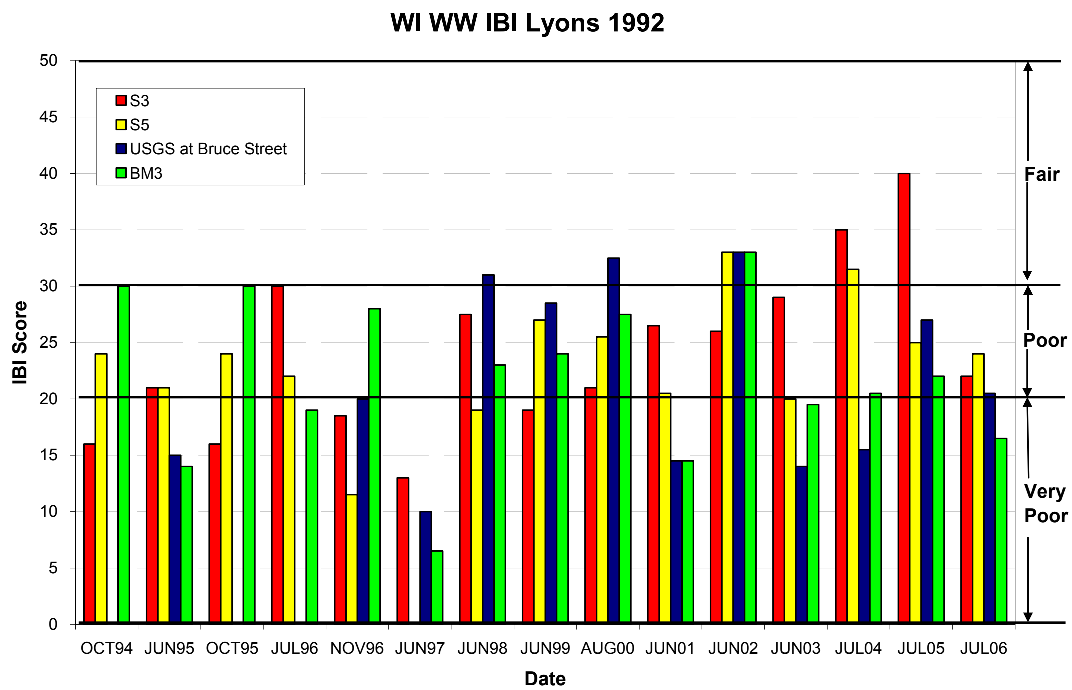


Figure 3. Wisconsin Warmwater Fishery Index of Biotic Integrity

The IBI uses 10 fish attributes called metrics and 2 correlation factors in calculating the Wisconsin version of the IBI. Table 1 below lists the metrics with associated interpretations.

Table 3. Fishery Warmwater IBI Metrics

Metric Category	Metric	Interpretation
Species Richness and Composition Metric	Total number of native species	Abundant in high quality streams
Species Richness and Composition Metric	Number of darter species	Abundant in high quality Streams
Species Richness and Composition Metric	Number of sucker species	Abundant in high quality streams
Species Richness and Composition Metric	Number of sunfish species	Abundant in high quality streams
Species Richness and Composition Metric	Number of intolerant species	Species that are sensitive to water quality and habitat degradation

		(dominant in high quality streams)
Species Richness and Composition Metric	Percent tolerant species	Species that are not sensitive to deteriorated waters (dominate in deteriorated stream)
Trophic and Reproductive Function Metrics	Percent omnivores	Species that eat at least 25 percent of their diet from plants and at least 25 percent from animal matter (Present but do not dominate in high quality streams)
Trophic and Reproductive Function Metrics	Percent insectivores	Species that feed primarily on insects and macroinvertebrates (common in high quality stream)
Trophic and Reproductive Function Metrics	Percent top carnivores	Species that feed primarily on vertebrates and large macroinvertebrates (common in high quality streams)
Trophic and Reproductive Function Metrics	Percent simple lithophils	Species that lay their eggs on clean gravelly substrate and to not build a nest or provide prenatal care (common in high quality streams)
Fish Abundance and Condition Correction Factors	Number of individuals per 300 m2 (If less than 50 fish subtract 10 from the overall IBI score)	Moderate to high abundance found in high quality streams (excluding tolerant species)
Fish Abundance and Condition Correction Factors	Percent of Fish with deformities, eroded fins, lesions, or tumors (DELT) (if greater than or equal to 4 percent subtract 10 from the IBI score)	Few to no individuals have DELT in high quality streams

Figures 4 through 7 below show the relative composition of the IBI for each station for each sampling period.

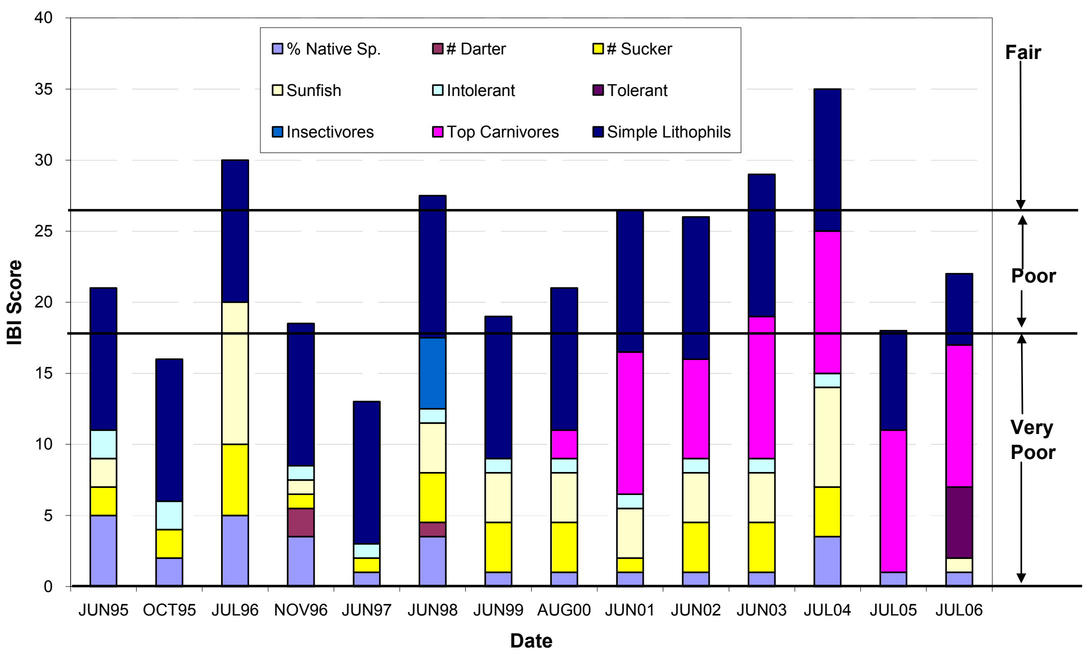


Figure 4. SR3 IBI Components

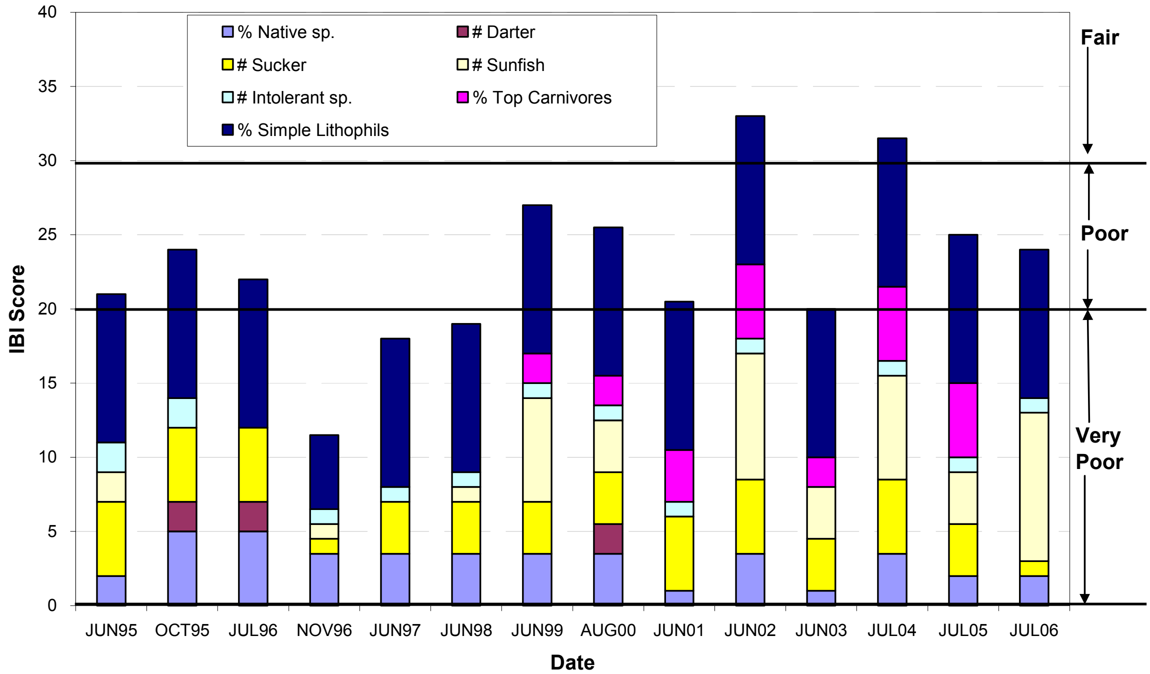


Figure 5. SR5 IBI Components

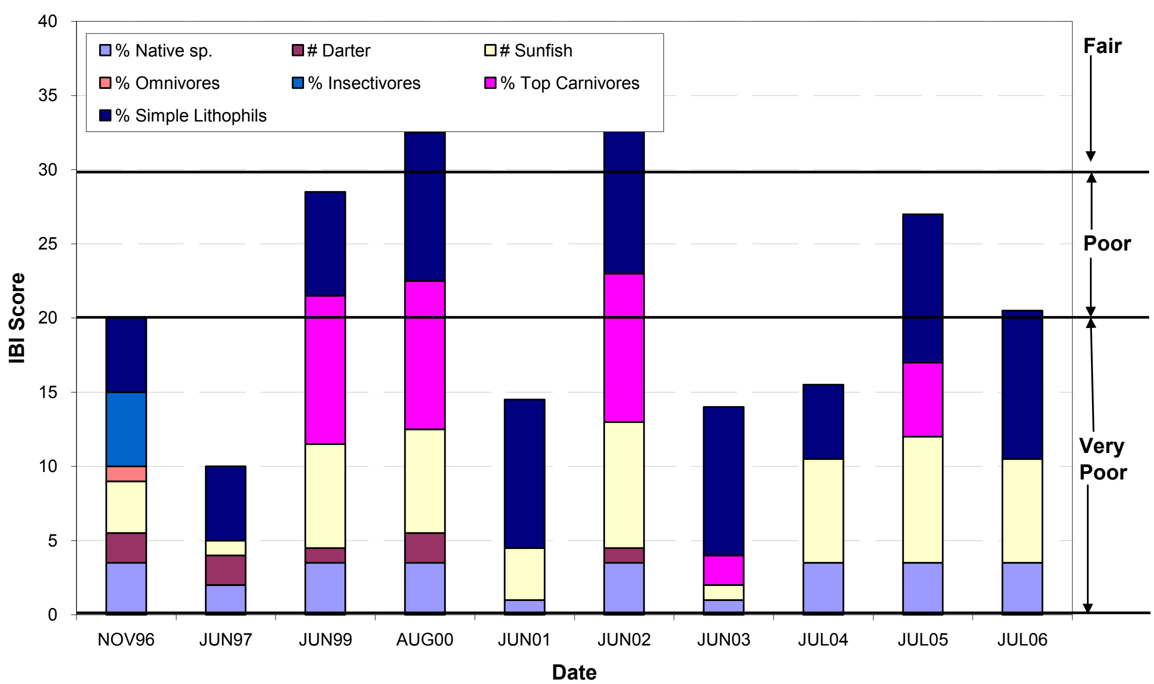


Figure 6. USGS Location IBI Components

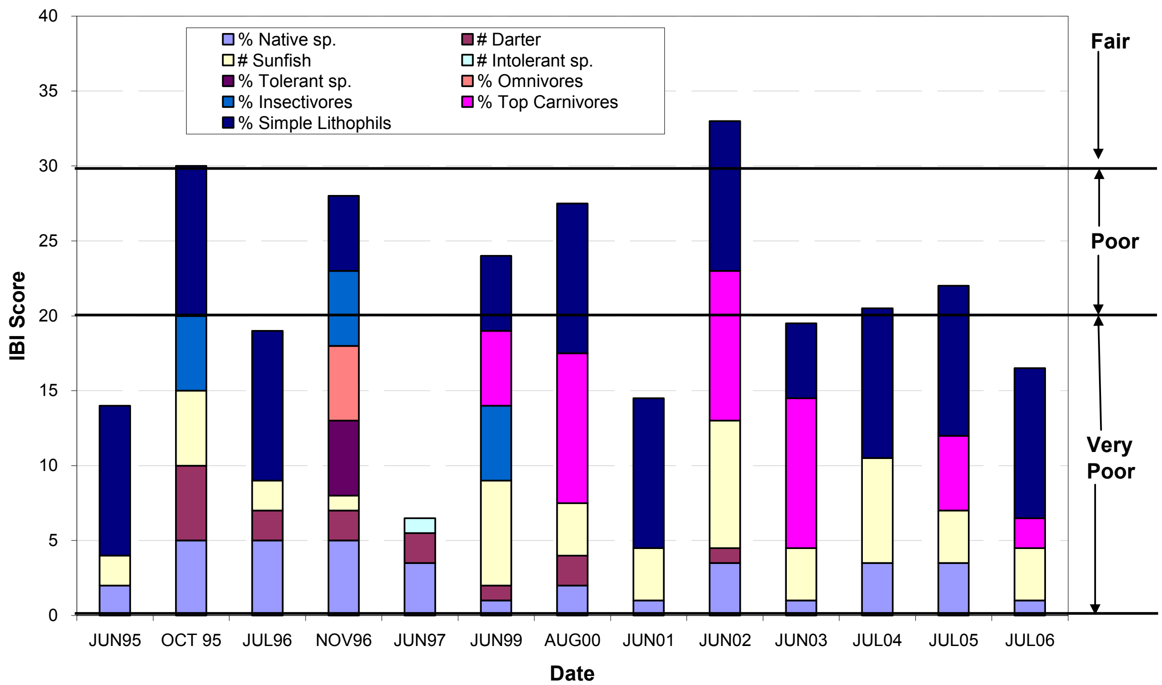


Figure 7. BM3 IBI Components

2.2 Macroinvertebrates

In addition to fishery data, MMSD also collected macroinvertebrate samples in the same locations as fishery data was collected (MMSD written communication). Samples were taken twice per year, once in the spring and once in the fall from 1994 to present. Three samples were collected from each site using kick samples collected in a standard D-Frame kick net. Each sample was spread over a 32 square gridded pan where the first 150 randomly selected organisms from each sample were removed and classified down to the species level. All organisms were classified using a dissecting microscope.

Specimen data that was collected was analyzed by various methods, two of which are biotic index and EPT index. The Hilsenholf Biotic Index uses arthropods as an indicator of organic pollutions. The EPT index looks at the total number of species in three insect orders: Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These orders of macroinvertebrates are considered intolerant orders, therefore, the higher the EPT number, the higher the water quality and habitat are for macroinvertebrates.

Figure 8 and Figure 9 below show Biotic index values for the Sugar River and Badger Mill Creek for April and October 1995-2005. Data samples from 2006 and 2007 have not yet been reported and therefore are not included in these graphs. Biotic index values for these sites range from fair to very good. Visual inspection of Figures 8 and 9 suggest that BI values may be getting worse through time, however we did not conduct any statistical trend analysis. In addition, BI values tend to be worse in the spring than in the fall.

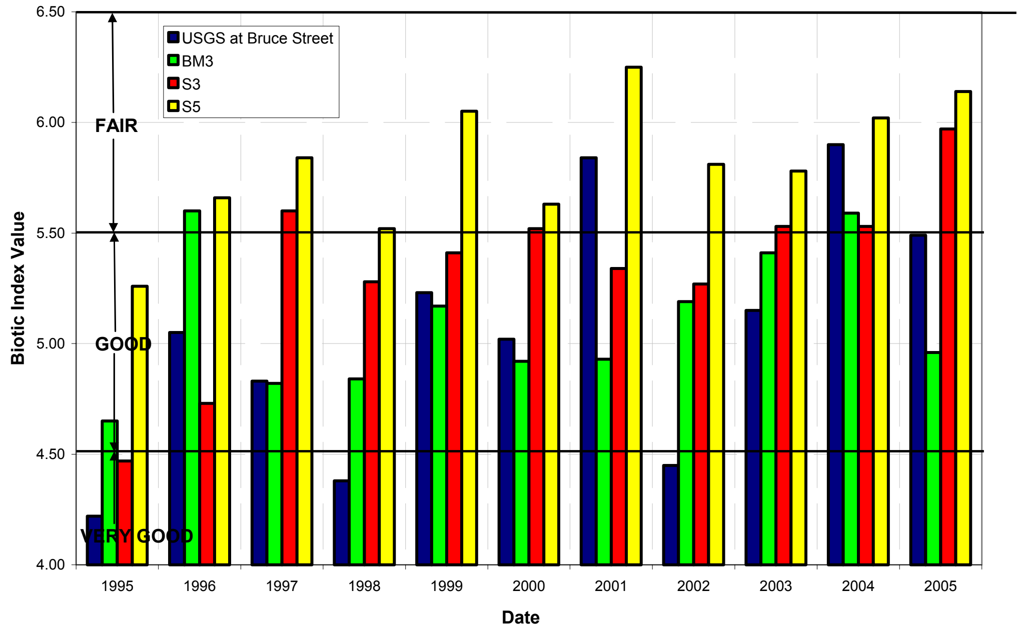


Figure 8. April Biotic Index Values

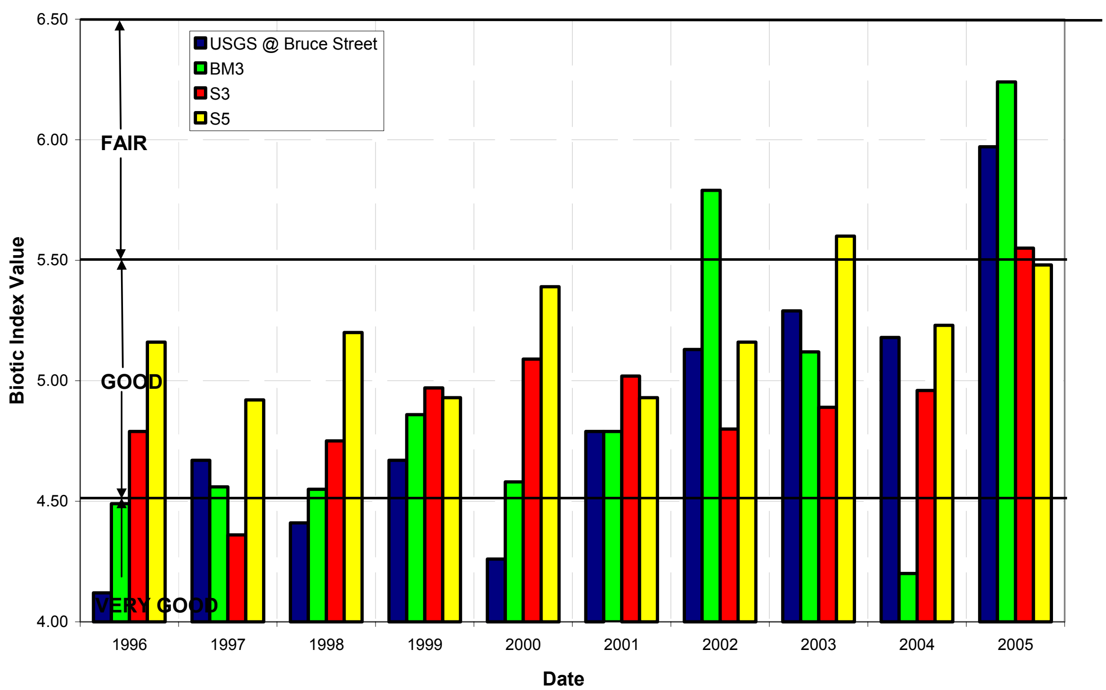


Figure 9. October Biotic Index

Figure 10 and Figure 11 show EPT values for the four sampling locations. Similar to the BI data, sample results from April may indicate a decrease in percent EPT through time. October results however do not appear to show a trend. Sample location S5 tends to have the highest percent EPT values as well as biotic index values.

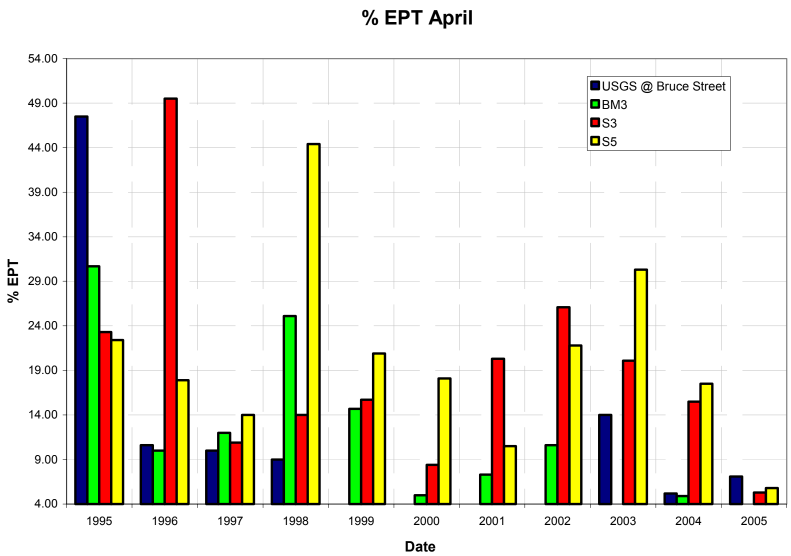


Figure 10. April EPT Values

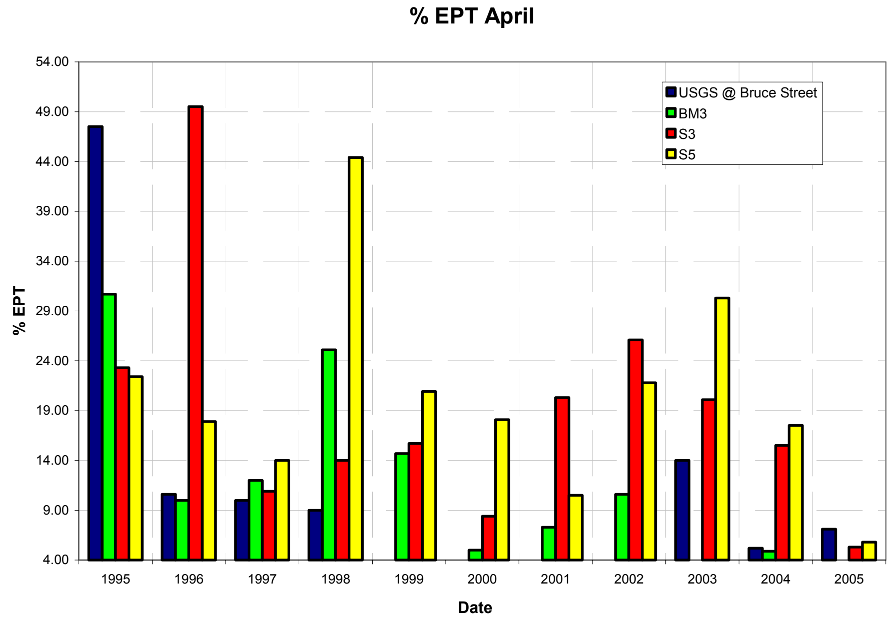


Figure 11. October EPT Values

2.3 Water Quality

MMSD has collected spot measurements of water quality parameters in the study area since 1993 (MMSD written communication). DO levels for both streams are marginal for trout, with daily minima of 6 – 7 mg/L (Figure 12). Summer temperatures recorded for Badger Mill Creek are typically 65 – 70°F, while those for the Upper Sugar River are 60 - 65°F (Figure 13). Average 5-day BOD ranges from 2.5 – 3.8 mg/L. Mean chloride concentrations are in Badger Mill Creek (132 – 263 mg/L) are near the EPA chronic exposure level of 230 mg/L, defined in the National Water Quality Criteria for freshwater aquatic life, while concentrations for the Sugar River (26 – 59 mg/L) are well below the standard. The greater chloride concentrations in Badger Mill Creek are reflected by higher mean electrical conductivity values (939 – 1323 μmhos/cm vs. 582-690 μmhos/cm, respectively). Total phosphorus (TP) for the effluent averaged 0.39 mg/L in 2007 (MMSD written communication, 2008); TP concentrations in Badger Mills Creek and the Upper Sugar River are approximately 0.21 – 0.35 mg/L and 0.13 – 0.15 mg/L, respectively. Concentrations of cadmium and lead in Badger Mill Creek are near the chronic standards.

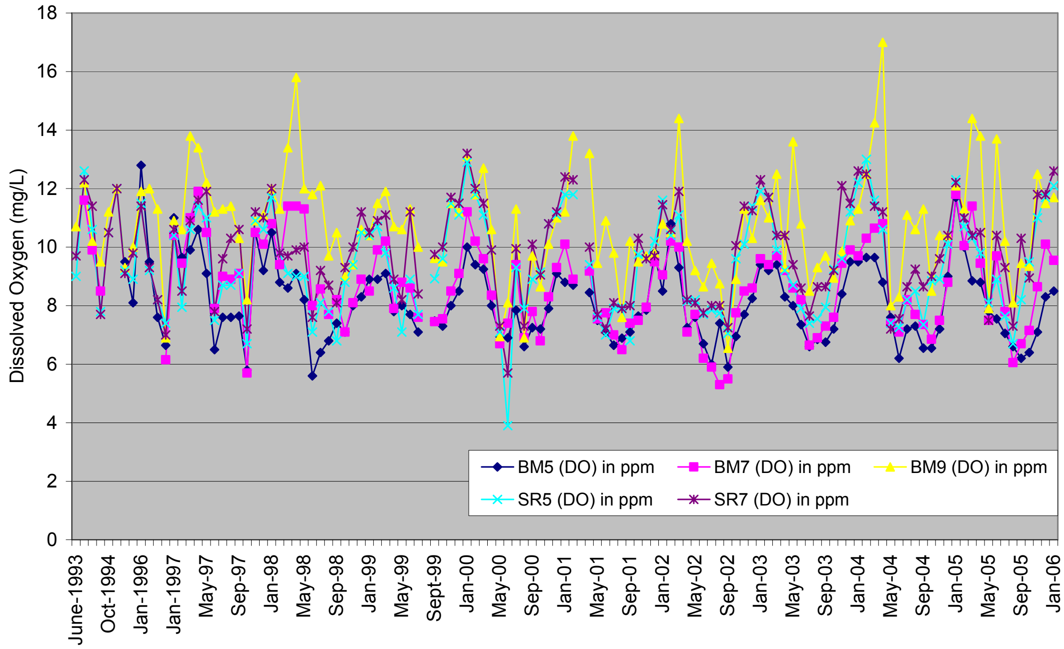


Figure 12. Dissolved oxygen for Upper Sugar River and Badger Mill Creek.
Source: MMSD spot measurements (written communication)

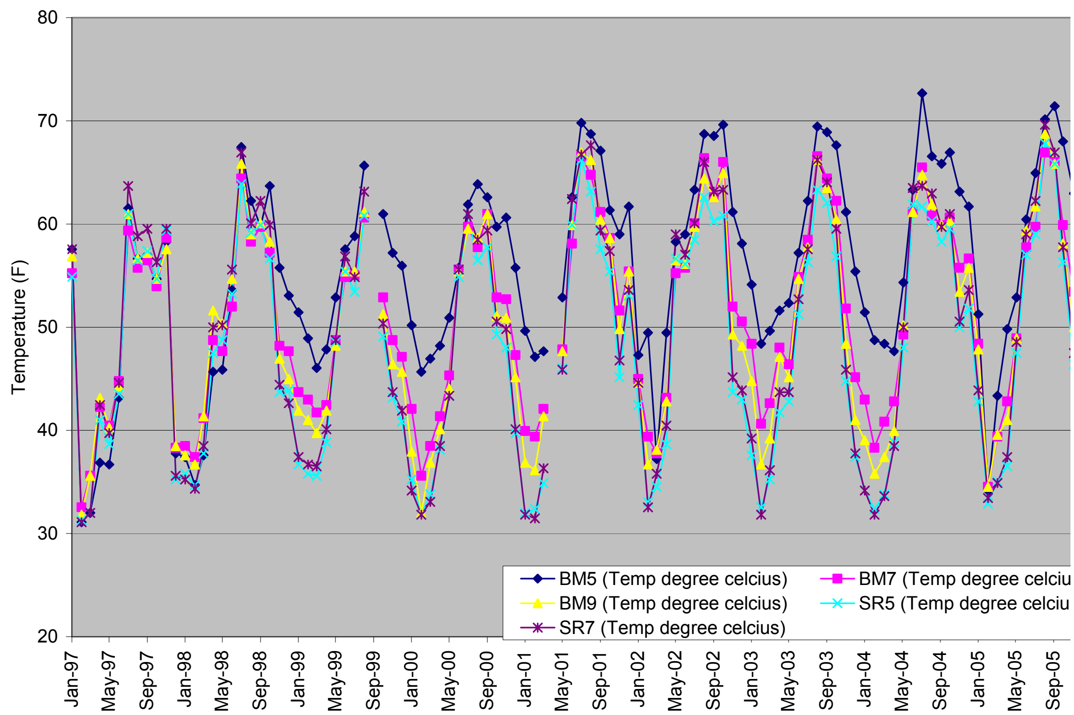


Figure 13. Temperature for Upper Sugar River and Badger Mill Creek.
Source: MMSD spot measurements (written communication)

Data on water temperature during winter and snow melt events, which can be critical for trout survival, is available for Badger Mill Creek from the USGS monitoring site at Bruce St. Daily mean water temperature during winter is generally greater than 41°F; however, the daily minimum temperature appears to dip to 35.6°F or during severe cold periods and snowmelt events (Figure 14). During very cold weather, the daily mean and maximum temperatures are also depressed; although snowmelt events create a pulse of cold water that lowers the daily minimum temperature, the mean and maximum temperatures tend to rise due to the warmer weather conditions. These observations underscore the importance of stream baseflow in buffering against both of these cold season situations. Although no winter temperature data is available for the Upper Sugar River, fewer cold-related impacts are expected due to its greater baseflow and less development.

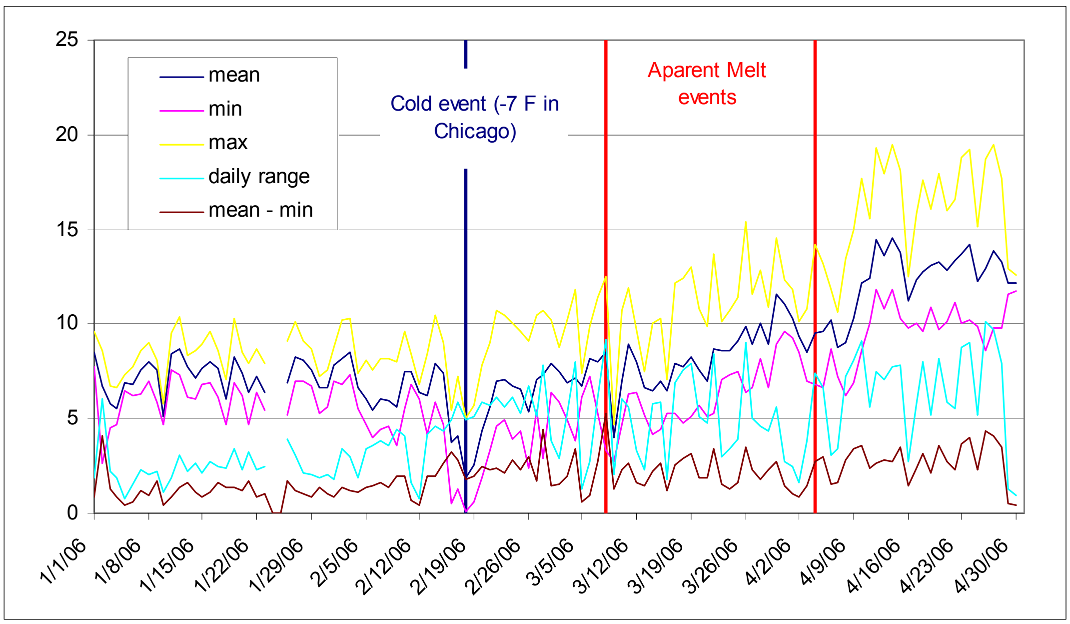


Figure 14. Cold weather temperature of Badger Mill Creek.
(Source: USGS and NOAA data).

2.4 Streamflow

The Madison Metropolitan Sewerage District (MMSD) typically discharges 4.8 cfs of treated effluent to Badger Mill Creek upstream of the City of Verona and the study area (MMSD, written communication). This discharge began in 1998 and is considered to be very important in maintaining conditions suitable for the fishery.

A University of Wisconsin-Madison Civil and Environmental Engineering course monitored baseflow at several locations on the Upper Sugar River and Badger Mill Creek in and near the study area in 1995 (before the MMSD return line was constructed). Flows for the Sugar River measured at that time are similar to those measured in the current study; their Badger Mill Creek measurement is lower than current flows by approximately 2 cfs, corresponding to the effluent discharge.

2.5 Wetlands

The Wisconsin Wetland Inventory (WWI) indicates that wetlands exist in narrow riparian corridors in most of the study area as well as in the State Natural Area. Based on the hydrologic modifier codes for the WWI map units (see Appendix A), most of these wetlands appear similar from a hydrologic standpoint, with a modifier of "K" indicating wet soil without prolonged inundation. These wetlands are typically several feet above river level, suggesting that they receive groundwater discharge seasonally when the water table is high. They are also periodically inundated by overbank flooding and runoff events.

An exception is the larger emergent wetland area within the State Natural Area, where several mapped units have a hydrologic modifier "H" indicating standing water during much of the growing season. Presumably groundwater discharge feeds these wetlands during more of each and year is a larger component of the water budget for these wetlands than the narrow riparian wetlands elsewhere in the study area. The known presence of the lady slipper in the State Natural Area wetlands is an indicator that springs are present.

2.6 Threatened and Endangered Species

An Endangered Resources Review by the Wisconsin Department of Natural Resources (attached) indicates the presence several endangered resources in and around the study area, including community types (e.g. calcareous fen and sedge meadow), several plant species, one butterfly (Mulberry Wing) and one bird (Acadian Flycatcher). Follow up actions identified by the WDNR include the following.

1. *Avoid impacts to the Acadian Flycatcher.* The study area does not contain any large woodland areas (greater than 40 to 80 acres), which is the nesting habitat required by this species. However, potentially suitable habitat is located immediately to the east of the study area. A development plan that includes wildlife corridors and maintains woodlands on steep slopes will be compatible with protection of this species.

2. *Avoid impacts to wetlands and waterways*. This issue is addressed by state, county and local ordinances regarding development of wetlands and floodplains. In addition, the recommended development zones will be located to avoid impacts to these features.

3. *Conduct additional assessments of significant open and semi-open tree canopy habitats, if encountered in development projects*. Of the five native communities identified in the DNR's database review, four are wetland communities. Protection of these communities and the rare plant species that inhabit them will be addressed as noted in item 2, as well as by plans to avoid disturbance in or near the State Natural Area where these communities most commonly occur. Semi-open dry forest lands in the study area generally occur on steep slopes or in proximity to existing development ; therefore , since these areas do not represent potentially developable land we do not expect this issue to have substantial impact on either development potential or on the associated native plant communities. As for the need for surveys to determine presence of these natural resources, this is a required protocol whenever development occurs on open lands and would be most appropriate at that time.

4. *Work with the WDNR if disturbance will occur near the Sugar River Wetlands State Natural Area.* Much of the land surrounding the State Natural Area may be unsuitable for development due to wet conditions or steep slopes, therefore we anticipate minimal development to occur near the State Natural Area. Protection the State Natural Area should be a consideration in designing stormwater drainage routes and in managing stormwater to maintain groundwater recharge.

5. *Recognize the presence of the Military Ridge State Trail in the northern portion of the study area.* The trail is located near the edge of the State Natural Area, and measures taken to protect the State Natural Area will also minimize impact to the state trail.

2.7 Geology

The streams in the study area flow over thick glacial outwash sand and gravel deposits that fill deep, preglacial bedrock valleys. The surrounding uplands consist of thin glacial till and/or colluvium over dolomite and sandstone bedrock. Ridges are generally underlain by the Sinnipee Group dolomites, with the St. Peter sandstone subcropping or outcropping mid-slope, and the dolomites of the Prairie du Chien Group near the foot of the slopes (Clayton and Attig, 1997). Soils developed on these dolomite uplands have a high clay content.

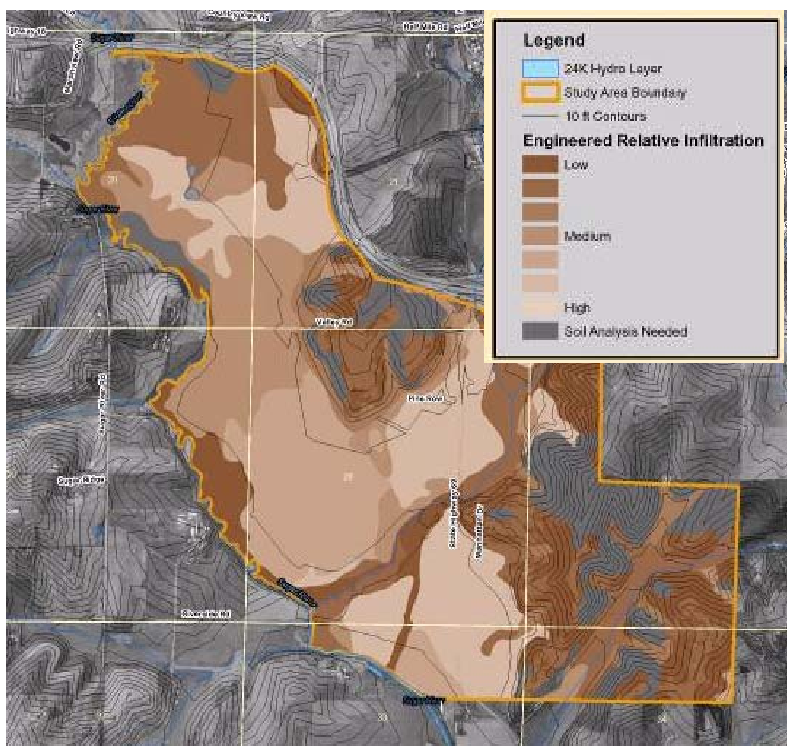


Figure 15. Engineered infiltration potential
(Source: Dane Co.)

As is common throughout much of the upper Midwest, karst features such as enlarged fractures are prevalent in the local dolomite uplands. These features can allow rapid flow of water through the bedrock, create locally high recharge rates, and supply groundwater to springs. The rapid transport through large openings in the rock provides little pollutant attenuation, and this is the rationale for restrictions on engineered stormwater infiltration systems in karst areas included in the Dane County ordinance. The locations of karst features are difficult to predict, and the thickness of the overlying clay soil greatly affects how much water drains into them. Where clay soils are thick, stormwater infiltration rates are likely to be very low. Where bedrock fractures are near the surface, however, infiltration rates can be very high and can lead to leaking stormwater detention ponds.

2.8 Soils

Dane County staff have conducted an analysis of the stormwater infiltration potential of soils in the study area (Dane County Community Planning and Analysis Division, 2005; Figure 15). This analysis used existing topographic and soils data to infer infiltration potential based on slope, soil permeability, depth to the water table, and depth to bedrock. Infiltration potential in the study area is generally shown as low to medium in upland areas and medium to high in valley bottoms, where floodplain and colluvial deposits overlie outwash sand and gravel.

2.9 Groundwater

Study Area Aquifers

Groundwater occurs in three aquifers in the study area:

- The sand and gravel that fills the buried bedrock valleys along the Upper Sugar River and Badger Mill Creek;
- The shallow sandstone and dolomite bedrock; and
- The deep Mt. Simon sandstone, underlying the Eau Claire shale aquitard.

Dane County has mapped three springs in the study area along the Sugar River and one spring near the mouth of Badger Mill Creek. Several more prominent springs can be observed within a mile of the upstream study area boundary, especially on the east side of the Sugar River near the Epic campus. Field and aerial photograph reviews suggest that the upstream springs appear to be related to fractures in the dolomite bedrock. The springs in the study area are presumably fed directly by the sand and gravel aquifer based on their locations away from the bedrock valley walls; however, flow from the underlying bedrock may contribute to these springs. The hydrogeologic details of these springs, including their source areas, are unknown.

A detailed groundwater study, including monitoring wells and stream gages, was previously conducted for the sand and gravel pit located in the study area along Highway 69 to the south of Badger Mill Creek. Information relevant to this project includes the following.

- The depth to the water table is generally 5 to 10 ft along the sandy terraces near Badger Mill Creek, except very close to the stream.
- Groundwater flow is generally to the south toward the Upper Sugar River.
- Silt and clay are common in the upper 5 feet of soil. This fine grained soil will likely need to be removed for engineered infiltration systems.

Existing Water Use

Several dozen private water supply wells are located in the study area. Well construction records show that these wells pump from the sand and gravel aquifer and the shallow bedrock. The bedrock uplands generally have shallow bedrock and groundwater at depths of 30 – 100 feet, while wells in the valleys are drilled primarily in sand and gravel with shallow groundwater (typically 10 to 20 feet).

We are not aware of any high capacity wells in the study area, however the City of Verona operates four municipal water supply wells located within the City limits to the north of the study area. Immediately to the south of the study area, the Bruce Company owns several permitted high capacity wells, including old farm wells and higher capacity wells installed recently. WDNR records indicate that these wells have a combined pumping rate comparable to one of the City of Verona municipal wells.

Future Conditions

Badger Mill Creek and the Upper Sugar River are in a separate groundwater basin than the Yahara Lakes to the east. The location of the groundwater divide separating these basins in uncertain but appears to be near the eastern limit of the City of Verona (Krohelski and others, 2000). It is possible that future pumping in the Madison area will influence the location of the divide. Presumably it would shift to the west if withdrawals in Madison increase more rapidly than those in Verona; this could result in future decreases in baseflow to Badger Mill Creek.

A screening analysis of groundwater impacts of future development conducted by the Dane County Community Analysis and Planning Division staff indicates that future reductions in baseflow for Badger Mill Creek and the Upper Sugar River are likely to be modest (Mike Kakuska, written communication, 2007). This analysis used the Dane County Regional Groundwater Model to assess changes in streamflow for Badger Mill Creek at Highway 60 and the Upper Sugar River at Highway 18/151 for several future scenarios including decreased groundwater recharge in the study area, increased pumping of the existing Verona municipal wells, and combinations of reduced recharge and increased pumping. This analysis assumes the MMSD effluent discharge to be maintained at 4.8 cfs. The most extreme scenario, simulating zero recharge over the entire study area and triple the 2000 pumping rates for the four Verona wells, predicts only modest decreases in the baseflow of the streams (losses of 0.4 cfs for the Upper Sugar River and 1.0 cfs for Badger Mill Creek). This modest magnitude of these impacts is likely a reflection of (1) the small size of the study area relative to the upstream watersheds, and (2) the fact that the Verona wells draw some of their water from the deep sandstone aquifer below the Eau Claire shale, which provides some protection against local groundwater declines by distributing the impacts of pumping to surrounding areas.

2.10 Archaeological & Historical Sites

A literature review of known archaeological and historical sites in the study area was conducted as part of this study by Archaeological Consulting and Services, Inc. The area includes ten documented archaeological sites, included four mound sites. Although more detailed investigations will likely be needed as the area develops, it does not appear that the presence of these sites create major issues for future development.

3 NEW DATA COLLECTION AND ANALYSIS

3.1 Data Gaps to be Addressed

The available data provide valuable information regarding the condition of the study area, however some data gaps were identified.

Fish and invertebrates. The available data from MMSD and WDNR provide adequate information on the condition of the fishery, including spatial and temporal variations. No additional data collection is necessary for the purpose of this study.

Wetlands. Little information other than the Wisconsin Wetland Inventory is available for wetlands, especially for those outside of the State Natural Area. Limited fieldwork to check and update information in the WWI, such as approximate wetland boundary locations and hydrologic conditions, would be beneficial.

Streamflow. Continuous discharge data is available only for Badger Mill Creek at the USGS site, and spot discharge measurements are available for a few locations on each stream for different dates over the past decade. Continuous flow data for the Upper Sugar River would provide valuable information on runoff response characteristics and the duration of low flows relative to Badger Mill Creek. Spot measurements of discharge at multiple locations on each stream would provide spatial information on groundwater inflow to streams useful for interpreting temperature and other water quality data.

Water Quality. Although a substantial volume of water quality data exist for both streams, it is difficult to interpret these results for parameters such as temperature and dissolved oxygen that have large daily fluctuations. Because these parameters are critical for trout habitat, continuous temperature and dissolved oxygen data would be valuable.

Soils. The previous work by Dane County provides a framework for evaluating stormwater infiltration potential and the impacts of future development. Limited field verification of this information was deemed important before applying that soils analysis to this planning study.

Groundwater. The Dane County Regional Groundwater Model (Krohelski and others, 2000) is a valuable tool for evaluating general impacts to the groundwater flow system and streamflow, including impacts of changes in recharge and groundwater pumping. This model was not designed for site-specific analyses of surface water impacts, and construction of a detailed model of the study area is beyond the scope of this study. However, useful information for planning purposes can be gained by sensitivity analyses with the regional model to understand the potential magnitude of changes related to future development. The Dane County Regional Planning Commission has conducted such an analysis, as discussed in Section 4.4 of this report.

3.2 Streamflow

New streamflow and water quality data was collected at several sites within, upstream of, and downstream of the study area (Figure 16).

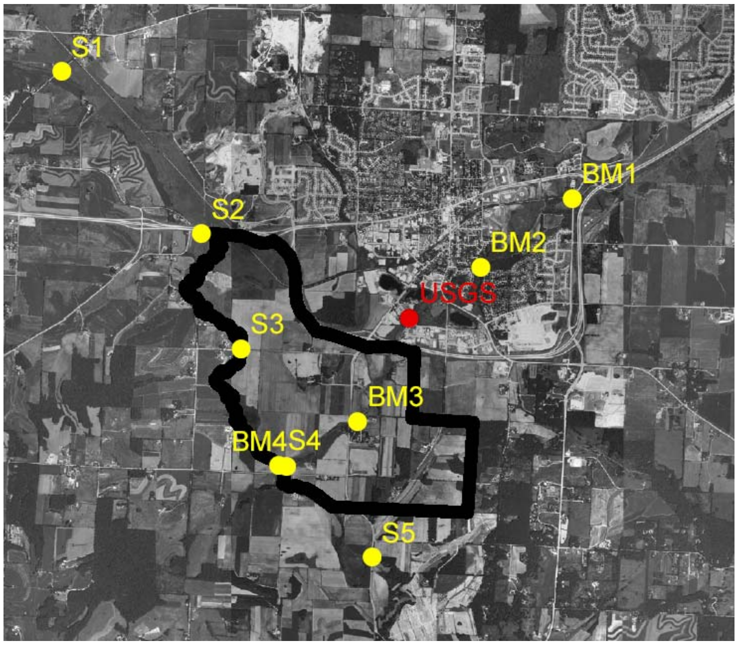


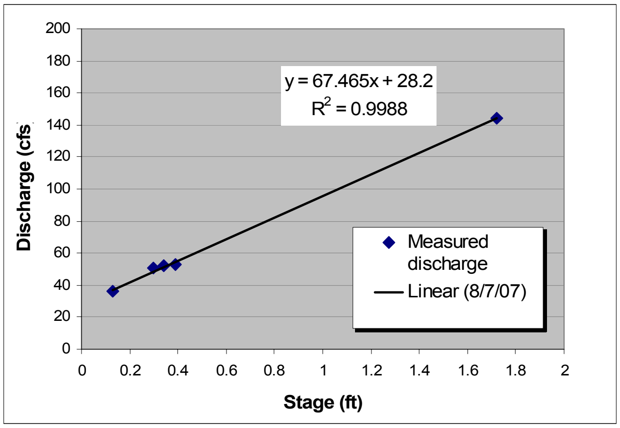
Figure 16. Monitoring sites for this study.
USGS station on Badger Mill Creek at Bruce Street shown in red.

Gaging station establishment

We established a gaging station on the Upper Sugar River at Hwy 69 (site S5), approximately 1 mile downstream of the study area. River stage was monitored continuously, with manual discharge measurements to develop a limited rating curve (Figure 17).

High-flow response

Comparison of streamflow of the Upper Sugar River at S-5 and Badger Mill Creek at the USGS gaging station at Bruce St indicates that flood peaks occur more rapidly and have a shorter duration in Badger Mill Creek (Figure 18). This is likely due to the increased urban development in Badger Mill Creek as well as the fact that the Sugar River site is downstream of Badger Mill Creek.



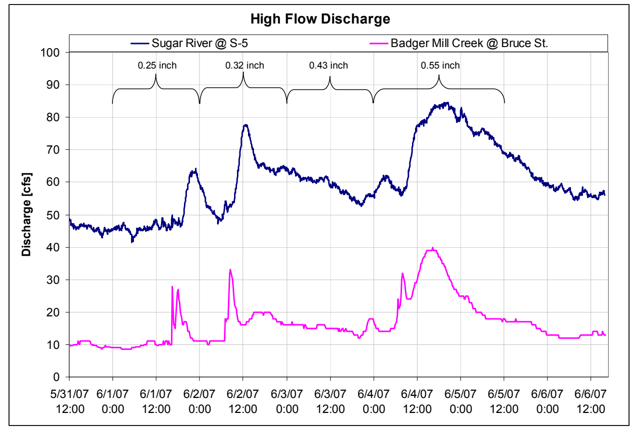


Figure 17. Discharge rating curve for Upper Sugar River.

Figure 18. Sugar River and Badger Mill Creek hydrograph comparison.

The rapidity of flood response can be quantified using a "flashiness index" (Baker and others, 2004). This index describes day-to-day variations in flow; the more rapid the change from low flow, to flood peak, and back to low flow, the higher the flashiness index. Flashiness indices for the Upper Sugar River at S-5 and Badger Mill Creek at Bruce Street during the summer of 2007 are 0.15 and 0.6, respectively. Compared to Midwestern streams of similar drainage area, the Upper Sugar River flashiness index value is low, and that for Badger Mill Creek is moderate to high (Baker and others, 2004).

The flashiness index tends to increase with urbanization and watershed area, and high flashiness is typically correlated with low baseflow (Baker and others, 2004). The higher flashiness of Badger Mill Creek probably reflects its greater degree of urbanization and the larger watershed area for the Upper Sugar River monitoring site S-5 at Highway 69. Ongoing research on Wisconsin streams by the US Geological Survey indicates that streams with higher flashiness indices tend to have lower quality fish habitat (Jeff Steuer, personal communication, 2007).

Low flow Characteristics

The discharge of Badger Mill Creek fluctuates by about 2 cfs during a typical day, and this pattern is recorded at both the USGS gage at Bruce Street and at site S5 on the Upper Sugar River downstream of Badger Mill Creek (Figure 19). This fluctuation does not appear to be related to the MMSD effluent discharge, which is constant other than a daily 5-minute reduction in flow. It is possible that these discharge fluctuations are related to daily variation in evapotranspiration, because they are most pronounced in the summer and do not appear to occur in the winter.

We conducted two "synoptic surveys" of baseflow in the Upper Sugar River and Badger Mill Creek to assess spatial patterns in streamflow. This involved measuring streamflow at multiple locations in a single day to provide a snapshot of spatial variations in each stream. We measured discharge at multiple locations on June 14 and August 2, 2007, in periods of dry weather representative of baseflow conditions (Figure 20). The sources of water during baseflow periods are presumably groundwater discharge, the MMSD effluent discharge into Badger Mill Creek, and releases from stormwater detention basins within the watershed. Both streams exhibit gradual increases in baseflow through the study area. Plotting these survey results as discharge divided by the upstream surface watershed area (Figure 21) provides insight into relative groundwater contributions; assuming the surface and groundwater basins coincide. Higher discharge per unit area indicates higher groundwater inflow to the stream. Groundwater inputs to the Upper Sugar River appear to be greatest upstream of the study area, which is consistent with the observation of prominent springs in the reach between sites S1 and S2. The flow per area for the Badger Mill Creek headwaters is augmented by the MMSD effluent. The declining trend in flow per area indicates that there is only modest groundwater input in the study area, which may lead to less stable temperatures as meteorological conditions have a relatively greater influence.

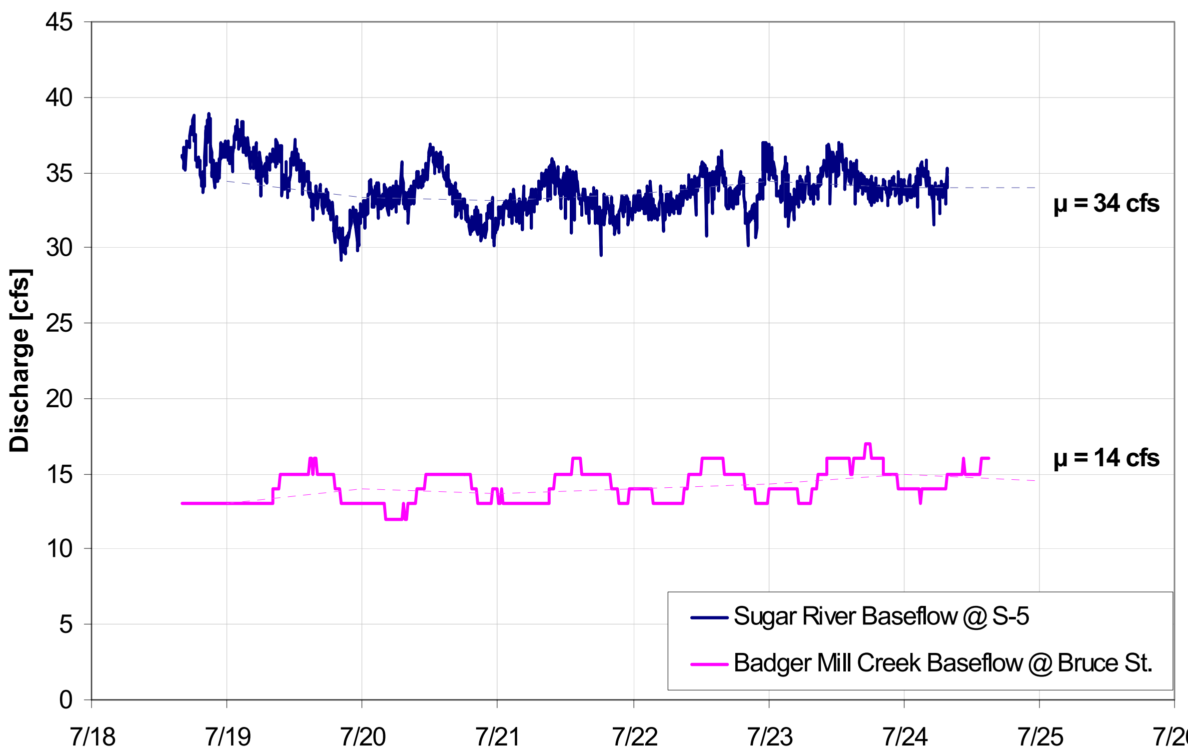


Figure 19. Low flow hydrograph comparison
(Provisional 2007 data)

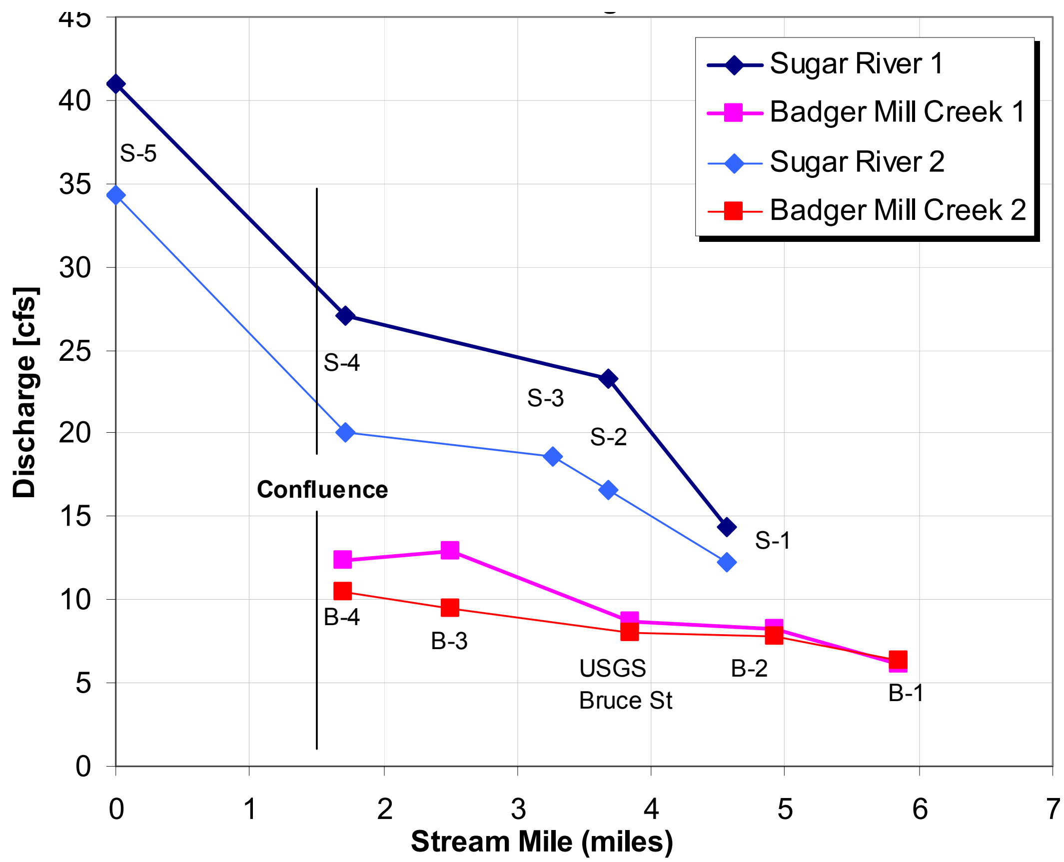


Figure 20. Synoptic baseflow survey results.

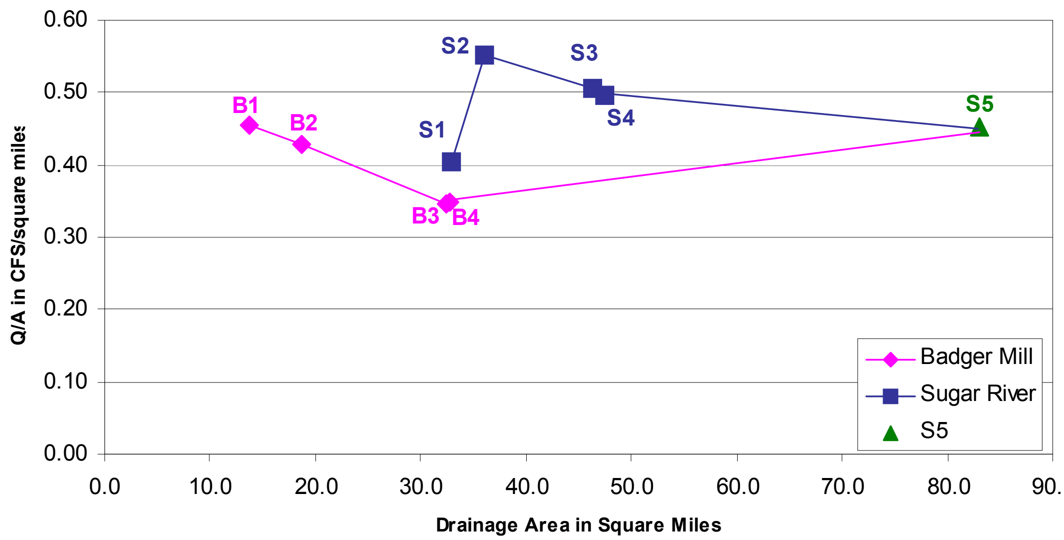


Figure 21. Baseflow per unit drainage area.

3.3 Temperature

We monitored temperature at approximately 5-minute intervals at 9 sites on both streams, and the USGS monitors the temperature of Badger Mill Creek at Bruce Street. This data provides information on water spatial and temporal patterns in stream temperature during baseflow periods and during runoff events.

During warm weather baseflow periods, the Upper Sugar River is colder than Badger Mill Creek (Figure 22). Upstream of the study area, the temperature of Badger Mill Creek drops sharply by approximately 4°F downstream of the MMSD effluent return line, between stations B-1 and B-2. This presumably occurs because the effluent is warmer than the groundwater, and groundwater flowing into the stream mixes with the effluent and reduces the stream temperature. As Badger Mill Creek flows through the study area, it is warmed by weather conditions, with an average temperature increase of approximately 2°F.

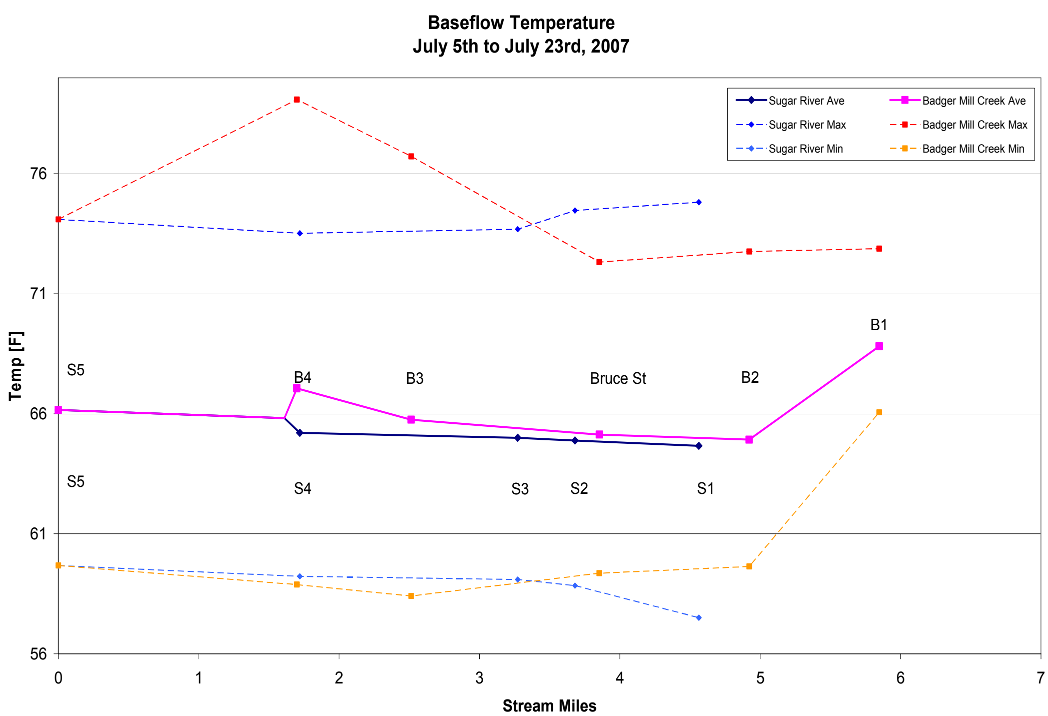


Figure 22. Average baseflow Temperatures for SR and BMC
Data from July 5th through July 23rd, 2007

We conducted additional measurements with a hand-held thermometer to investigate if the warm temperature at B-1 is indeed caused by the effluent, or if it is related to conditions farther upstream in Badger Mill Creek. Measurements on September 6, 2007 found that the stream of effluent joining Badger Mill Creek immediately downstream of the outfall was warmer than the upstream temperature of Badger Mill Creek (70.5°F vs. 68.2°F). The measured downstream temperature of 70.3°F is consistent with a simple mixing calculation, assuming flows of 4 cfs for the effluent and 2 cfs upstream to match the measured 6 cfs at B-1. Data collected by MMSD at the Nine Springs treatment plant indicate that a typical effluent temperature in early September is 70 – 71°F, measured (Paul Nehm, MMSD, written communication). This indicates that the effluent temperature does not change appreciably during its transport to the discharge location.

Several runoff events during hot weather caused a rapid increase in the temperature of Badger Mill Creek. A temperature spike of approximately 7°F was detected during a 0.39-inch rainfall on May 24, 2007. It appears that the temperature spike originated between stations B-1 and B-2, and it was detected in downstream stations in Badger Mill Creek and at site S-5 in the Upper Sugar River below the confluence with Badger Mill Creek (Figure 23). Several similar events were recorded in the summer. In each case, temperature impacts occur downstream of B-1 and persist downstream to S-5 on the Upper Sugar River. Above the confluence, the Upper Sugar River is relatively unaffected. The magnitude of the temperature increase does not appear to be well correlated with the discharge of the runoff event, and other factors such as the air and surface temperatures before the rainfall and the time since the previous rainfall probably have a substantial influence. Discussion with City of Verona staff suggests that the source of this temperature spike is an uncontrolled stormwater outfall a short distance upstream of site S2. This demonstrates the need to include thermal mitigation measures in stormwater designs in the study area.

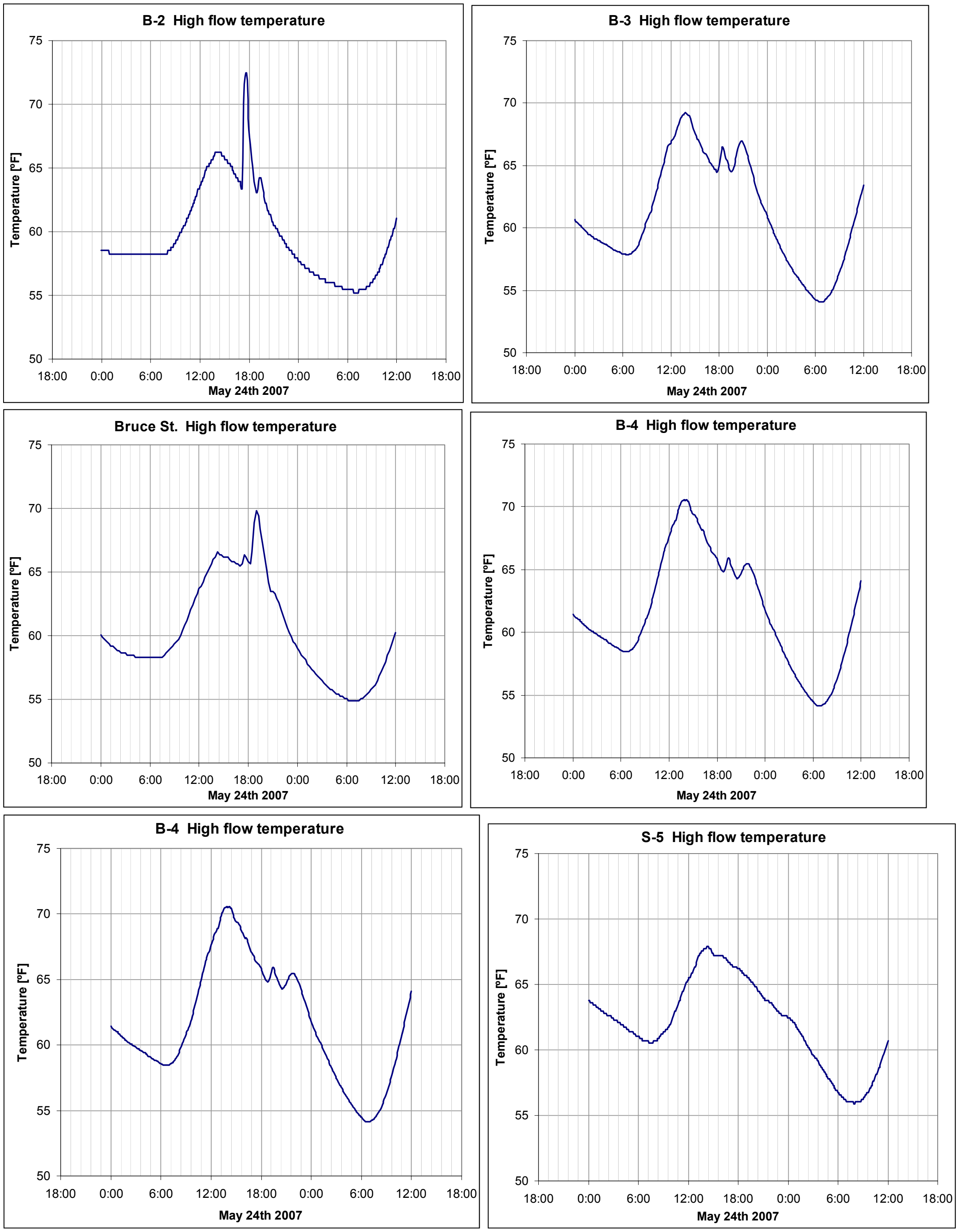


Figure 23. May 24th temperature monitoring on the Sugar River and Badger Mill Creek

3.4 Dissolved Oxygen

We have installed continuous dissolved oxygen (DO) monitoring equipment on the Upper Sugar River immediately upstream of confluence with Badger Mill Creek (site S4). This data supplements continuous DO data collected by USGS on Badger Mill Creek at Bruce St. The Upper Sugar River and Badger Mill Creek sites have similar daily DO fluctuations, although DO is 1-2 mg/L lower for Badger Mill Creek (Figure 24).

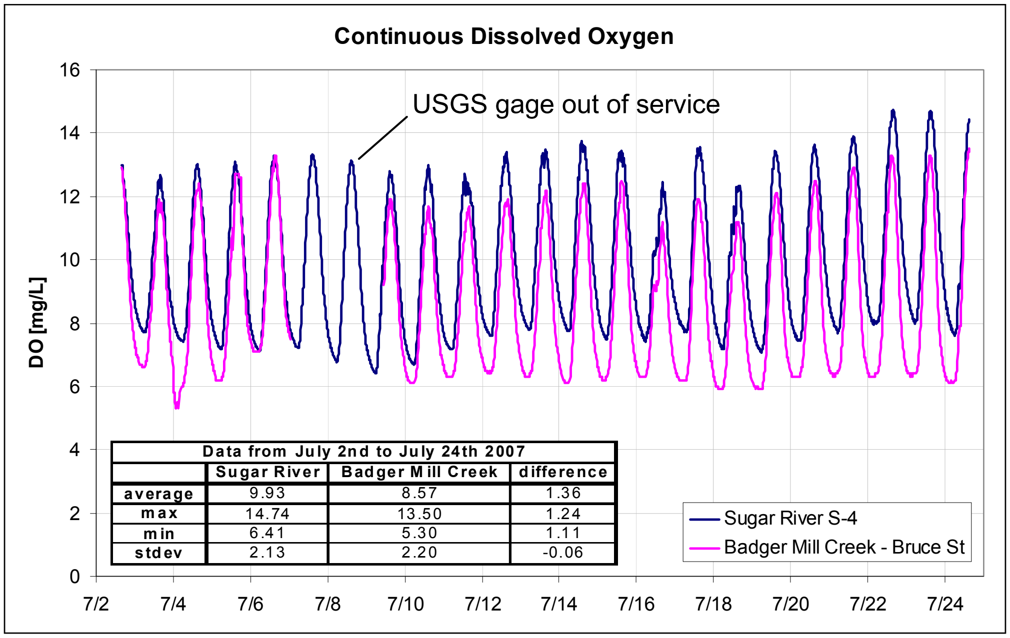


Figure 24. Continuous Monitoring of Dissolved Oxygen
Sugar River and Badger Mill Creek (07/02/07 to 07/24/07)

On July 24, 2007 a synoptic survey of DO was conducted in early morning hours, when DO is near its daily minimum and is changing slowly. This allows comparison of approximate daily minimum DO between sites to detect upstream-downstream patterns (Figure 25). This survey also indicates that DO is 1 – 2 mg/L lower for Badger Mill Creek. On each stream, measured DO values are within about 1 mg/L, with the exception of the uppermost sites on the Sugar River. It is uncertain whether the measurements at sites S-1 and S-2 are truly representative of DO conditions, or whether they reflect the depth of sampling where deep, slow moving water may create stratified DO conditions.

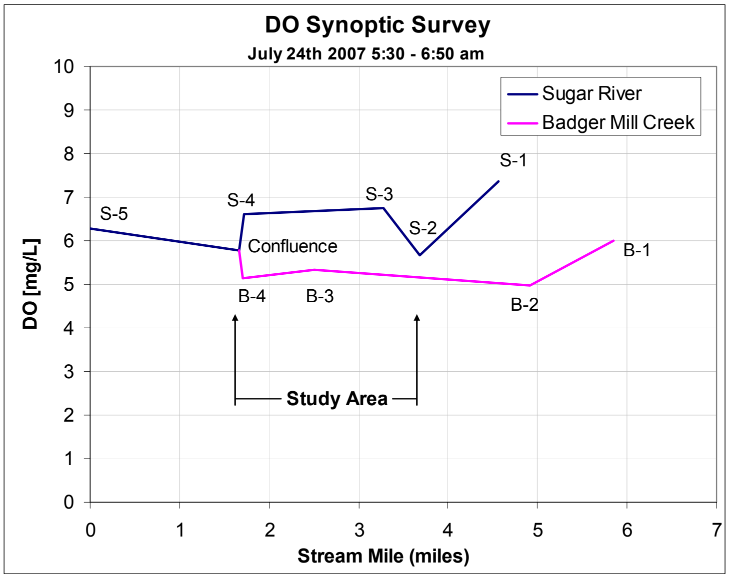


Figure 25. Dissolved Oxygen Synoptic Survey of Daily Low Temperatures for SR and BMC (07/24/07)

3.5 Soils

We augmented the Dane County analysis of soil infiltration potential by performing several soil auger transects (Figure 26) to observe soil conditions, and by conducting an analysis of how soil properties vary with landscape slope position (Appendix B). Upland areas with convex slopes (e.g. ridges) tend to have fractured dolomite very near the land surface, overlain by drainage-inhibiting clay in some locations. Convex slope areas (e.g. drainage swales) have deep, silt and clay soils (Figure 27). At the toe of the slopes, it appears that many feet of fine grained soil are present above the sand and gravel valley fill.

These results suggest that infiltration potential on ridges is variable, with high infiltration rates likely where the clay is absent and the bedrock is fractured. However these areas would provide limited water quality treatment. The convex drainage swales have very low infiltration potential, however their thick fine grained soils make them well suited for stormwater conveyance with low risk of impacting groundwater quality. The highest infiltration potential is in the sandy valley bottom soils, however removal of several feet of overlying fine grained colluvium and/or floodplain deposits would probably be necessary.

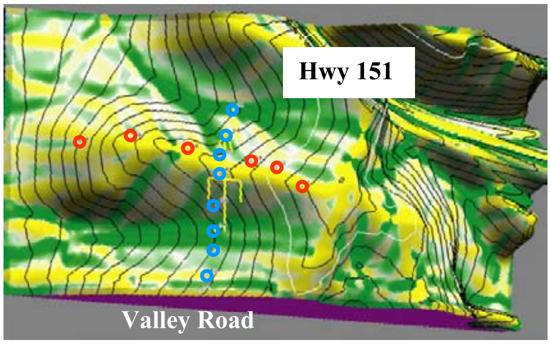


Figure 26. Soil terrain analysis.

Figure 27. Fine grained soil on concave slope.

3.6 Wetlands

A review of available data on wetlands, plus limited field review of wetland communities and boundaries were conducted to determine the approximate extent of wetlands and to identify key resource considerations for planning purposes (Appendix A). This work was conducted to assist determination of appropriate areas for development and does not eliminate the need for site-specific wetland delineations for proposed development projects. Observed wetland boundaries are similar to those shown by the Wisconsin Wetland Inventory; field investigation indicated that wetlands extend beyond the WWI boundary in the southeastern part of the State Natural Area and in the riparian zone of Badger Mill Creek downstream of Highway 69 (Figure 3 in Appendix A).

The DNR Rapid Assessment Methodology was used to appraise different aspects of study area wetlands. Floral diversity within the wetlands is generally low, with reed canary grass dominating riparian wetlands of the Upper Sugar River and Badger Mill Creek. Some of the actively managed wetland areas in the State Natural Area have medium floral diversity scores. Wildlife and fishery habitat within the wetlands is low to medium, with the wetlands directly adjacent to the Sugar River and Badger Mill Creek higher in these values than non-adjacent wetlands. All of the wetlands within the study area provide valuable flood and stormwater attenuation and water quality protection functions, with high rankings for these functional values. Shoreline protection, where applicable, is generally in the low to medium range. The groundwater functional value for these wetlands is low to medium, with many of the wetlands helping to maintain stream base flow and/or containing springs. The aesthetics functional value is medium to high for the actively managed wetlands near the existing recreational trail, low to medium for the wetlands directly adjacent to the Sugar River, and low elsewhere.

3.7 Stream Channel Habitat

As part of a reconnaissance of the streams in the study area, limited data was collected on physical stream channel habitat. This was collected to provide general information on the condition of the streams throughout the study area and a baseline for comparison in the future. Information on water depth, substrate condition, bank stability and riparian vegetation was recorded at several locations on the Upper Sugar River and one location on Badger Mill Creek (Plate 1; Appendix C). Spring locations were also verified in the field.

Above the confluence, the channel of the Upper Sugar River generally appears more stable and shows less sign of sedimentation issues than Badger Mill Creek. Below the confluence, the Upper Sugar River is wider and shallower and appears to have a higher sediment load (Plate 1).

3.8 Analysis of Future Development in the Upstream Watershed

The streams in the study will be affected not only by adjacent land use, but also by the cumulative impacts of land use changes in the upstream watersheds. In the next few decades, relatively modest development is expected in the upstream parts of the Upper Sugar River watershed, while a significant conversion of agricultural land to residential development is expected in the Badger Mill Creek watershed upstream of the study area, in the Cities of Verona and Madison (Figure 28; Kamran Mesbah, written communication).

To quantify the magnitude of hydrologic impact of future upstream development, we constructed a watershed model using XP-SWMM to simulate runoff conditions for current conditions and in the year 2050. This analysis calculates flows entering the study area from the upstream watershed; it does not simulate land use change in the study area itself. The model computes runoff volume as an indicator of the impact of urbanization. Calculation of runoff peaks is beyond the scope of this study, as that would require detailed analysis of existing and future stormwater detention practices in the upstream watersheds. Implementation of the County ordinance should ensure that the 2 – 10 year peak discharges are controlled to pre-development levels. Peaks for smaller events are likely to increase, because stormwater systems are not typically designed to control these more frequent events.

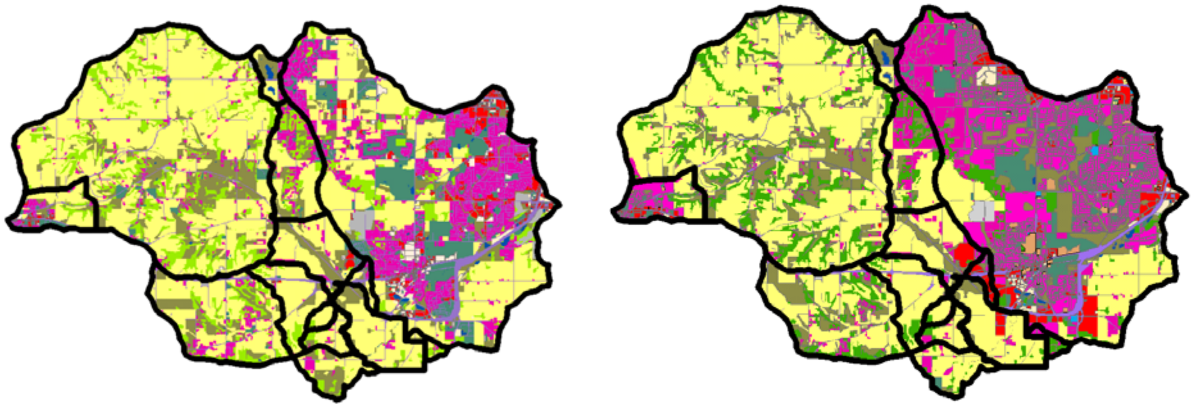


Figure 28. Current and projected 2050 land use in the study area and upstream watersheds
Pink and purple indicates developed areas. Yellow indicates agricultural areas. Note that the Badger Mill Creek watershed is expected to undergo more urbanization that the Upper Sugar River Watershed

The model predicts only a modest increase in stormwater volumes for the 2 – 100 year events (Table 4). Although this may appear unexpected, it reflects the transition from current row crop agriculture to future residential development, which are commonly assumed to have similar runoff characteristics. There is likely to be a more pronounced increase in stormwater volumes for smaller, more frequent events, however implementation infiltration practices may limit such volume increases.

In summary, upstream development is likely to result in modest increases in stormwater peaks and volumes, however conditions are not expected to change dramatically. Although not considered in this model analysis, construction-time erosion has the potential to substantially increase sediment loads to the streams if effective erosion control practices are not implemented.

Table 4. Simulated Stormwater Runoff Volumes
Badger Mill Creek and Upper Sugar River watersheds upstream of the study area

Simulation Scenario	Stormwater Runoff Volume (acre feet)		
	2-year storm event (2.9 inch rainfall)	10-year storm event (4.2 inch rainfall)	100-year storm event (6.0 inch rainfall)
Current Land Use	3,818	7,290	12,012
2050 Land Use Projection	3,970	7,447	12,174

3.9 Resource Assessment Summary

Table 5 summarizes key findings regarding the hydrologic and ecological conditions in the study area.

Table 5. Summary of Study Area Resource Assessment

Issue	Upper Sugar River	Badger Mill Cr	Locust Road Dry Tributary
Stream baseflow	Modest inflow in study area. Apparent recharge rate 5.5 – 7.5 in/yr.	30 - 50% effluent. Low inflow in study area. Apparent recharge rate 2 – 3 in/yr.	NA
Flashiness of runoff response	Low (R-B Index 0.15) Wetlands help attenuate peaks.	High (R-B Index 0.6)	NA
Temperature	Fair for stocking, marginal for natural reproduction.	Marginal for adult trout	NA
Water quality	DO poor for juvenile trout. Well below EPA standards for chlorides & metals	DO marginal for adult trout & poor for juveniles. Near EPA freshwater aquatic life chronic standards for chloride, cadmium & lead.	NA
Channel – habitat & stability	Fair above confluence. Impacted below confluence	Substantial erosion & sedimentation	NA
Wetland quality	Low - Medium	Low	None documented
Upland resources	Primarily agricultural land. Minimal forest.	Primarily agricultural land. Minimal forest.	Small woodlands present
Fish	Poor-fair rankings since 1999. – High tolerant & omnivore spp. – Lack of darters & insectivores Indicates degraded and undesirable conditions.	Very Poor-fair rankings – High tolerant & omnivore spp. – Suckers; low darter, intolerant & insectivore spp. Indicates higher level of degraded and undesirable conditions.	NA

Issue	Upper Sugar River	Badger Mill Cr	Locust Road Dry Tributary
Invertebrates	– EPT approx. 20% in the spring and between 36-54% in the fall – BI values fair-very good – Indicates low to modest water quality impairment	– EPT approx 11% in the spring and 22-31% in the fall – BI values fair-very good – Indicates low to modest water quality impairment	NA
Soil infiltration potential	Valley bottom – High Uplands - Low	Valley bottom – High Uplands - Low	Low
Future upstream development impacts	Modest runoff volume increase		NA

4 DEVELOPMENT ANALYSIS AND RECOMMENDATIONS

4.1 Fishery

Habitat Suitability Index (HSI) models were constructed by the Fish and Wildlife Service in 1986 to relate known habitat requirements for brown trout to varying stages of life (Raleigh and others, 1986). This model gives a quantifiable method to assess current conditions within a stream and infer impacts of hydrologic alteration on stream ecosystems. The HSI considers many habitat parameters, including several for which no data is available for the study area. However, site-specific temperature and dissolved oxygen data can be compared with the HSI to gain an understanding of key sensitivities. In

Figure 29 through Figure 31, data from the Upper Sugar River is plotted in red and data for Badger Mill Creek is plotted in blue. A suitability index value of 1.0 indicates optimal habitat. This analysis indicates that summer water temperature and dissolved oxygen are marginal in both streams.

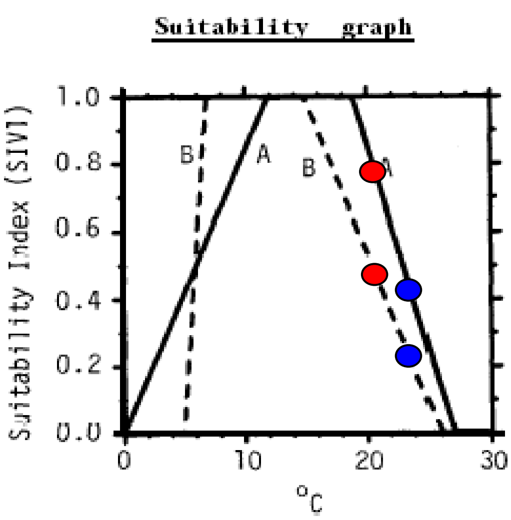


Figure 29. HSI for maximum summer water temperature

Solid lines labeled "A" for adults and juveniles, Dashed lines labeled "B" for fry. Data collected in this study for Sugar River at site S-4 (21.4°C) and Badger Mill Creek at site B-4 (25.5°C).

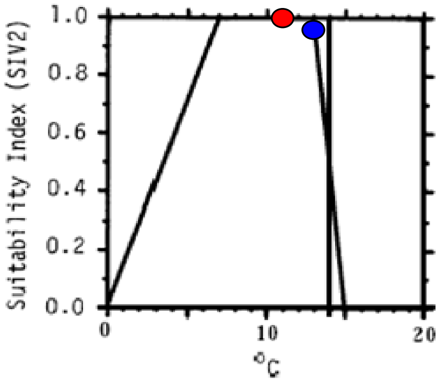


Figure 30. HSI for maximum water temperature during embryo development
Maximum Temperatures Taken From MMDS for October - December 2004 and 2006 at Stations BM9 (~13.2°C) and SR5 (~11°C).

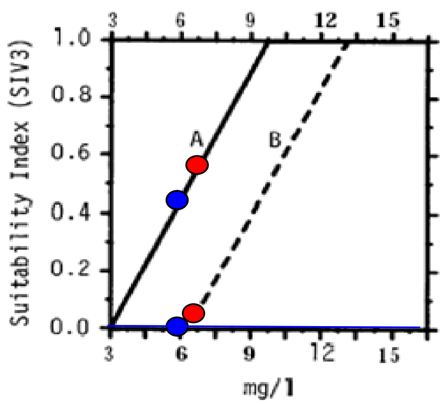


Figure 31. HSI for minimum late season DO
Solid line labeled "A" for adults and juveniles; dashed line labeled "B" for fry. Sugar River data collected in this study at site S-4 (6.0 mg/L). Badger Mill Creek data from USGS monitoring site at Bruce Street (4.7 mg/L).

Relationships between baseflow and fish communities have been studied in detail for Michigan streams (e.g. Zorn and others, 2002). Although these relationships are likely to vary geographically and may not accurately represent conditions in southern Wisconsin, this work provides additional insight into the condition of streams in the study area. Comparison of baseflow and catchment area data for our monitoring sites on the Upper Sugar River and Badger Mill Creek indicates that the baseflow of these streams is low compared to brown trout fisheries in Michigan (Figure 32).

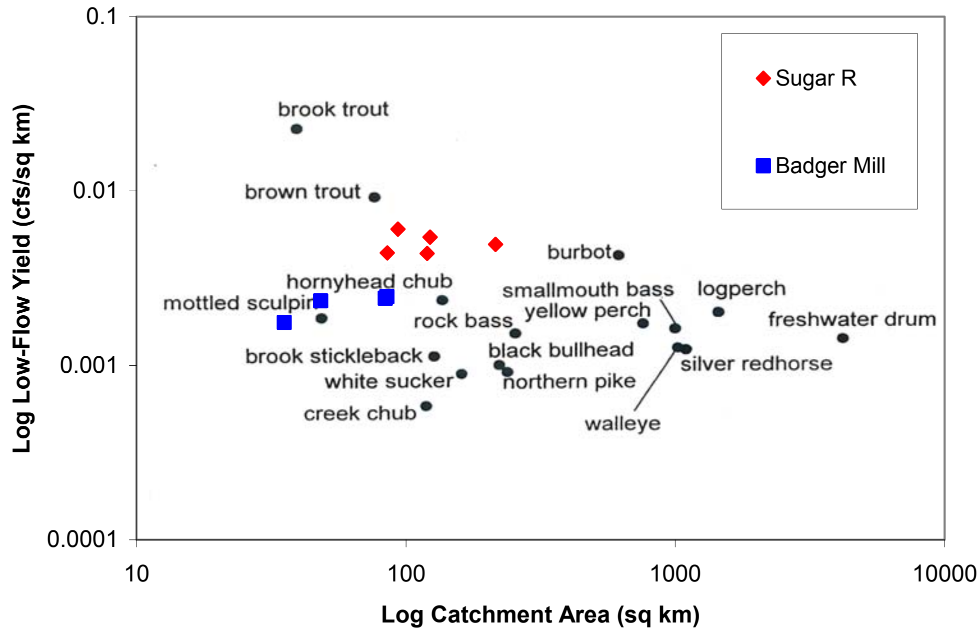


Figure 32. Relationship between fish communities, catchment area and baseflow yield. Developed for Michigan streams by Zorn and others, 2002. Baseflow data collected in this study plotted for comparison.

4.2 Stream Channel Stability

Observations of the streams in the study area suggest that the channel of the Sugar River above the confluence is rather stable, with well vegetated banks and a sandy bottom. Badger Mill Creek shows signs of incision, with steep, eroded banks in numerous locations. Downstream of the confluence, the Sugar River channel becomes noticeably wider and shallower with few pools, presumably related to inflows of stormwater and sediment from Badger Mill Creek.

Bledsoe and Watson (2001) suggest it is possible to predict stream channel instability based on the slope (S), estimated channel forming discharge (Q), and median bed material size (d_{50}). A "mobility index" is calculated as:

$$S\sqrt{\frac{Q}{d_{50}}}$$

We estimate mobility index values for the Upper Sugar River and Badger Mill Creek of 0.1 and 0.3, respectively (Figure 33), using slope and discharge data from the 1995 University of Wisconsin study and typical diameters for sand. Comparison with the model presented by Bledsoe and Watson (2001) suggests that Badger Mill Creek is at greater risk of destabilization; this is consistent with the field observations described above and the higher flashiness index for Badger Mill Creek. It appears that a modest increase in the discharge for small, frequent flood events (Q) in Badger Mill Creek could lead to a substantial decrease in stability for Badger Mill Creek.

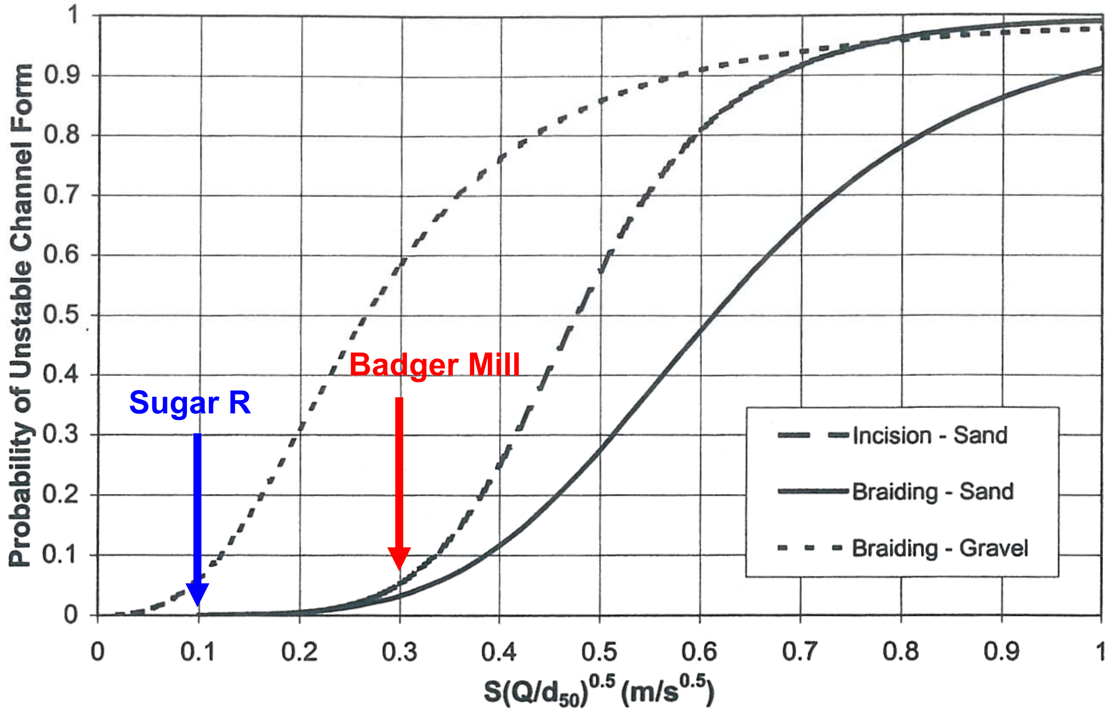


Figure 33. Stream channel stability index.

4.3 Wetlands

Most of the riparian wetlands in the study area are not considered to be highly sensitive to further impacts. They are dominated by invasive reed canary grass, have low floral diversity, and are already subject to frequent runoff events. The State Natural Area wetlands are likely to be highly sensitive to changes in hydrology due to the presence of rare and threatened plant species, and the assumed importance of groundwater inflow. Efforts to protect the SNA wetlands should focus on maintaining groundwater inflow to the wetlands and minimizing changes in stormwater inputs.

4.4 Groundwater

To better understand the sensitivity of springs and streamflow to future development, we conducted additional groundwater model analyses to supplement the previous work of County staff. Although a detailed analysis of the local groundwater system is beyond the scope of this study, the Dane County Regional Groundwater Model and a more detailed inset model of the Nine Springs wetlands in Fitchburg (Swanson, 2001) provide insight into the groundwater source areas, aquifers and flow paths that feed springs and streams in the study area.

The Nine Springs model includes more details of the bedrock aquifers than the regional model and therefore may provide additional insights into groundwater-surface water interactions in the study area. The model was constructed primarily to study the impact of upper bedrock units, such as the sandstones of the Tunnel City Group, on spring flow in Fitchburg, however it includes Badger Mill Creek in the easternmost part of the study area. Primary similarities and differences in the models include the following.

- The Nine Springs model has 6 aquifer layers; the regional model has 4 layers.
- The Nine Springs model has a thin, very high hydraulic conductivity layer in the shallow bedrock system representing bedding plane fracture zones in the Tunnel City Group which are thought to be important in supplying water to springs.
- Both models represent the Eau Claire shale as a significant barrier to vertical flow.

Both models suggest that streams and springs in the study area are fed by both the shallow and deep aquifer systems. Shallow groundwater flows to Badger Mill Creek and the Upper Sugar River in the upper bedrock aquifer and sand and gravel aquifer, with contributing areas in the uplands well beyond the boundaries of the study area (Figure 34). The regional model illustrates that flow in the deep aquifer (below the Eau Claire shale) is generally eastward toward the Yahara River, but that some water from the deep aquifer flows upward through the shale to feed the Sugar River and Badger Mill Creek (Figure 35). Pumping wells capture some of the deep aquifer water near the study area, probably at the expense of flow to the streams, especially Badger Mill Creek.

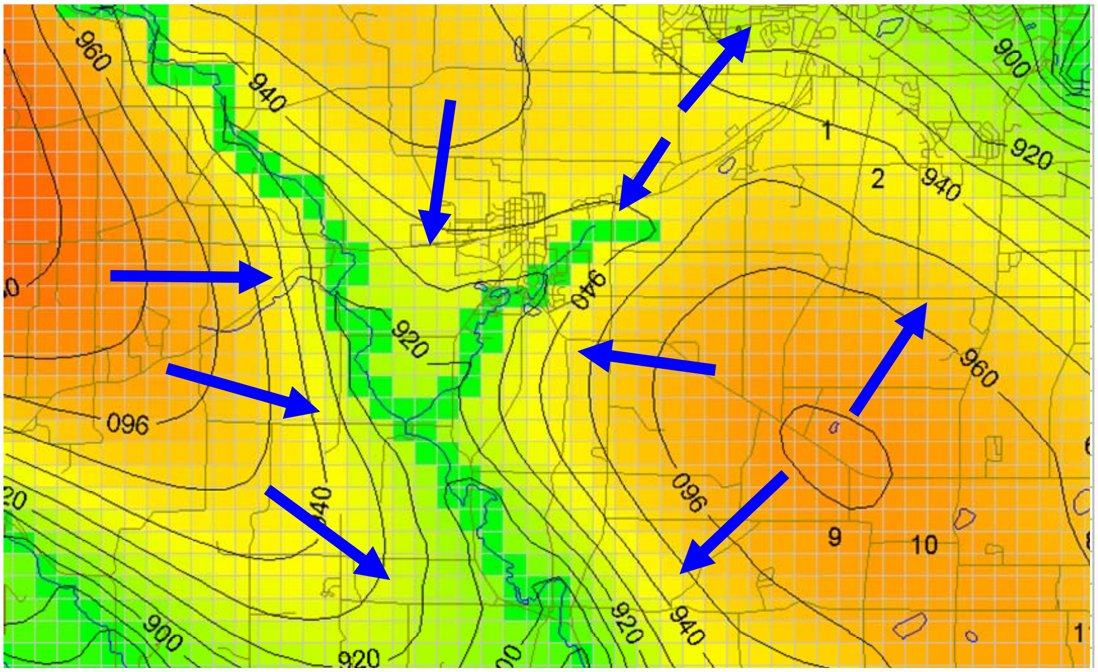


Figure 34. Simulated shallow water table map.
From Dane County Regional Groundwater Model. Contours show elevation of the water table in feet. Arrows show general groundwater flow directions.

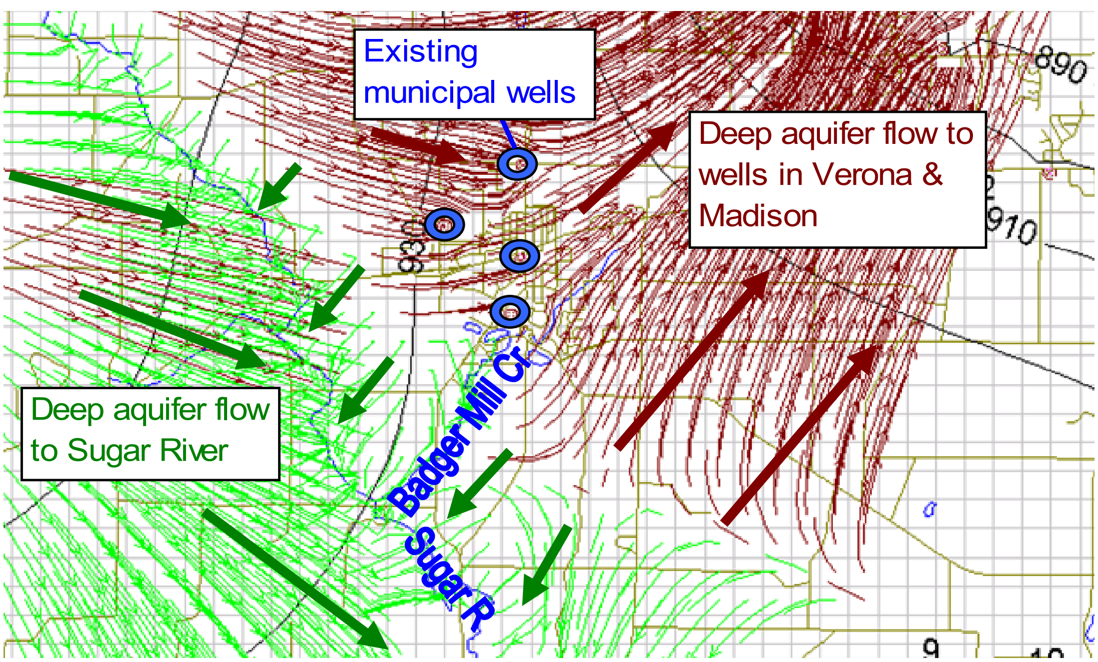


Figure 35. Simulated groundwater flow directions in the deep sandstone aquifer.
Forward particle traces in the Dane County Regional Groundwater Model. Particles released in the lower sandstone aquifer below the Eau Claire shale. Green traces indicate capture by streams, red by pumping wells. Verona municipal wells shown by blue circles.

The impact of pumping was further investigated by simulating hypothetical new high capacity wells to assess the impact of pumping rate and well location relative to the streams. Due to the incomplete coverage of the study area for the Nine Springs model, well locations were chosen to the east of Badger Mill Creek to allow simulation with both models. The wells were assumed to be open only below the Eau Claire shale, as is the norm for new high capacity wells in the area. We used a conservative range of pumping rates from 100 gpm to 500 gpm. (WDNR records for 56 high capacity wells in Dane County that pump from the sandstone aquifer indicate that median and mean normal pumping rates of 50 gpm and 147 gpm, respectively.) For each pumping scenario, we compared the simulated flow of Badger Mill Creek near Highway 69 to the flow in the original, calibrated models representing existing conditions (Table 6).

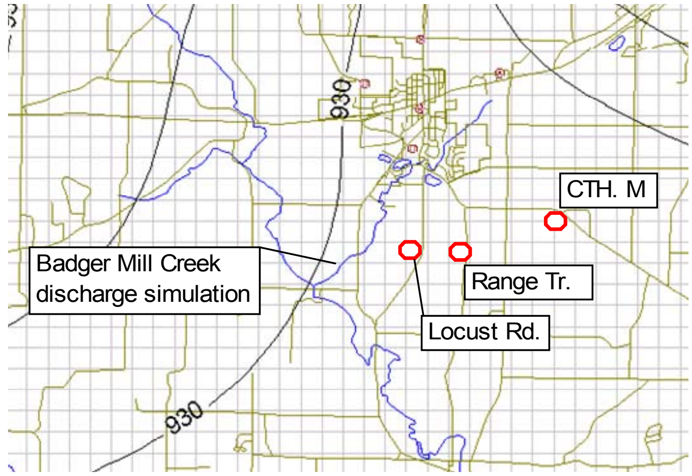


Figure 36. Simulated pumping well locations.

Table 6. Simulated Badger Mill Creek Discharge with Additional High Capacity Wells

Distance from Badger Mill Creek	Pumping Rate (gpm)	Model	Badger Mill Discharge (cfs)	% Change
None	None	Regional	2.92	--
		Nine Springs	1.81	--
2000 ft	100	Regional	2.89	-1.0 %
(Locust Rd.)		Nine Springs	1.77	-2.1 %
	200	Regional	2.86	-2.0 %
		Nine Springs	1.73	-4.3 %
	500	Regional	2.78	-4.9 %
		Nine Springs	1.62	-10.6 %
4500 ft	200	Regional	2.86	-2.0 %
(Range Trail)		Nine Springs	1.73	-4.2 %
7200 ft	200	Regional	2.86	-2.1 %
(CTH M)		Nine Springs	1.74	-4.1 %

Note: Simulated discharges represent only groundwater inflow to streams and do not include the discharge of approximately 4 cfs from the MMSD effluent return line.

The Nine Springs model predicts approximately double the flow reduction than the regional model. The reason for this is unclear, because the Nine Springs model represents the Eau Claire shale with a lower vertical hydraulic conductivity than the regional model (6.0 x 10-5 ft/d versus 7.2 x 10-4 ft/d). In interpreting these results, it is important to note that neither model was designed to assess the impact of pumping on the flow in these streams, and that Badger Mill Creek is near the western boundary of the Nine Springs model, where the model boundary condition may affect the simulation results.

Based on this screening level groundwater analysis, and the work by Dane County staff discussed in Section 2.9, we infer the following.

- Streamflow due to groundwater withdrawals from deep wells open below the Eau Claire shale is more sensitive to pumping rate than well location. The Eau Claire shale distributes impacts over a broader area than would be the case for a well pumping from the shallow aquifer.
- Groundwater levels and streamflow have declined due to pumping throughout the region; future pumping impacts should be addressed on a regional, rather than site-by-site basis.
- Additional pumping near the study area at a rate comparable to a typical non-municipal high capacity well might reduce streamflow in the study area by up to approximately 5 %.
- Streams in the study area are likely to be somewhat more sensitive to local changes in groundwater recharge, because recharge directly feeds the shallow aquifer.
- The contribution to streamflow by recharge in the study area can be estimated from the size of the study area (1700 ac) and the average recharge rate. An average rate of 7 in/yr over this area equates to 1.4 cfs of streamflow shared by the Upper Sugar River and Badger Mill Creek (Mike Kakuska, written communication, 2007).

4.5 Resource Sensitivity Summary

Key resource protection considerations for future development are summarized in Table 7.

Table 7. Resource Sensitivity Summary

Issue	Upper Sugar River	Badger Mill Cr	State Natural Area Wetlands
Recharge	High	High	High
Runoff / stream stability	Low - Moderate	High	NA
Municipal water supply withdrawal in or near study area	Low	Low	Low
Water quality	Low (Most stormwater constituents substantially reduced by County sediment control requirements. Chloride primary concern.)	Moderate (Most stormwater constituents substantially reduced by County sediment control requirements. Chloride primary concern.)	High (Native plant species sensitive to stormwater quality impacts.)
Impacts from upstream development	Moderate (Modest increase in runoff volume & peaks expected.)		

4.6 Environmental Corridors

We recommend the environmental corridors include the following areas:

- Public land intended for resource protection
- Regulatory wetlands
- Floodway, unless individual application with DNR approval of compensatory conveyance
- Floodfringe, unless compensatory storage is provided.
- Minimum 75 ft buffer beyond the ordinary high water mark of perennial streams and wetland boundaries (per the Dane County Water Quality Plan)
- Minimum 25 ft buffer from intermittent streams, with 75 ft minimum total width (per the Dane County Water Quality Plan and NR 151)
- Slopes steeper than 12%, unless individual site specific approval is warranted

From a hydrologic perspective, the key issue for buffers is their effectiveness in dispersing runoff to avoid concentrated discharges to streams or wetlands. Designing the buffers to treat and distribute runoff entering from adjacent uplands, to avoid concentrated discharge from the stormwater system is likely to be more effective for water quality protection than increasing the buffer beyond a reasonable minimum width. For example, even a very wide buffer offers little protection against stormwater outfalls from a sewer pipe or traditional conveyance channel with a direct hydraulic connection to the stream channel. The 75 ft minimum buffer width is consistent with numerous regulatory and planning documents.

- The Dane County Water Quality Plan recommends a minimum buffer of 75 ft from streams and wetlands, or the 100 year floodplain if wider. The Dane County shoreland zoning ordinance specifies a 75 ft setback to structures from OHWM or wetlands.
- The preliminary draft SEWRPC Regional Water Quality Plan states that a 75-foot buffer is optimal for protecting water quality.
- Dane County Phase 1 Water Body Classification – recommends minimum 75 – 100 foot buffers for most circumstances. Buffers wider than 100 ft offer diminishing returns for water quality, with the primary benefit for shoreland wildlife. Wetlands should receive similar protection.
- The Dane County Shoreland Zoning Ordinance specifies a 37.5 ft vegetative buffer and a 75 foot building setback.

In most parts of the study area, the recommended environmental corridor extends beyond the minimum 75 foot buffer due to the presence of wetlands, the floodway, or the presence of public lands dedicated for preservation (Figure 37).

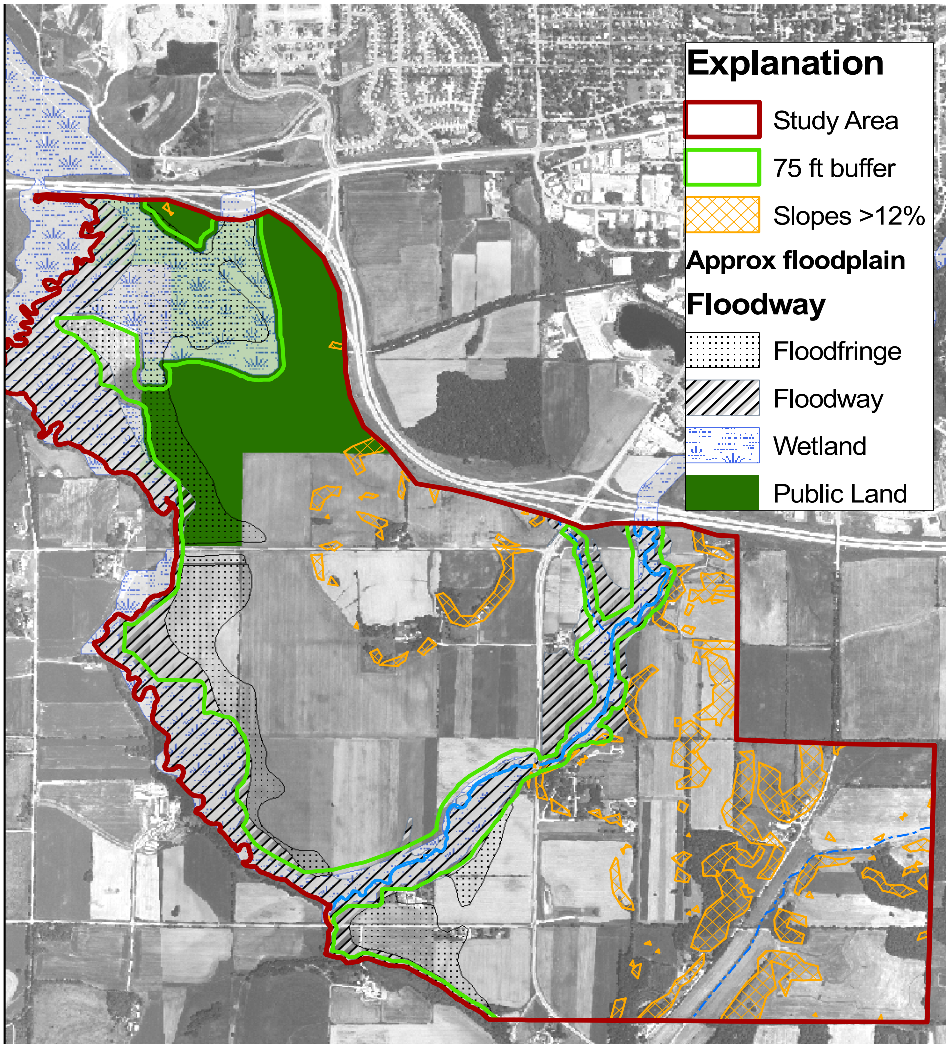


Figure 37. Environmental Corridor Components
Floodway and floodfringe boundaries drawn as approximate and are currently under review by WDNR

4.7 Hydrologic Performance Standards

Our development recommendations within the study area are based on hydrologic performance standards rather than prescribed land use details. This approach focuses on maintaining conditions that are important for the health of the ecological resources and allows flexibility in development options and management approaches.

The Dane County stormwater ordinance (Chapter 14) adequately addresses most issues of concern, such as peak detention, thermal impact, and water quality treatment. We recommend additional performance standards to manage runoff volume and groundwater recharge to address the key sensitivity issues discussed above, in particular the importance of maintaining groundwater recharge throughout the study area and the sensitivity of the Badger Mill Creek channel to destabilization with increases in runoff volume.

The Dane County ordinance (Ch. 14) has a two-tiered system of performance standards for new development. Developments must be designed to meet a primary target regarding site-wide infiltration volume (Table 8); however, if this requires more area than a specified threshold, a secondary groundwater recharge target (which is easier to achieve) is applied.

Table 8. Current Dane County Stormwater Ordinance Requirements

Ordinance Requirement	Residential	Non-residential
Infiltration Target	90% of predevelopment volume	60% of predevelopment volume
Infiltration Area Threshold	1% of total site area	2% of total site area
Recharge Target	7.6 in/yr	7.6 in/yr

Note that the ordinance requires a conservative approach for estimating runoff for existing conditions, requiring use of hydrologic parameters representative of native vegetation. Agricultural land, such as in much of the study area, typically generate more runoff than would be calculated by this required method. Thus for crop land, calculation per the ordinance is likely to underestimate runoff for existing conditions. For conversion of such agricultural land to development, meeting the 90% infiltration volume requirement essentially would result in no change in runoff volume.

We analyzed the expected impacts of development on runoff volume and groundwater recharge using the RECARGA model. This model, based on the Green-Ampt infiltration method, allows continuous simulation of runoff and groundwater recharge for sites with different soil types, percent impervious cover, and area dedicated for stormwater infiltration. The model computes annual depths representing groundwater recharge and total infiltration. Note that not all water that infiltrates the soil becomes groundwater recharge; some water evaporates and some is transpired by plants.

RECARGA was applied to two distinct hydrologic settings that exist in the study area: sandy valley bottoms, and upland areas with fine grained soil and shallow bedrock (Figure 38). Model simulations are based on typical soil properties published in the NRCS soil survey for Dane County. Site-specific conditions are likely to vary from these estimates, however this analysis provides planning level information on the expected performance of stormwater infiltration systems in the study area.

Figure 39 illustrates simulated infiltration (solid curves) and recharge (dashed curves) for residential development in an upland area with a low infiltration rate of 0.24 in/hr. The 90% infiltration target is approximately 24 in/yr. For low densities (e.g. 20% impervious area), post-development runoff with no engineered infiltration is approximately the same as runoff for current conditions. This reflects an expected reduction in runoff with a change from agricultural land to managed turf. Higher development densities would require substantial portions of each site dedicated for infiltration to meet the 90% target (3% of the site for 60% impervious cover, or 4% of the site for 80%

impervious cover). Because this is more than the 1% threshold, the County ordinance allows use of the recharge target. Meeting the recharge target would require 1.5 – 2% of the site and result in infiltration of approximately 19 – 21 in/yr for development densities of 60% and 80% impervious area, respectively. This would result in a modest increase in runoff for high density residential development. Note, however, that actual soil conditions in the uplands are likely to be quite variable, and the presence of lower infiltration rate soils and/or shallow bedrock is possible.

Infiltration rates are considerably higher in the sandy valley bottom soils. For example, a development with 60% impervious area can be designed to meet the 90% pre-development infiltration target using slightly less than 2% of the site for infiltration (Figure 40). Applying the County ordinance allowance to use the recharge target would require only 1% of the site for

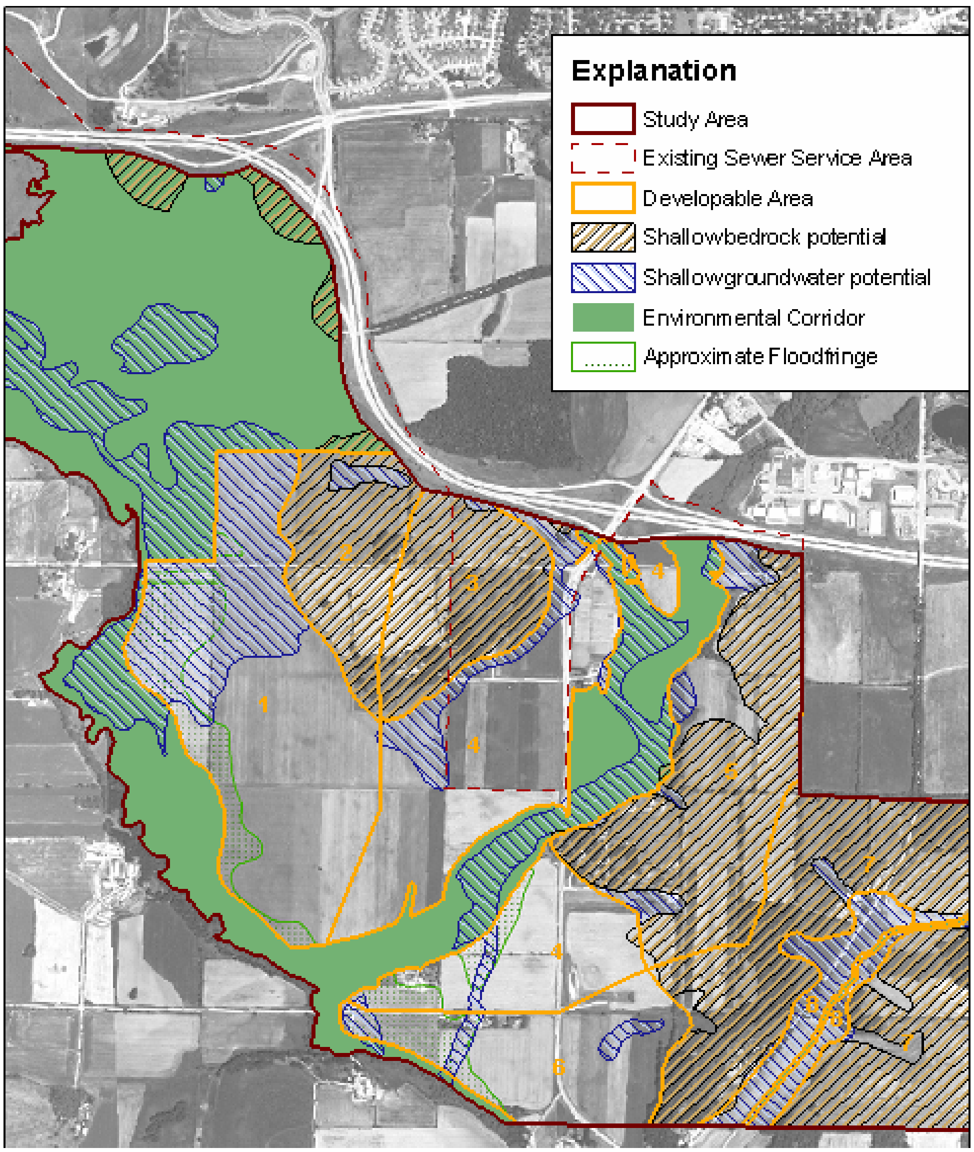


Figure 38. Soil and Hydrologic Conditions

infiltration and would result in infiltration of 21 in/yr, a modest reduction from existing conditions.

The different requirements for non-residential sites in the County ordinance would result in a substantially higher impact for developments of similarly high densities. The lower target of 60% of the pre-development volume is achievable with substantially less infiltration area – commonly less than the 2% cap. In many situations, the ordinance requirement could be met with a system that would produce a recharge rate of less than the estimated predevelopment rate of 7.6 in/yr (Figure 41). Thus, widespread non-residential development of typical density would likely result in both a substantial increase in runoff volume and decrease in groundwater recharge under the County ordinance requirements.

Given the sensitivity of the stream ecosystems, it is appropriate to apply performance standards that provide more protection than the County ordinance (Table 9). For the Upper Sugar River, the primary concern is maintaining groundwater recharge and stream baseflow. This can be addressed by requiring that all sites meet the 7.6 in/yr recharge target, regardless of predicted infiltration volumes. This should require less than 2% of a site to be used for infiltration. Increases in runoff volume pose a risk of instability for the Badger Mill Creek channel, which would also impact the Upper Sugar River by increased sediment influx at the confluence. We therefore recommend a more protective approach of applying the residential site requirement of 90% infiltration volume to all sites (residential and non-residential) and applying an infiltration area cap of 2% to all sites. As can be seen from Figure 40, using 2% of a site for infiltration can limit the loss of infiltration volume to modest levels even for high density developments.

Table 9. Recommended Performance Standards.

Watershed	Objective	Recommended Performance Standard
Upper Sugar River	Maintain recharge	All sites must achieve at least 7.6 in/yr recharge
Badger Mill Creek	Maintain recharge & minimize runoff volume increases	Infiltration target of 90% for all sites & 2% threshold

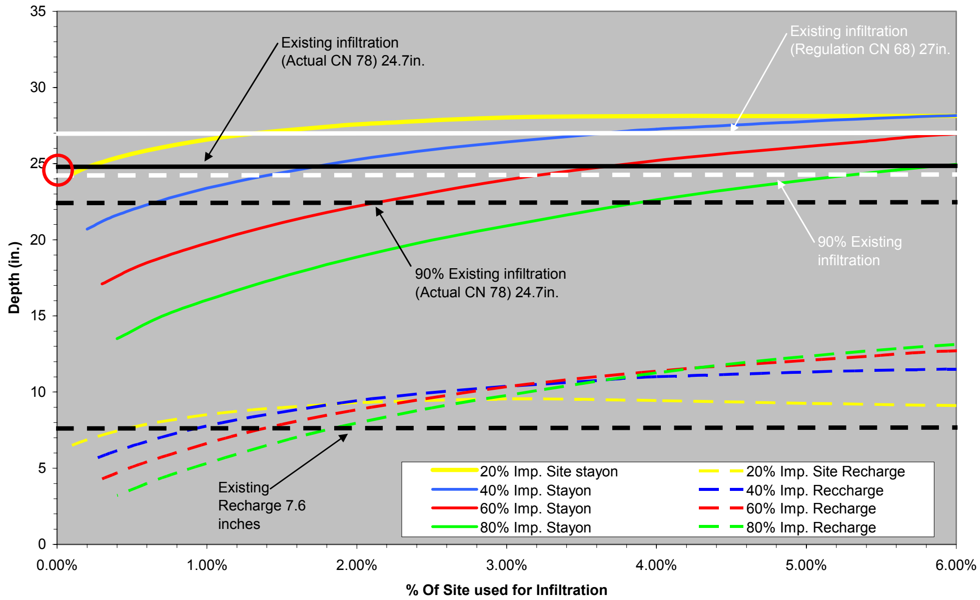


Figure 39. RECARGA model analysis of uplands

Represents residential site with infiltration rate 0.24 in/hr and hydrologic soil group B soils. Note that for 20% impervious area, infiltration volume (solid yellow curve) is approximately equal to runoff volume for existing agricultural conditions (indicated by red circle)

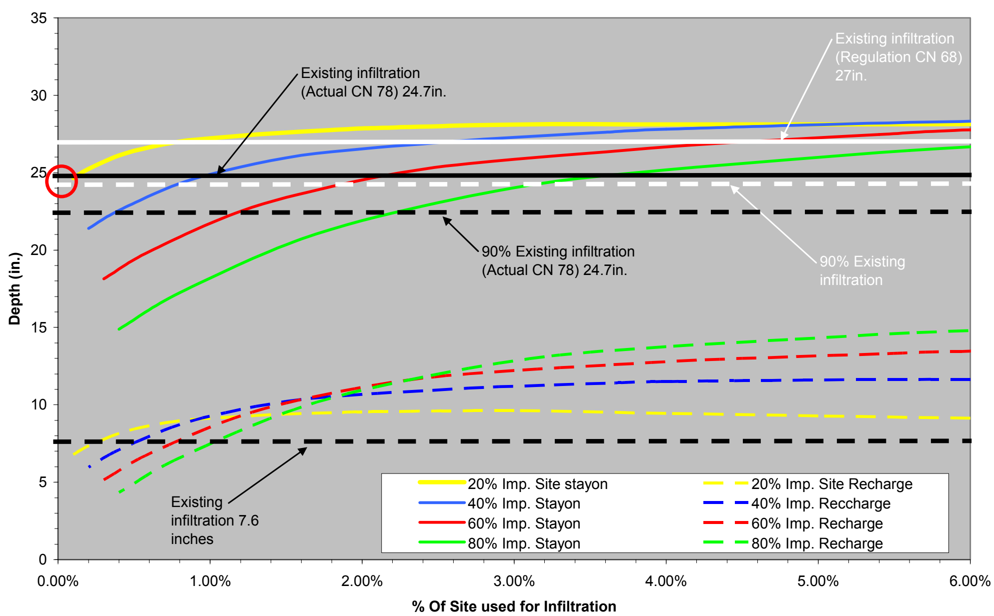


Figure 40. RECARGA analysis of residential development of valley bottom

Represents hydrologic soil group B soils using a conservatively low infiltration rate of 1.6 in/hr

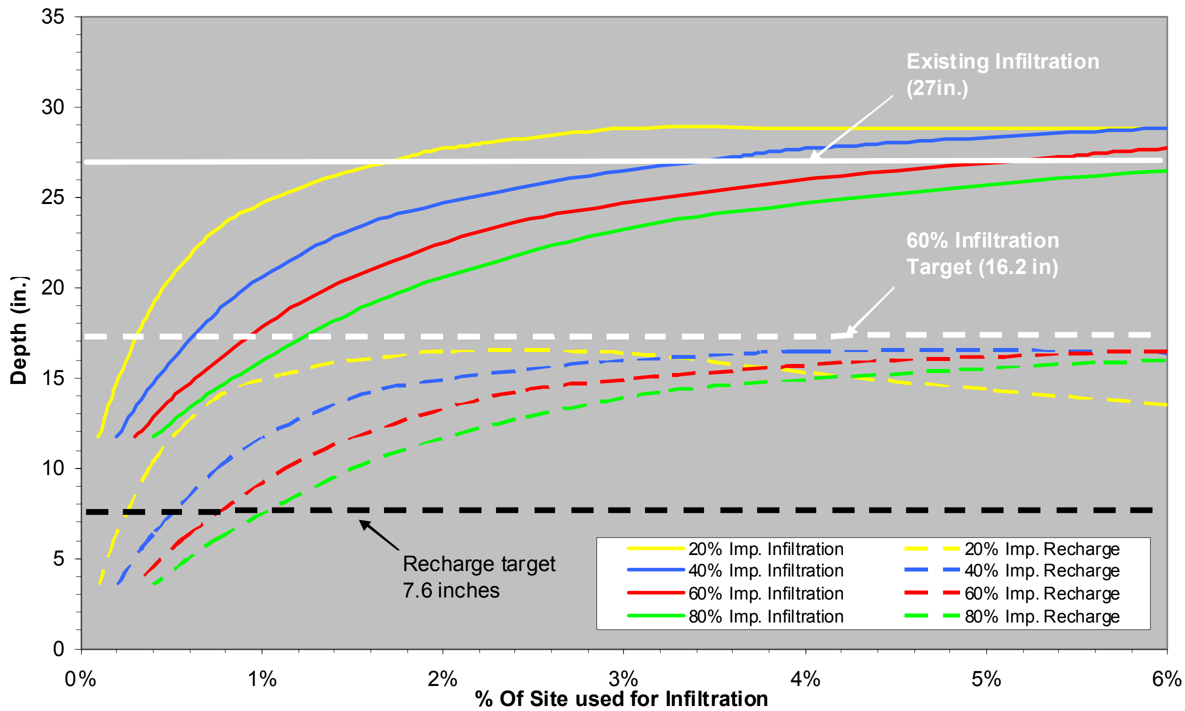


Figure 41. RECARGA analysis for non-residential development of valley bottom
Represents hydrologic soil group B soils using a conservatively low infiltration rate of 1.6 in/hr

4.8 Development Recommendations

Potentially developable land in the study area can be divided into 8 sub-areas based on soil conditions (upland vs. lowland) and receiving stream (Upper Sugar River vs. Badger Mill Creek). Recommendations for development of these 8 areas are summarized in Table 10 and Plate 2, and they are discussed in more detail below. Note that individual development projects will need to verify site-specific conditions and develop design details that achieve the performance standards.

Even with the more protective performance standards we recommend, some modest impacts are possible, including increased runoff volume and increased concentrations of typical urban stormwater constituents. The development recommendations include mitigation measures to address these potential impacts. (1) The riparian buffers will be wider than for existing conditions in most locations, and this will enhance streambank stability. (2) The aggressive recharge goals should meet or exceed existing groundwater recharge, maintaining or possibly improving baseflow and stream temperature. Toxicity impacts are enhanced when trout are subject to temperature stress. As such, maintaining adequate water temperature will provide some protection against toxicity impacts on the fishery due to stormwater pollutants (Tim Ehlinger, UW-Milwaukee, personal communication).

Table 10. Recommendations Summary

Issue	Upper Sugar River	Badger Mill Cr	Locust Road Dry Tributary
Performance standards	County ordinance, Ch. 14 plus: Maintain 7.6 in/yr recharge	County ordinance, Ch. 14 plus: Maintain 90% predevelopment infiltration volume with 2% cap (both residential & non-residential sites)	County ordinance, Ch. 14
Exemptions & exclusions	• Apply requirements to all sites, including <20,000 ft2. • Remove infiltration exemption for new roads. • Apply high standard to demonstration of soils unsuitable for infiltration in valley bottom. • If site is unsuitable for infiltration due to soil, bedrock or groundwater conditions, runoff volume reduction shall be achieved through evapotranspiration (e.g. biofiltration) to the maximum extent practicable (up to the 2% cap).		
Environmental corridor extent	• Public land intended for resource protection • Regulatory wetlands • Floodway (flood fringe shown on Plate 2 but not part of environmental corridor) • Minimum 75 ft buffer beyond OHWM of perennial streams & wetland boundaries • Minimum 25 ft buffer for non-navigable streams (75 ft total width minimum)		

<table>
<tr><th>Issue</th><th>Upper Sugar River</th><th>Badger Mill Cr</th><th>Locust Road Dry Tributary</th></tr>
<tr><td>Environmental corridor design</td><td colspan="2">Environmental corridor to be designed with water protection and environmental restoration features, including:
• No direct discharge of storm sewers to streams or watercourses;
• Grading to provide distribution and infiltration of runoff water entering the corridor with multiple points of discharge to the stream;
• Planting of native vegetation;
• Stabilizing bare soil or unstable banks above the OHWM;
• Require design of open corridor drainage ways at locations shown approximately on the map, including designs for erosion control and stability, water quality filtration and infiltration opportunities;
• Provide trail access within corridor for management access, outdoor education, and recreation.</td><td>Require design of open corridor drainage ways at approximate locations shown on Plate 2, including designs for erosion control and stability, water quality filtration and infiltration opportunities.</td></tr>
</table>

Issue	Upper Sugar River	Badger Mill Cr	Locust Road Dry Tributary
Management of design and implementation	Design of stormwater management features to be reviewed and approved by City and CARPC at time of GDP or preliminary plat submittal. Identification of ownership and long-term operation and maintenance procedures to be determined and approved at that time. Details of design construction plans and specifications, including any stormwater conveyance and treatment features in the environmental corridor, to be reviewed and approved by the City prior to construction; CARPC to be a resource in final design review. Final designs submittal will include a schedule of construction and identification of responsibilities for quality control and as-built documentation of drainage-related features between private and public parties. Detailed review of drainage and environmental corridor feature construction to be monitored in the field by designated quality control personnel, with documentation to and quality assurance by the City or designated agent. City to approve all drainage and environmental corridor construction upon completion. City to approve an agricultural land use water quality plan to be approved by City as part of annexation, or inclusion in the Urban Service Area if consolidation occurs.		
Monitoring and adaptive management	A regional water quality monitoring effort should be undertaken to assess the effectiveness of management policies and practices. Suggested parameters include discharge, water quality parameters (to be determined) and periodic fish surveys (responsible party to be determined). Stream monitoring should be evaluated approximately every five years, and the management plan adjusted accordingly.		Periodic monitoring of soil erosion and stormwater sampling for TSS (responsible party to be determined)

Discussion of Potential Development Areas

Detailed comments on each potential development area are discussed below and included on Plate 2. Although the performance standards recommended for much of the study area are more protective than the County ordinance, meeting the standards should not simply require traditional "end-of-pipe" stormwater devices that are substantially larger than are common elsewhere. Rather, design approaches that integrate planning and management of typical urban green spaces into the stormwater management plan should be successful in meeting the specified performance standards.

Area 1

This area occupies the sandy valley fill in the Sugar River watershed immediately downstream of the State Natural Area. Potential infiltration rates for engineered systems are high. However, infiltration system construction may require removal of the uppermost several feet of fine grained soil to reach the underlying sand and gravel deposits, and engineered soil mixtures will likely be necessary to achieve the pollutant removal capabilities specified in the County ordinance. In evaluating the infiltration potential of a site, the stormwater designer should make reasonable efforts to assess the thickness of the fine grained surfcial soil and the hydraulic properties of the underlying sandy soils. Shallow groundwater may limit infiltration in some locations.

Due to its high infiltration potential, Area 1 can also be used to infiltrate water from the adjacent uplands of Area 2. For example, if low to moderate density development occurs in the Area 2 uplands, an additional 1 – 2 acres of Area 1 would be required for infiltration, based on a rule of thumb that the infiltration area should be approximately 10% of the contributing impervious area. This additional infiltration area is approximately 1% of the potentially developable land in Area 1.

Area 2

This upland area drains to the Upper Sugar River and is expected to have variable infiltration potential due to discontinuous clay soil layers and shallow fractured bedrock. These areas may be suitable for infiltration of roof runoff, which is relatively clean, however infiltration from other sources may be inadvisable. In that case, runoff should be routed downhill to infiltration areas in the sandy valley bottom soils of Area 1.

Area 3

This area is adjacent to and similar to Area 2, however it drains to Badger Mill Creek. The same considerations apply to this area that are discussed for Area 2, except for the higher performance standard for the Badger Mill Creek watershed. In the case of unsuitable soil conditions for infiltration, the alternative of routing water downhill to infiltration devices in Area 4 should be considered.

Area 4

This area occupies sandy soils in the Badger Mill Creek valley along Highway 69. The considerations discussed for Area 1 also apply to this area, however the Badger Mill Creek performance standard should apply. This area could also be used to infiltrate runoff from Area 3.

Area 5

This area includes uplands tributary to Badger Mill Creek, and the performance standard for the Badger Mill Creek watershed should be applied. Challenges for development include steep slopes, fine grained soils, and the potential for shallow, fractured bedrock. Unlike upland Areas 2 and 3, there are few high infiltration potential areas downhill of Area 5. If conditions prove unsuitable for infiltration, the same site area should be used to achieve stormwater volume reductions, to the maximum extent practicable, through methods such as biofiltration that enhance evapotranspiration.

Area 6

This valley bottom area drains to the Upper Sugar River downstream of the confluence with Badger Mill Creek. Modest areas of potentially developable land are present along Highway 69 and Riverside Road, however it is possible that some of this land may be mined in the future as a part of the existing sand and gravel operation on the east side of Highway 69. The mining activity will create a quarry pond, reducing the land available for development. The considerations discussed for Area 1 also apply to Area 6.

Area 7

These uplands are part of the Locust Road valley, which contains an intermittent tributary of the Upper Sugar River. We recommend application of the County ordinance to this area. Steep slopes may limit development of a substantial portion of Area 7. Shallow bedrock and fine grained soils are expected, however infiltration of roof runoff should be feasible and encouraged. Designs that include infiltration of roof runoff, measures to enhance evapotranspiration where infiltration is not feasible, and an open, vegetated drainage route over the relatively long distance to the Upper Sugar River (through Area 8) are expected to perform well relative to the targets specified in County ordinance.

Area 8

This area includes the valley bottom along Locust Road and the adjacent intermittent drainage, which conveys runoff from Area 7 to the Upper Sugar River. This area is likely to contain fine grained soils with low infiltration potential and possibly high groundwater. Where infiltration is infeasible, site designs should be designed to reduce runoff volume through evapotranspiration, as discussed above.

No detailed flood study has been conducted for this valley, however limited field observations suggest that the minimum 75 ft buffer may not be adequate for flood conveyance. We recommend planning for a corridor approximately 100 ft wide and conducting a detailed hydrologic and hydraulic analysis before development to determine the width of the conveyance corridor needed for flood protection.

Cumulative Watershed Impacts

The hydrologic impact of future development in the study area will depend upon many factors, including the specific type and density of development planned for each part of the study area. However, an estimate of these impacts is possible based on the recommended performance standards and potential development scenarios. We used the RECARGA model to assess the impacts of one development scenario on the study area (Table 11) and, by extension, the cumulative impact that would occur if the upstream parts of the watershed projected to develop in the future are held to the same standards. Although this analysis is not definitive, it illustrates the magnitude of impacts that can reasonably be expected.

For the scenario analyzed, runoff volume and groundwater recharge in the study area are projected to increase by 41% and 4%, respectively (Table 11). By 2050, the additional impervious surface area in the upstream watersheds is projected to be 11% for Badger Mill Creek and 4% for the Upper Sugar River (Table 1), Applying a 41% increase in runoff volume to 11% of the Badger Mill Creek watershed and 4% of the Upper Sugar River watershed, and assuming the same conditions for the remaining portions of the watershed, results in cumulative runoff volume increases of 5% for Badger Mill Creek and 2% for the Upper Sugar River.

Table 11. Study Area Hydrologic Change for Hypothetical Development Example.

Study Unit	Area (acres)	Native Soil Infiltration Rate (in/hr)	Example Development Type	Existing Infiltration		Assumed Existing Recharge		Post-Development Infiltration		Post-Development Recharge	
				Depth (in)	Volume (ac-ft)	Depth (in)	Volume (ac-ft)	Depth (in)	Volume (ac-ft)	Depth (in)	Volume (ac-ft)
1	209	1.63	High density commercial	24.7	430	7.6	132	19.2	334	7.6	132
2	69	0.24	Low-medium density residential	24.7	142	7.6	44	25.5	147	7.6	44
3	78	0.24	Low-medium density residential	24.7	161	7.6	49	24.2	157	6.5	42
4	226	1.63	High density commercial	24.7	465	7.6	143	24.3	458	11.8	222
5	161	0.24	Low density residential	24.7	331	7.6	102	24.2	325	6.5	87
6	91	1.63	High density commercial	24.7	187	7.6	58	19.2	146	7.6	58
7	270	0.24	Low density residential	24.7	556	7.6	171	24.2	545	6.5	146
8	40	0.24	Low density residential	24.7	430	7.6	25	24.2	81	6.5	22
Total	**1144**				**2355**		**725**		**2191**		**753**

<u>Summary</u>

- For annual total precipitation of 28.8 inches, total precipitation volume in study area = 2747 ac-ft.
- Existing study area runoff volume = 392 ac-ft
- Post-development study area runoff volume = 555 ac-ft
- Post-development changes in study area: Runoff volume 41% increase, Recharge 4% increase.

Additional Considerations

- *Protection of the State Natural Area*. DNR policies for review of sewer service area extensions requires wetland protection when the area is or has been known to be a habitat for state or federally designated rare, threatened or endangered species, or where it is determined that the wetland type is scarce or rare either statewide or regionally. It is possible to develop in the northwest part of the study area along Valley Road. However, stormwater should be routed away from the State Natural Area. This could be accomplished by infiltration, if soil and groundwater conditions prove suitable, and/or by designing conveyance routes along Valley Road or to the south of the road.
- *Dane Co. Parks and Open Space Plan*. The Badger Mill Creek and Upper Sugar River corridors in the study area are included in natural resource areas in this plan. The boundaries of these natural resource areas generally follow the floodplain boundary. Development is not prohibited in these areas, however they are high priorities for conservation efforts, including working with private landowners on a voluntary basis. Development in these areas should be planned for compatibility with the goals of the plan to the extent possible. These areas provide opportunities for "green" stormwater infrastructure, such as drainage ways, constructed wetlands and infiltration areas, that are required by nearby developments and provide a transition from developed areas to the environmental corridor.
- *Corridors for stormwater conveyance and wildlife*. Routes for conveyance of stormwater from uplands to the valley bottoms, and ultimately to Badger Mill Creek and the Upper Sugar River, are needed, however specific locations are flexible. Suggested locations, based in part on expected soil and groundwater conditions, are indicated on Figure 38. We suggest an open drainage system managed with native and/or adapted vegetation, for detention routing, water quality treatment and wildlife. Steep slopes in the southeastern part of the study area also provide opportunities for wildlife corridors that connect to the forested areas east of the study area.

➢ *Buffer design*. An important function of buffers should be to reduce concentrated stormwater discharges which can severely impact stream channels. Stormwater channels should be designed to spread discharge across the stream buffer to reduce these impacts. Options range from engineered level spreaders (Figure 42) to less engineered systems of swales and storage basins. Appropriate design depends on site-specific conditions and stormwater design discharges. Additional information on buffer design is available from the Center for Watershed Protection (Schueler, 1995). It is commonly recommended that the zone of buffers nearest the stream be wooded; however, there is some debate in the scientific community about the relative merits of trees versus grass. Trees provide more shade to limit warming by the sun however, depending on tree species present, wooded banks can be more susceptible to erosion than grass covered banks. Current buffers are dominated by reed canary grass, which although non-native and invasive, is very effective for stabilizing streambanks.

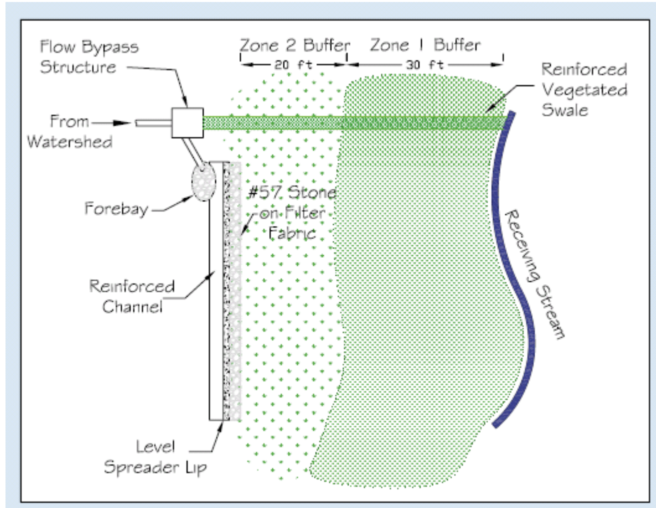


Figure 42. Level spreader system.
(From NC Cooperative Extension Service, 2006).

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PLATES

Badger Mill - Sugar River Study
City of Verona, WI

Montgomery Associates
2820 Walton Commons West, Suite 135
Madison, WI 53718

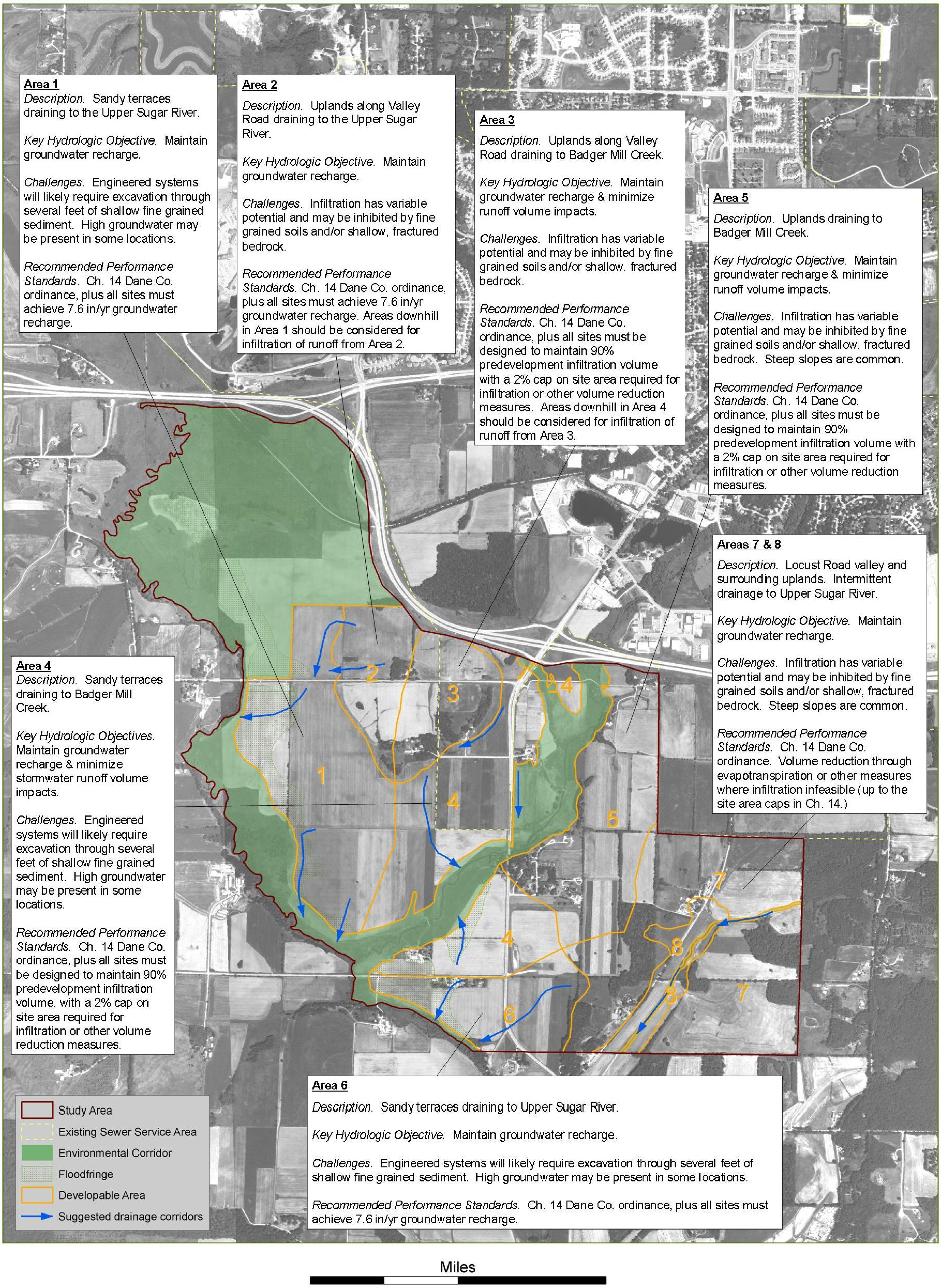
Produced by SJG
1/6/08

Spring locations field checked October 2007.
Limited habitat observations recorded at indicated stations in October 2007.

Miles
0 0.25 0.5 1

Plate 1
Resource Summary

Montgomery Associates
2820 Walton Commons West, Suite 135
Madison, WI 53718



Boundaries approximate. Use for planning purposes only.

Produced by SJG
1/6/08

Plate 2
Development Recommendations

APPENDIX A

NATURAL RESOURCES CONSULTING, INC. MEMORANDUM ON WETLAND EVALUATION

NRC
Natural Resources Consulting, Inc.
119 South Main Street | PO Box 128 | Cottage Grove, Wisconsin 53527-0128
Ph: 608.839.1998 | Fax: 608.839.1995
www.nrc-inc.net

Memorandum

To: **Jon Gumtow, PSS, PWS, NRC**

From: **Neil Molstad, PSS, CPSS, NRC**

Date: **July 24, 2007**

Re: Wetland Evaluation – Upper Sugar River/Badger Mill Creek Environmental Study Area

---

Introduction and Objective

Natural Resources Consulting, Inc. (NRC) conducted a general evaluation and functional assessment of the existing wetland areas within the Upper Sugar River/ Badger Mill Creek Environmental Study Area (Study Area). The evaluation was completed using existing wetland information and field reconnaissance. The purpose of the evaluation was to determine the approximate extent of jurisdictional wetlands within the Study Area, to compare actual wetland extent to the existing available wetland information for the Study Area, and to evaluate how these wetlands are functioning within the Study Area as a whole.

Methodology

The Study Area is located in the west-central portion of Dane County, in the Town of Verona. Prior to the fieldwork, existing information including the Wisconsin Wetland Inventory (WWI) maps, Natural Resources Conservation Service (NRCS) Soil Survey maps, and Federal Emergency Management Administration (FEMA) 100 year floodplain maps was evaluated to provide insight into where wetlands within the Study Area had been previously identified and additional locations within the Study Area that might qualify as wetland. Then, these areas were visited in the field, where the existing wetland boundaries were confirmed or modified as needed and then evaluated using the Wisconsin Department of Natural Resources Rapid Assessment Methodology for Evaluating Wetland Functional Values (RAM). The RAM evaluations provide a complete picture of wetland functionality by addressing the following factors: floral diversity, wildlife and fishery habitat, flood/stormwater attenuation, water quality protection, shoreline protection, groundwater, and aesthetics.

Results

In general, the wetlands within the Study Area were consistent with boundaries indicated on the WWI mapping with the exception of two areas (see attached Figure). Within the north portion of the study area the wetland boundary is larger than depicted on the WWI map adjacent to the Sugar River and within the state-owned land. Within the central portion of the Badger Mill Creek corridor the wetland boundary is larger and extends north to STH 69.

For the purposes of this study, the assessment of the wetlands within the Study Area was divided into three general categories: 1) Wetland complex indirectly associated with the Sugar River found in the northern portion of the Study Area, 2) Wetland complex associated with the Sugar River, and 3) Wetland complex associated with Badger Mill Creek. Detailed summaries of the RAM evaluations for each of the three wetland categories follow below. The RAM evaluation forms are attached.

1) Wetland Complex Indirectly Associated with the Sugar River

As stated above, this wetland complex is located in the northern portion of the Project Area, to the east of the Sugar River. This wetland complex is publicly owned and parts of it appear to be actively managed (there was evidence of a recently conducted prescribed burn). This wetland contains shallow marsh/emergent, shrub-carr, hardwood swamp, sedge meadow, and wet meadow plant communities, with the overall floral diversity functional value in the low to medium range. The wildlife and fishery habitat functional values for this complex are in the low range, primarily due to the complex's isolated nature and no direct connection to a permanent water body. The flood/stormwater attenuation and water quality protection functional values of this wetland are in the high range due to dense vegetation and the wetland's position within the landscape that allows it to store and filter overland flow. The shoreline protection functional value is low, and not really applicable for this wetland complex, since it is not directly associated with a navigable waterway or lake. The groundwater functional value was considered to be in the low to moderate range; the wetland is believed to contribute to the base flow of the nearby Sugar River. Finally, the aesthetics functional value of this wetland is in the moderate to high range, due to a recreational trail running through it, the wetland's proximity to the greater Verona (and by extension, Madison) area, and the presence of different types of plant communities within the wetland, which is mainly due to the ongoing management activities by the state.

Wetland Complex Associated with the Sugar River

This general wetland category encompasses all wetlands directly associated with the Sugar River, which flows from north to south along the western edge of the Project Area. The majority of these wetland areas are on private lands. Wet meadow, shrub-carr, and floodplain forest plant communities are found in these wetlands, but the wetlands are dominated by invasive, low quality plants and the floral diversity functional value is low. The wildlife habitat functional value is considered low to medium, mainly due to these wetlands isolated nature, surrounded mostly by active agricultural fields, although these areas do provide a narrow corridor along the river that wildlife can utilize. The fishery habitat functional value is considered medium; the Sugar River is a designated trout stream/exceptional resource water. Both the flood/stormwater attenuation and water quality protection functional values for these wetlands are high, due to their vegetative density, high water holding capacity, and landscape position directly adjacent to the Sugar River. The shoreline protection functional value is in the low to medium range, with dense riverbank vegetation in some places keeping the banks of the Sugar River stabilized. The groundwater functional value is medium, with some known springs in these wetlands and the ability of these wetlands to contribute to the base flow of the Sugar River. The aesthetics functional value of these wetlands is low to medium, with the main recreational opportunity being canoeing, boating, and fishing along the Sugar River.

Wetland Complex Associated with Badger Mill Creek

This general wetland category covers all wetland areas directly associated with Badger Mill Creek, which flows from northeast to southwest across the central portion of the Study Area. The majority of the wetland associated with Badger Mill Creek is utilized as active pasture, and is almost totally dominated by reed canary grass, a low quality and invasive plant species. All of the functional values for the wetlands associated with Badger Mill Creek match those for the wetlands associated with the Sugar River; with the exception of the aesthetics functional value for the Badger Mill Creek wetlands, which is considered to be low.

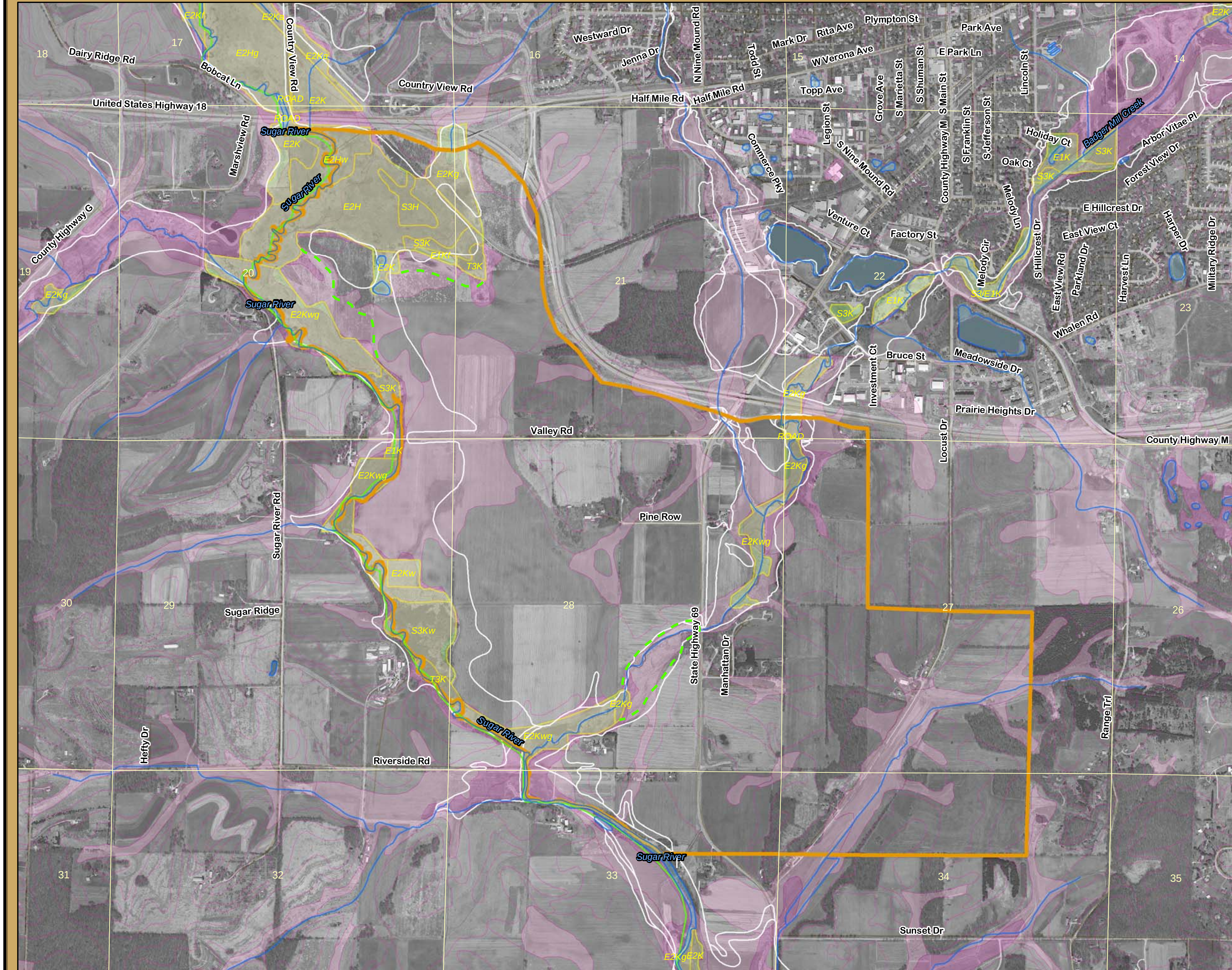
Summary

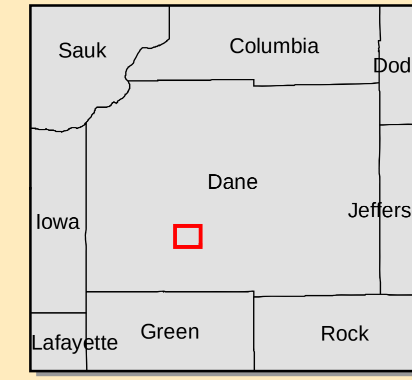
The RAM evaluations for the three wetland categories found within the Study Area provide a general overall picture about how the wetlands in the Study Area function within the landscape as a whole. Generally, floral diversity within the wetlands is low, with the exception of some of the actively managed wetland areas in the northern portion of the Study Area. Wildlife and fishery habitat within the wetlands is low to medium, with the wetlands directly adjacent to the Sugar River and Badger Mill Creek higher in these values than non-adjacent wetlands. All of the wetlands within the Study Area provide valuable flood/stormwater attenuation and water quality protection functions and are considered high for these functional values. Shoreline protection, where applicable, is generally in the low to medium range. The groundwater functional value for these wetlands is low to medium, with many of the wetlands helping to maintain stream base flow and/or containing springs. The aesthetics functional value is medium to high for the actively managed wetlands near the existing recreational trail, low to medium for the wetlands directly adjacent to the Sugar River, and low everywhere else.

It should be noted that the RAM evaluations were conducted based, for the most part, on one field visit to the wetland areas in question. For some of the functional values such as floral diversity, which can vary seasonally, repeated visits could develop a fuller picture of the functional value.

FIGURE 3. PROJECT LOCATION & HYDROLOGIC FACTORS

Upper Sugar River/Badger Mill Creek Study





Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

Project Information

NRC Project Number #: 07-009-01
Modified March 19, 2007

0 750 1,500 Feet

Legend

- Springs
- Exceptional Resource Water
- 24K Hydro Layer
- Study Area Boundary
- FEMA 100 Yr Floodplain
- WWI Dane County
- Approximate Wetland Boundary*

NRCS SOIL SURVEY DATA

- Hydric Soils
- Poss. Hydric Inclusions
- Non-Hydric Soils

*Determined by NRC Field Work

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APPENDIX B

NATURAL RESOURCES CONSULTING, INC. MEMORANDUM ON SOIL INFILTRATION ANALYSIS

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Memorandum

To: **Jon Gumtow, PSS, PWS, NRC**

From: **Neil Molstad, PSS, CPSS, NRC**

Date: **July 20, 2007**

Re: Soil Infiltration Analysis – Upper Sugar River/Badger Mill Creek Environmental Study Area

---

Introduction and Objective

Natural Resources Consulting, Inc. (NRC) and Soil Investigations, LLC (Soil Investigations) were retained to conduct a detailed analysis of the soil infiltration potential within the Upper Sugar River/ Badger Mill Creek Environmental Study Area (Study Area). The analysis was completed using existing soil survey information and field soil sampling to develop a predictive landscape model.

Background

As part of previous studies conducted by Dane County within the Upper Sugar River/Badger Mill Creek Environmental Study Area the stormwater infiltration potential was evaluated. NRC and Soils Investigations reviewed this previous study and completed a field sampling plan and landscape model to refine the stormwater infiltration potential within the Study Area.

The Study Area is located in the west-central portion of Dane County, in the Town of Verona. Geologically, the Study Area is located at the interface between the glaciated and nonglaciated portions of Wisconsin. The western half of the Study Area contains landscapes and soils that developed in glacial outwash deposits from the Sugar River. The eastern half of the Study Area contains landscapes and soils that developed from bedrock. The bedrock controlled areas were the focus of the soil fieldwork, since the depth to bedrock within these areas can vary considerably within short distances and topographic maps for the area are not precise enough to reflect these changes, specifically relating to the infiltration potential of these areas.

Methodology

To evaluate the complicated landscapes found in the bedrock portions of the Study Area, NRC and Soil Investigations utilized a computerized landscape model called 3DMapper. 3DMapper utilizes various sources and models to produce a seamless landscape picture.

Specifically convex and concave slopes within the bedrock controlled landscapes were evaluated. The hypothesis developed was that bedrock would be encountered at relatively shallow depths on the convex portions of the landscape and that bedrock would be deeper underground, or not found at all, on the concave portions of the landscape.

To test the hypothesis, four sampling transects were established and 26 soil borings were completed. These transects are all located within the bedrock controlled portions of the Study Area, in areas predicted to have both convex and concave landscape positions by 3DMapper. Soil borings were dug by hand using a bucket auger, and descriptions for each boring were recorded using standard USDA soil description terminology. Additionally, the slope class at each boring (convex vs. concave) was recorded.

Results

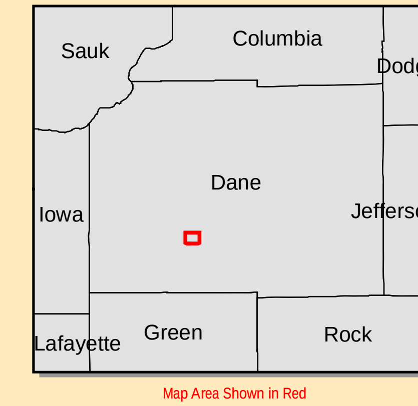
The results of the soil mapping fieldwork correlate with the landscape model developed by NRC and Soil Investigations using the 3DMapper software. The results of this study indicate bedrock was encountered at every soil boring location on convex landscape positions and bedrock was not observed at any of the soil boring locations on concave landscape positions.

Conclusion

The confirmation of the landscape model provides evidence that there are portions within the Study Area that contain bedrock controlled landscapes where bedrock is not a limiting factor for stormwater infiltration, and that these areas can be found on concave landscape positions. The actual extent of areas deep to bedrock was determined to be larger using the 3DMapper program as opposed to using topographic mapping, soil mapping, or other discrete sources of information. It should be noted that additional factors must be considered, along with the depth to bedrock, in order to conclusively determine the overall suitability of a specific location within the Study Area for stormwater infiltration.

SOIL TRANSECTS & NRCS SOIL SURVEY DATA

Upper Sugar River/Badger Mill Creek Study



Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

Project Information

NRC Project Number #: 07-009-01
Modified May 24, 2007

N

0 400 800 Feet

Legend

- Soil Boring Transect 1
- Soil Boring Transect 2
- Soil Boring Transect 3
- Soil Boring Transect 4
- Hydric Soils
- Poss. Hydric Inclusions
- Non-Hydric Soils
- 24K Hydro Layer
- Study Area Boundary

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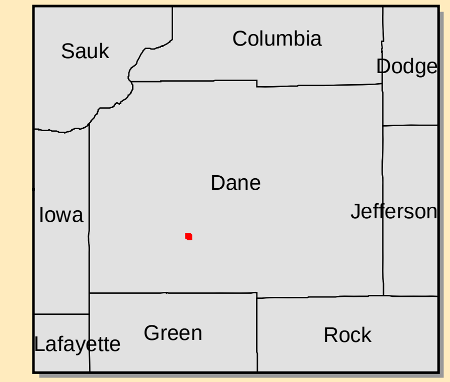
SOIL PIT TRANSECTS 1-3

Upper Sugar River/Badger Mill Creek Study



Map Area Shown in Red

Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

N

Project Information

NRC Project Number #: 07-009-01
Modified May 24, 2007

0 100 200 Feet

Legend

- Soil Boring Transect 1
- Soil Boring Transect 2
- Soil Boring Transect 3
- Soil Boring Transect 4
- Hydric Soils
- Poss. Hydric Inclusions
- Non-Hydric Soils
- 24K Hydro Layer
- Study Area Boundary

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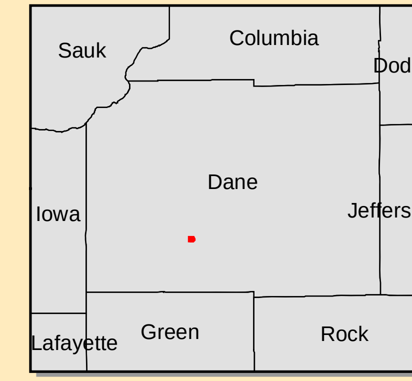
SOIL PIT TRANSECT 4

Upper Sugar River/Badger Mill Creek Study



Map Area Shown in Red

Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

Project Information

NRC Project Number #: 07-009-01
Modified May 24, 2007

N

0 100 200 Feet

Legend

- Soil Boring Transect 1
- Soil Boring Transect 2
- Soil Boring Transect 3
- Soil Boring Transect 4
- Hydric Soils
- Poss. Hydric Inclusions
- Non-Hydric Soils
- 24K Hydro Layer
- Study Area Boundary

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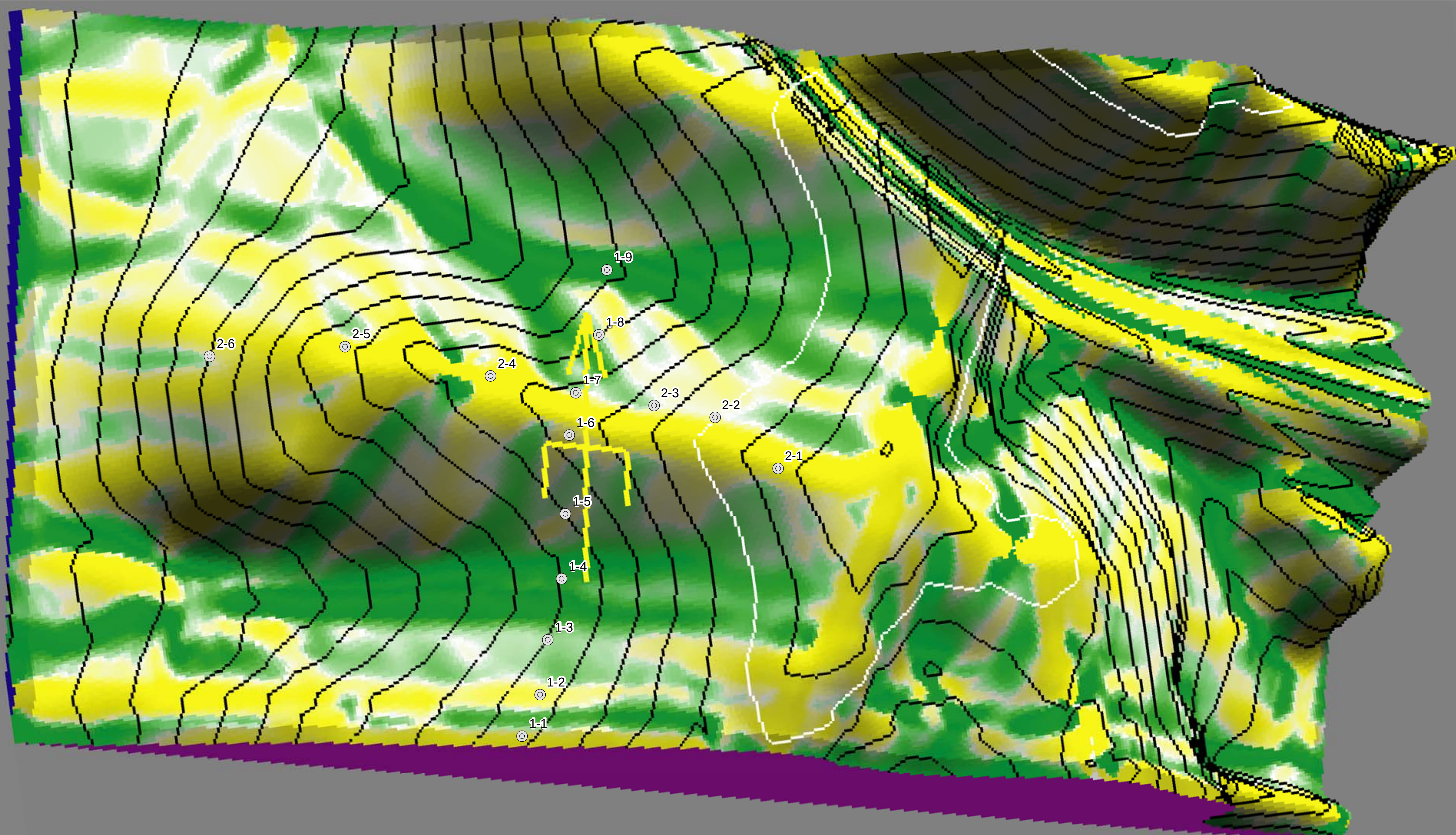
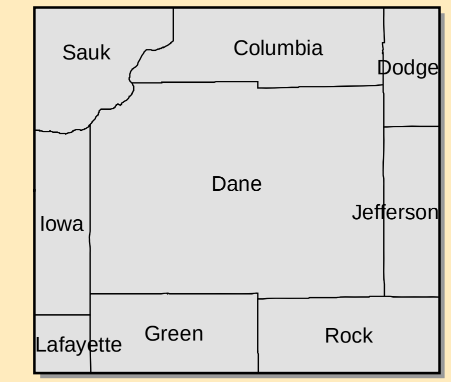
3D MAPPER EXHIBIT 1

Upper Sugar River/Badger Mill Creek Study





Map Area Shown in Red

Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

Project Information

NRC Project Number #: 07-009-01
Modified July 25, 2007

Image Not to Scale

Legend

- Concave
- Convex
- Linear
- Soil Boring Location

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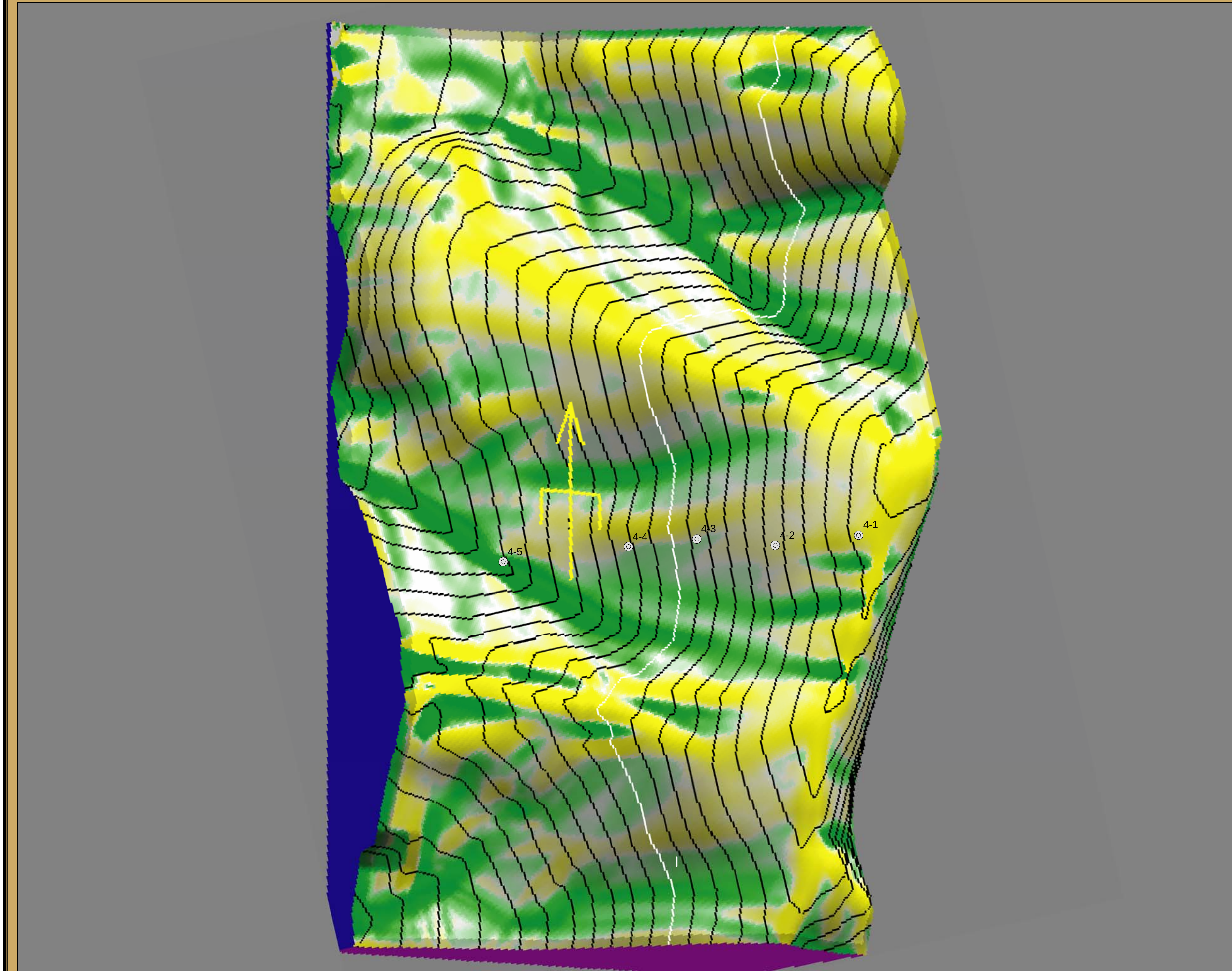
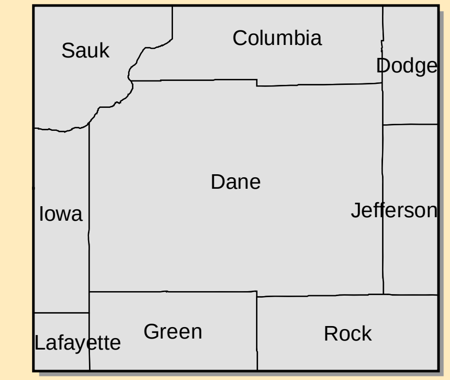
3D MAPPER EXHIBIT 2

Upper Sugar River/Badger Mill Creek Study





Map Area Shown in Red

Location

Portions of Sec. 20, 21, 22, 27, 28, 29, 33 and 34,
Township 6 North, Range 8 East,
Town of Verona, Dane County, WI

Project Information

NRC Project Number #: 07-009-01
Modified July 25, 2007

Image Not to Scale

Legend

- Concave
- Convex
- Linear
- Soil Boring Location

NRC Natural Resources Consulting, Inc.

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NRC
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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-1
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Basco (BaB2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes:
Convex.
Better fits concept of Elkmound series

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color / Size / Abund / Contrast	Infiltration Rate (in/hr)	Other Features
0-9	Ap	as	10YR 3/2	sil	0%	2/m/sbk 2/m/gr				
9-15	2Bt1	cs	7.5YR 4/3	loam	gr/17%	2/m/sbk				clay films
15-20	2Bt2	aw	7.5YR 4/2	grsl	gr/17%	1/m/sbk				spotty clay films
20+	2Cr									Chert/dolostone

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-2
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Dunco (DuC2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes:
Convex... 10-20% gravel/cobble on ground surface.
Better fits concept of Elkmound series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles/Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-4	Ap	as	7.5YR 3/2	loam	gr/5%, cb/5%	2/m/sbk				
4-14	Bt		7.5YR 4/4	cl	g-/30%	2/m/co/sbk				
14+	2Cr	-		cherty dolostone						clay films

NRC
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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-3
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Elkmound (EmD2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes:
Concave, adjacent to grassed waterway. No rock within 61"
Better fits concept of Virgil or Elburn series

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-8	Ap	cs	7.5YR 3/1	sil	0%	2/f/sbk 2/m/gr				
8-12	AB+	cs	7.5YR 3/2	sil	0%	2/m/sbk				
12-23	Bt1	cs	7.5YR 4/3	light sicl	0%	2/m/sbk				clay/organic films
23-27	Bt2	cs	7.5YR 4/4	clay loam	0%	2/m/sbk				clay/organic films
27-36	Bt3	gs	7.5YR 4/4	clay loam	0%	1/m/sbk co		7.5YR 5/2/1/c/d		clay films
36-42	BCt1	cs	7.5YR 4/4	clay loam		1/co/sbk		7.5YR 4/6/1/c/d 7.5YR 5/2/2/m/d		clay films, Mn masses
42-50	BCt2	cs	7.5YR 4/4	sicl	0%	1/co/sbk		7.5YR 4/6/1/m/d 7.5YR 3/2/2/m/d		spotty clay films, Mn masses
50-61+	C		7.5YR 5/3	sicl	1%	0/m		7.5YR 4/6/1/m/d 10YR 5/1/2/m/p		spotty clay films, many Mn masses

NRC
Natural Resources Consulting, Inc.
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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-4
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Sexton (SnB)
Classification: Typic Hapludults
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Concave, 5% gravel/cobble on ground surface, no bedrock within 60"

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color / Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-8	Ap	as	7.5YR 3/2	sil	0%	2/m/sbk 2/m/gr				
8-15	Bt1	cs	7.5YR 4/3	sicl	0%	2/m/sbk				
15-20	Bt2	cs	7.5YR 4/4	sicl	0%	2/m/sbk				clay films
20-27	Bt3	gs	10YR 5/4	sicl	0%	2/m/sbk				clay films
27-38	BCt1	gs	10YR 5/4	sicl	0%	1/co/sbk		7.5YR 4/6 / 1 / f / p		clay films
38-50	BCt2	gs	10YR 5/4	sicl	0%	0/m				spotty clay films
50-60+	Cd		10YR 5/4	sil	0%	0/m		10YR 4/6 / 1 / c / d 10YR 5/1 / 1 / c / d		isolated clay films dense

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-5
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Bucco (BcC2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Linear, 5% gravel cobble on ground surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size / Qty	Structure Gr. Size, Type	Consistence (Moist)	Mottles, Redox Color, Size, Abund, Contrast	Infiltration Rate (in/hr)	Other Features
0-9	Ap	as	7.5YR 3/2	sil	gr 13%	2/f/sbk				
9-11	2Bt		5YR 4/3	clay loam	gr 18%	2/m/sbk				some subsoil mixing
11+	2Cr	-		chert/dolostone						clay films

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-6
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Elkmound (EmC2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Convex, 5% gravel on ground surface

Better fits concept of Boaz series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-9	Ap	as	7.5YR 3/2	sil	gr/3%	2/m/sbk				some subsoil mixing
9-12	Bt1	cs	7.5YR 4/3	sil	gr/3%	2/m/sbk				clay films
12-17	Bt2	cs	7.5YR 4/4	cl	gr/8%	2/m/sbk				clay films
17-22	Bt3	aw	7.5YR 4/4	cl	gr/5%	1/m/sbk				clay films
22-26	2Bt4	as	5YR 4/6 10YR 5/6	sicl	0%	0/m		5YR 4/6/1/c/p 10YR 5/1/2/c/p		clay films, Mn masses, dense
26-35	3C	as	10YR 6/4	fine sl	gr/10%	0/m		10YR 5/1/1/c/d 10YR 4/6/1/c/d		very dense
35-37	3Cg	as	10GY 6/1	sicl	0	0/m				mixed with rotten siltstone
37+	3R		dolomite							weathered dolomite?

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-7
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Elkmound (EmC2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Convex ridgetop, 15-20% gravel/cobble on ground surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size, Qty	Structure Gr. Size, type	Consistence (moist)	Mottles / Redox Color, Size, Abund., Contrast	Infiltration Rate (in/hr)	Other Features
0-10	Ap	as	7.5YR 3/2	sil	gr/8%	2/m/sbk				
10-14	2BC	as	7.5YR 3/2 7.5YR 4/4	vgr-sl	gr 15-20%	2/m/gr 1/f/sbk				
14+	2Cr	-	sandstone bedrock							mixed with rotten rock

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 1-8
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Elkmound (EmD2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes: Convex/linear sideslope, 5-10% gravel/cobble on ground

Better fits concept of Boone series

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size / Qty	Structure Gr. Size Type	Consistence (moist)	Mottles / Redox Color / Size / Abund. Contrast	Infiltration Rate (in/hr)	Other Features
0-9	Ap	as	7.5YR 3/2	sicl	gr/3%	2/m/sbk				
9-16	2Bt	aw	5YR 4/4	sicl	gr/8% cb/5%	1/m/sbk				
16-24	3BC	-	7.5YR 6/3 7.5YR 4/6	fsl	gr/2%	1/f/sbk				dis., clay films
24+	3Cr			sandstone						mixed with rotten sandstone

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Project Name:
Client:
NRC Project #:
Date: 4/30/07
Conditions:

Soil Pit #: 1-9
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Virgil (VwA)
Classification: Udollic Endoaqualfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: concave, no gravel on surface

Better fits concept of Senten series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-7	Ap	cs	7.5YR 2.5/1	sil	0%	2/m/sbk 2/m/gr		—		
7-14	ABt	cs	7.5YR 3/2	sil	0%	2/m/sbk		—		
14-20	Bt1	cs	7.5YR 4/3	sicl	0%	2/m/sbk		—		spotty clay films
20-32	Bt2	gs	10YR 4/4	sicl	0%	2/m/sbk		—		clay films
32-47	BCt	gs	10YR 4/4	sicl	0%	1/co/sbk		—		clay films
47-55	C1	cs	10YR 4/4	sicl	0%	0/m		10YR 5/2 / c / 1 / d		spotty clay films
55-60	C2		10YR 4/4	cl	0%	0/m		—		

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 2-1
Soil Map Unit: Vasco (VaC2)
Vegetation (or crop):
Classification: Mollic Hapludalfs
Drainage Class:
Slope:
Parent Material:
Groundwater:
Elevation:
Position:
Additional notes: Convex slope, 5% gravel on surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag (Size / Qty)	Structure (Gr. Size/ Type)	Consistence (moist)	Mottles / Redox (Color/ Size/ Abund/ Contrast)	Infiltration Rate (in/hr)	Other Features
0-4	Ap	as	7.5YR 3/2	sicl	gr/2%	2/m/sbk				
4-8	2Bt1	cs	5YR 4/4	sicl	gr/4%	2/m/sbk				
8-20	2Bt2	cs	5YR 4/6	sicl	gr/15%	1/co/sbk				thick clay films
20-25	2Bt3	aw	5YR 4/6	sicl	gr/10%	0/m				clay films, dense
25+	3R			chert/dolostone					spotty clay films →	mixed with 10YR 5/8 material

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Client:
NRC Project #:
Date: 4/30/07
Conditions:

Soil Pit #: 2-2
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Reno (RnC2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: linear/concave slope, 7% gravels on surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-5	Ap	as	7.5YR 3/2	sil	gr 12%	2 m sbk		—		
5-8	2Bt1	cs	7.5YR 4/3	sicl	gr 15%	2 m sbk				
8-12	2Bt2	-	5YR 4/4	sicl	gr 15%	2 co sbk				clay films
12+	3Cr			chert siltstone gravel						thick clay films dense Impenetrable

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Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 2-3
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Ellwood (EmC2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Flat/slightly convex ridgetop - 15% gravel/cobble on surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund. Contrast	Infiltration Rate (in/hr)	Other Features
0-6	Ap	aw	7.5YR 3/2	loam/sil	gr 18%	2/m/sbk 2/m/gr				
6+	Cr			Impenetrable (bedrock) dolostone gravel/cobble						

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Client:
NRC Project #:
Date: 4/30/07
Conditions:

Soil Pit #: 2-4
Vegetation (or crop):
Slope:
Elevation:
Additional notes: Convex ridgetop, 15-20% gravel/cobbles on surface

Soil Map Unit: Elkmound (EmC2)
Classification: Typic Dystrudepts
Parent Material:
Position:

Drainage Class:
Groundwater:

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size / Qty	Structure Gr / Size / Type	Consistence (moist)	Mottles / Redox Color / Size / Abund / Contrast	Infiltration Rate (in/hr)	Other Features
0-5	Ap	as	7.5YR 3/2	sil	gr/18%	2/m/sbk 2/m/gr				
5+	Cr			chert/dolostone fragments/gravel						

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NRC Project #:
Date:
Conditions:

Soil Pit #: 2-5
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Elkmound (EmD2)
Classification: Typic Dystrudepts
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Steep convex sideslope, 25% - 30% gravel/cobble on ground

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag. Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles, Redox Color Size Abund. Contrast	Infiltration Rate (in/hr)	Other Features
0-8	Ap	aw	10YR 3/2	loam	gr/7%	2/f/sbk 2/m/gr				
8+	Cr			weathered sandstone bedrock						

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Client:
NRC Project #:
Date: 4/30/07
Conditions:

Soil Pit #: 2-6
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Sextan (SmB)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes: Slightly concave, 1% gravel on surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles, Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-8	Ap	cs	10YR 3/1	sil	0%	2/f/sbk				
8-13	A	as	10YR 3/2	sil	0%	2/f/sbk				
13-20	Bt1	cs	10YR 4/3	sil	0%	2/m/sbk				
20-25	Bt2	cs	10YR 4/3	sicl	0%	2/m/sbk				spotty clay films
25-35	Bt3	cs	10YR 4/4	sicl	0%	2/m/sbk		10YR 4/6/1/c/d		clay films
35-43	BCt	gs	10YR 4/4	sicl	0%	1/co/sbk		10YR 5/2/1/c/d 7.5YR 4/6/2/c/p		clay films
43-50	Cd		10YR 4/4	sil	0%	0/m		10YR 5/2/2/c/d 7.5YR 4/6/1/c/p		spotty clay films
50-55	C1		10YR 5/3 7.5YR 4/6	cl	0%	0/m		10YR 5/2/2/c/d		dense
55-60	C2		10YR 5/3	sicl	0%	0/m		7.5YR 4/6/1/m/p 10YR 5/1/2/c/d		

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Project Name:
Client:
NRC Project #:
Date: 5/1/07
Conditions:

Soil Pit #: 3-1
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Dreso (DaB2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Slight convex, 1-2% gravel on surface

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag (Size, Qty)	Structure (Gr, Size, Type)	Consistence (moist)	Mottles, Redox (Color, Size, Abund, Contrast)	Infiltration Rate (in/hr)	Other Features
0-8	Ap	as	7.5YR 3/2	loam	0%	2/m/sbk 2/m/gr				
8-16	Bt1	cs	5YR 4/3	cl	gr 4%	2/m/sbk				
16-27	Bt2	-	5YR 4/4	sandy clay loam	gr 6%	2/m/sbk		some sandy loam stratification	mixed with whitish rotten rock	clay films
27+	2R			rock (unknown)						clay films

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Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 3-2
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Basco (BaB2)
Classification: Mollic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Convex shoulder slope, 0% gravel on surface
Free water ~ 25"

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-7	Ap	as	7.5YR 2/1	sil	0%	2/f/sbk				
7-14	Bt1	cs	10YR 4/3	sicl	0%	1/m sbk				
14-28	Bt2	as	10YR 5/3	sicl	0%	1/m/sbk				clay films, dense
28-36	2C	aw	7.5YR 4/4	sandy clay loam	gr 7%	0/m		10YR 5/1 2/c/d 10YR 4/6 1/1/c/d 5YR 4/6/1/c/p 5YR 5/1 2/c/p	posts close to saturated	clay films, dense
36+	3R			impr. rock						very dense

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 3-3
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Gale (GaC2)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes: Convex sideslope, 5% gravel/cobble on surface
Saturation at 24"

Depth	Horizon	Bnd.	Matrix Color	Texture	Rock Frag. Size - Qty	Structure Gr. Size Type	Consistence (Moist)	Mottles / Redox Color Size Abund. Contrast	Infiltration Rate (in/hr)	Other Features
0-6	Ap	as	7.5YR 3/2	sil	gr/3%	2/m/sbk 2/m/gr				
6-16	Bt1	cs	7.5YR 4/3	sicl	gr/3%	2/m/sbk				
16-20	Bt2	cs	7.5YR 4/3	sicl	gr/3%	2/m/sbk		7.5YR 4/6/1/c/d		clay/organic films
20-24	Bt3		7.5YR 5/3	sicl	gr/5%	2/m/sbk		7.5YR 5/2/2/c/d 7.5YR 4/6/1/c/d		clay films
24+	2R			imp. rock				7.5YR 5/2/2/c/f		clay films

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 3-4
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Fenton (FeR)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes: Convex sideslope, 5% gravel on ground surface
Better fits the concept of the Gale series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size - Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-8	Ap	as	7.5YR 3/2	loam	gr 13%	2/f/sbk 2/m/gr				
8-28	Bt1	gs	2.5YR 4/3	sandy clay loam	gr 15% cb 15%	1/m/sbk				
28-31	Bt2	-	2.5YR 4/3/ 7.5YR 4/3	clay loam	gr 17%	1/m/sbk				spotty clay films
31+	2R			sandstone bedrock						spotty clay films

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Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 3-5
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Sentin (SmB)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Concave footslope, no gravel on surface

Saturation = 52" Free Water = 55"

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-18	A1	cs	7.5YR 3/1	sil	0%	2/f/sbk 2/m/gr				
18-23	A2	cs	7.5YR 3/2	sil	0%	2/m/sbk 2/m/gr				
23-31	Bt1	gs	10YR 4/3	sil	0%	2/m/sbk				
31-38	Bt2	gs	10YR 4/4	sicl	0%	2/m/sbk				clay/organic films
38-48	Bt3	gs	10YR 4/4	sicl	0%	1/m/sbk		10YR 5/2/2/c/d 10YR 4/6/1/c/d		clay films
40-60	Cd		10YR 5/4	sicl	0%	0/m		10YR 5/2/2/c/d 7.5YR 4/6/1/c/p		spotty clay films /dense

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Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 3-6
Soil Map Unit: Elburn (EgA)
Vegetation (or crop):
Classification: Aquic Argiudolls
Drainage Class:
Slope:
Groundwater:
Parent Material:
Elevation:
Position:
Additional notes: Concave (flat footslope

Saturation ~ 45"

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size - Qty	Structure Gr - Size - Type	Consistence (moist)	Mottles / Redox Color - Size - Abund - Contrast	Infiltration Rate (in/hr)	Other Features
0-16	A1	cs	7.5YR 2.5/1	sil	0%	2/f/sbk 2/m/gr				
16-20	A2	cs	7.5YR 3/2	sil	0%	2/m/sbk				
20-28	Btg	gs	7.5YR 4/2	sil	0%	2/m/sbk		7.5YR 4/6/1/c/d 7.5YR 5/2/1/c/f		
28-36	Bt1	gs	7.5YR 5/3	sicl	0%	2/m/sbk		7.5YR 5/1/2/m/d 7.5YR 4/6/1/c/d		clay films
36-48	Bt2	gs	7.5YR 5/3	sicl	0%	1/co/sbk		7.5YR 5/1/2/m/d 7.5YR 4/6/1/c/d		clay films; spotty clay films
48-60	Cd		7.5YR 5/3	sil	0%	0/m		7.5YR 5/1/2/m/d 7.5YR 4/6/1/c/d		dense

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Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 4-1
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Dunbarton (DuB1)
Classification: Lithic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Additional notes: Slightly convex summit

Better fits the concept of the New Glarus series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-4"	Ap	CS	7.5YR 3/2	SiL	—	2 M SBK 2 M GR		—		—
4-13"	Bt1	CS	7.5YR 4/3	SiL	4%	2 M SBK 2 M GR		—		
13-19"	2Bt2	CS	5YR 4/4	SiCL	4%	1 M SBK		—		Clay/organic films
19-31"	2Bt3	GS	5YR 4/6	SiCL	4%	1 M SBK				Thick clay films
31-35	2Bt4	GS	5YR 4/6	SiCL	3%	1 CO SBK				Clay films Mn soft masses
35-44"	2BCt	C	5YR 4/6	SiCL	1	0/m				Clay films Mn masses
44-47	2C		5YR 4/6	SiCL	1%	0/m				Few clay films
47+	3R									mixed w/ weathered 5YR 7/1 bedrock
										bedrock

NRC
Natural Resources Consulting, Inc.
P.O. Box 128
Cottage Grove, WI 53527-0128
608-839-1998 • Fax 608-839-1995
www.nrc-inc.net

Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 4-2
Vegetation (or crop):
Slope:
Elevation:
Additional notes: Shoulder slope convex

Better fits concept of the Dunbarton series.

Soil Map Unit: Niwblaces (NcC2)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag (Size Qty)	Structure (Gr Size Type)	Consistence (moist)	Mottles / Redox (Color Size Abund Contrast)	Infiltration Rate (in/hr)	Other Features
0-6"	Ap	CS	7.5YR 3/2	SiL	—	2 M SBK 2 M Gr				
6-14"	2Bt1	CS	7.5YR 4/3	SiL	2%	2 M SBK 2 M Gr				Clay Films
14-16"	2C	-	5YR 4/4							
16"	3R									Bedrock

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 4-3
Soil Map Unit: New Glarus (NeD2)
Vegetation (or crop):
Classification: Typic Hapludalfs
Drainage Class:
Slope:
Parent Material:
Groundwater:
Elevation:
Position:
Additional notes: Convex side slope (linear) (upper)

Better fits the concept of the Dunbarton series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size/Qty	Structure Gr/Size/Type	Consistence (moist)	Mottles/Redox Color/Size/Abund/Contrast	Infiltration Rate (in/hr)	Other Features
0-5"	Ap	CS	7.5YR 3/2	SiL	-	2 m Gr				
5-9	Bt		7.5YR 4/3	SiL		2 m SBK 2 m Gr				Organic & clay films
9	2R	-								Chert

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 4-4
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: New Glarus (NeD2)
Classification: Typic Hapludalfs
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Lower Side Slope (convex-linear)

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles/Redox Color Size Abund Contrast	Infiltration Rate (in/hr)	Other Features
0-8"	Ap	AS	7.5YR 3/2	L		2 m SBK 2 m Gr				
8-18"	Bt1	CS	7.5YR 4/3	CL	Gr 5% Cb 5%	2 m SBK				
18-22"	2Bt2	GS	7.5YR 4/4	CL	Gr 5% [illegible]	2 m SBK				Clay + Organic Films
22-24	2Bt3		5YR 4/4	SiCL	Gr 5%	1 Co SBK				Clay + Organic Films
24+	3R									spotty clay + Organic films

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Project Name:
Client:
NRC Project #:
Date:
Conditions:

Soil Pit #: 4-5
Vegetation (or crop):
Slope:
Elevation:
Soil Map Unit: Churchburg (ChB)
Classification: Typic Udifluvents
Parent Material:
Position:
Drainage Class:
Groundwater:
Additional notes: Concave Footslope

Saturation ≈ 26"
FREE water = 30"
Better fits the concept of the Radford series.

Depth	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size Qty	Structure Gr Size Type	Consistence (moist)	Mottles / Redox Color / Size / Abund / Contrast	Infiltration Rate (in/hr)	Other Features
0-10	Ap	AS	7.5YR 3/1	SiL		2MGr		7.5YR 3/4 1CD		
10-28	A1	CS	7.5YR 3/1	SiL		2FSBK		7.5YR 4/2 1CD / 7.5YR 3/4 1CD		
28-38	A2	A	7.5YR 2.5/1	L/SiL		1MSBK		7.5YR 4/2 1CD 7.5YR 3/4 1CD		
38-44	A3	CS	N 2.5/	SiL		1MSBK		7.5YR 3/3 1CP		
44-50	A4	CS	N 2.5	SiL		0/M		7.5YR 3/3 1CP		
50-55	A5	CS	5YR 2.5/1	L		0/M				
55-56	A6		5YR 3/1	CL	25%Gr	0/M				

APPENDIX C

STREAM CHANNEL HABITAT OBSERVATION NOTES

PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Badger Mill Creek Site Mile: ____ Station No.: BA Date (YY MM DD): 9/28/07

Transect No.: ____ Distance from Start (m): ____ Stream Width (ft) 15

Habitat Type (check): ✔ Riffle ____ Pool ✔ Run

	Channel Position: 3.75 ft. from LOB	Middle	3.75 from ROB		
Water Depth (ft) Riffle	0.5	0.75	0.92		
Run	1.3	2.0	1.5		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by: In riffle cobble and sand, 20% fil. algae & Pondweed

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-________)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____ Undercut Banks ✔ Overhanging Vegetation ____ Woody Debris ____ Other Debris

____ Boulders ____ Submerged Macrophytes ____ Emergent Macrophytes ____ Other-Specify ________

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m ____ % RIGHT: ____ m ____ %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____ Cropland ____ Pasture ____ Barnyard ____ Developed ____ Other-Specify ________

____ Meadow ____ Shrubs ____ Woodland ____ Wetland ____ Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____ m RIGHT BANK: ____ m

Revised June 1993

Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION TRANSECT WISCONSIN DNR

Stream: Sugar River Site Mile:_____ Station No.: SA Date (YY MM DD): 9/28/07

Transect No.:_____ Distance from Start (m):_____ Stream Width (ft) 19 feet

Habitat Type (check): ____Riffle ____Pool ✔ Run

	Channel Position: 3 Ft. From LOB	Middle	3 Ft. From ROB		
Water Depth (ft)	3.6	9.5	2.6		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					
Percent (nearest 5%) of Stream Bottom Covered by: Silt					
BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-_____)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____Undercut Banks ____Overhanging Vegetation ____Woody Debris ____Other Debris

____Boulders ____Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify_____

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m 0 % RIGHT: ____ m 0 %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify_____

80 Meadow ____Shrubs 20 Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____m RIGHT BANK: ____m

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Left and Right overbank consists of Reed Canary Grass, Buckthorn, and Silver Maple.

Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Sugar River Site Mile:_____ Station No.: SAA Date (YY MM DD): 9/28/07

Transect No.:_____ Distance from Start (m):_____ Stream Width (ft) 29 feet

Habitat Type (check): ✔ Riffle ___Pool ___Run

	Channel Position				
	6 From LOB	Middle	6 From ROB		
Water Depth (ft)	1.1	1.1	1.3		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by: Bottom 70% sand, 30% gravel. 70% of bottom also covered in milfoil

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-_____)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

_____Undercut Banks _____Overhanging Vegetation _____Woody Debris _____Other Debris

_____Boulders _____Submerged Macrophytes _____Emergent Macrophytes _____Other-Specify_____

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: _____ m _____ % RIGHT: _____ m _____ %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

_____Cropland _____Pasture _____Barnyard _____Developed _____Other-Specify_____

_____Meadow _____Shrubs _____Woodland _____Wetland _____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: _____m RIGHT BANK: _____m

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LOB 20 ft. of meadow and trees then corn. ROB brush and trees. 30% canopy. Trees present are White Oak, Black Walnut, and Willow.

Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Sugar River Site Mile:______ Station No.: SB Date (YY MM DD): 9/28/07

Transect No.:______ Distance from Start (m):______ Stream Width (ft) 16 feet

Habitat Type (check): ____Riffle ____Pool ✔ Run

	Channel Position 4 Ft. From LOB	Middle	4 Ft. From ROB		
Water Depth (ft)	2.3	2.25	2.2		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by: Silty-Sand/ 40 to 50% pondweed

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-______)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____Undercut Banks ____Overhanging Vegetation ____Woody Debris ____Other Debris

____Boulders ____Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify______

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m 0 % RIGHT: ____ m 0 %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify______

100 Meadow ____Shrubs ____Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____ m RIGHT BANK: ____ m

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Left and Right overbank consists of of mostly Reed Canary Grass with some Marsh Milkweed, Blue Vervain, Carex, Canadian Thistle, and Stinging Nettles

Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION   TRANSECT   WISCONSIN DNR

Stream: Sugar River   Site Mile:____   Station No.: SCC   Date (YY MM DD): 9/28/07

Transect No.:____   Distance from Start (m):____   Stream Width (ft) 35 feet

Habitat Type (check): ____Riffle   ____Pool   ____Run

	Channel Position				
	8.75 From LOB	Middle	8.75 From ROB		
Water Depth (ft)	1.0	1.0	1.0		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by: Shallow gravelly bottom start to see algae

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-____)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____Undercut Banks ____Overhanging Vegetation ____Woody Debris ____Other Debris

____Boulders ____Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify____

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m ____ %   RIGHT: ____ m ____ %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify____

____Meadow ____Shrubs ____Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____ m   RIGHT BANK: ____ m

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Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Sugar River Site Mile: ______ Station No.: SH Date (YY MM DD): 9/28/07

Transect No.: ______ Distance from Start (m): ______ Stream Width (ft) 24 feet

Habitat Type (check): ____Riffle ____Pool ✔ Run

	Channel Position				
	6 From LOB	Middle	6 From ROB		
Water Depth (ft)	3.2	1.8	1.2		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by: Bottom silty loam with clay. 15% bottom vegetation.

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-______)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____Undercut Banks ____Overhanging Vegetation ____Woody Debris ____Other Debris

____Boulders ____Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify______

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m ____ % RIGHT: ____ m ____ %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify______

____Meadow ____Shrubs ____Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____m RIGHT BANK: ____m

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Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Sugar River Site Mile:____ Station No.: SM Date (YY MM DD): 9/28/07

Transect No.:____ Distance from Start (m):____ Stream Width (ft) ____

Habitat Type (check): ____Riffle ____Pool ✔ Run

	Channel Position 1/4 Stream	Middle	1/4 Stream		
Water Depth (ft)	4	2.6	2.25		
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					
Percent (nearest 5%) of Stream Bottom Covered by:					
BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-____)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transect (within 0.15 m) with:

____Undercut Banks ✔ Overhanging Vegetation ____Woody Debris ____Other Debris

____Boulders ✔ Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify____

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m 0 % RIGHT: ____ m 0 %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify____

80 Meadow ____Shrubs 20 Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____m RIGHT BANK: ____m

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Figure 8.—*Transect data sheet.*

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PRIORITY WATERSHED FISH HABITAT EVALUATION — TRANSECT — WISCONSIN DNR

Stream: Sugar River Site Mile:_____ Station No.: SQ Date (YY MM DD): 9/28/07

Transect No.:_____ Distance from Start (m):_____ Stream Width (ft) 30

Habitat Type (check): ____Riffle ____Pool ✔ Run

	Channel Position				
	1/3 Stream	Middle	1/3 Stream		
Water Depth (ft)		2.9			
Depth of Fines & Water (m)					
Embeddedness (nearest 5%) of Coarse Gravel and Rubble/Cobble					

Percent (nearest 5%) of Stream Bottom Covered by:

BEDROCK (solid slab)					
BOULDER (>.25 m)					
RUBBLE/COBBLE (.065-.24)					
GRAVEL (.002-.064)					
SAND (.000062-.0019)					
SILT (.000004-.000061)					
CLAY					
DETRITUS					
OTHER (Specify-______)					
ALGAE (attached & fila., %)					
MACROPHYTES (%)					
CANOPY/SHADING (%)					

Cover for Fish (m): Length (nearest 0.01 m) of transcect (within 0.15 m) with:

____Undercut Banks ✔ Overhanging Vegetation ✔ Woody Debris ____Other Debris

____Boulders ✔ Submerged Macrophytes ____Emergent Macrophytes ____Other-Specify______

Bank Erosion: Length (nearest 0.01 m), within 1 m of stream, and % of entire bank, along transect, with bare soil:

LEFT: ____ m 0 % RIGHT: ____ m 0 %

Riparian Land Use (%): Percent (nearest 5%) of bank (within 5 m of stream edge, along transect) with:

____Cropland ____Pasture ____Barnyard ____Developed ____Other-Specify______

____Meadow ____Shrubs 100 Woodland ____Wetland ____Exposed Rock

Riparian Buffer Width (m): Length (nearest 0.1 m) of undisturbed Land Uses along transect, within 10 m of stream:

LEFT BANK: ____m RIGHT BANK: ____m

Revised June 1993

Some cobbles on bottom. ROB has 30 ft. of woodland moving into pasture. LOB has 20ft. of woodland moving to corn crops. Canopy=60%.

Figure 8.—*Transect data sheet.*

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