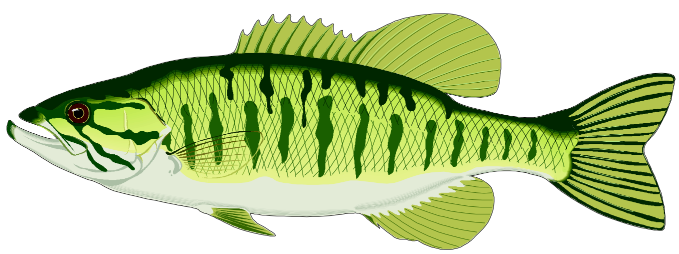
Griffy Lake Watershed GIS Mapping and Management Plan

For: The City of Bloomington, Indiana Planning Department

By:

Commonwealth Biomonitoring, Inc.
8061 Windham Lake Drive
Indianapolis, Indiana 46214
(317) 297- 7713



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I. Executive Summary

This study was conducted to evaluate the effects of land use on the water quality of Griffy Lake in Monroe County, Indiana. Griffy Lake and its immediate surroundings are owned by the City of Bloomington Utilities. The areas is managed by the Bloomington Parks and Recreation Department and is used for boating, fishing, picnicking, hiking, and environmental education. Griffy Lake is also an emergency potable water supply for the City of Bloomington. The information in this plan will be used in the city's "source water protection plan."

The watershed area upstream from the lake is roughly 1700 hectares. The watershed is drained by Griffy Creek, which has three equally sized branches or forks. Presently, the North Fork watershed is fairly pristine, the Middle Fork is in the first stages of urbanization, and the South Fork is rapidly urbanizing. As land uses in the watershed change from forested to urban, the lake's water quality is expected to change as well. A management plan is needed to minimize potential harmful environmental effects of land use changes on the lake.

A geographical information system (GIS) approach was used to determine and evaluate land use effects on the lake. GIS used available information on topography, zoning and planning restrictions, manufacturing and commercial areas, residential development patterns, wildlife habitats, and soils data to produce a set of watershed maps which document present land uses and potential erosion control problems. The information was also used to zero-in on hotspots (areas which require special immediate attention) and "areas of concern" (potential problem areas based on soil types, slopes, and land use). Nonpoint source pollution treatment strategies are proposed for the areas designated as hotspots and an estimated cost for each treatment is given.

The Eutromod lake model, commonly used to determine the potential effects of various land uses on lake quality, was run to compare the present lake status to what might be expected to occur under various land use scenarios. Eutromod predicted that Griffy Lake would change from its present mesotrophic status to eutrophic or hypereutrophic if land uses upstream from the lake changed from primarily forested to urban or urban/agricultural.

In addition to GIS and modeling, several additional methods were used to assess the ecological health of the Griffy Lake watershed. Water chemistry measurements, a rapid bioassessment technique, and "semipermeable membrane devices" were used to provide a snapshot of present water quality conditions. All sites on Griffy Creek had dissolved oxygen, pH, and conductivity readings well within the ranges acceptable to aquatic life. Suspended solids concentrations were low during dry weather. However, very high solids values were recorded during a severe storm. One sample collected for bacterial analysis showed that E .coli levels met Indiana water quality standards for recreational use in the North Fork. However, E. coli exceeded state standards in the Middle and South Forks.

The quality of the benthic community of Griffy Creek was measured twice on all three forks. This is an especially valuable water quality measurement tool because these animals are exposed continuously to conditions in the watershed. In July 1998, all three forks had similar biotic index scores, indicating "slight" environmental impact. However, another set of samples in December 1998 showed that water quality on both sites in the South Fork and one site in the

Middle Fork had declined to "moderately impacted." The most probable cause for the decline was organic enrichment and sedimentation.

Semipermeable membrane devices (SPMDs) are a relatively new monitoring technique, used to determine the potential for bioconcentrating chemicals to cause adverse changes in the aquatic environment. SPMDs consist of a long membrane containing a highly purified oil. These devices are placed in a stream or lake and as water passes over them, bioconcentrating chemicals pass through the membrane and accumulate in the oil, similar to what occurs in fish. SPMDs were placed in both the North and South Forks of Griffy Creek for three weeks, then analyzed for polycyclic aromatic hydrocarbons (PAHs), a class of compounds associated with urban runoff. No PAHs were detected in the North Fork, but the South Fork sampler contained traces of four different compounds. The total PAH concentration in the South Fork was similar to that observed in SPMDs from highly impacted urban streams in Wisconsin and Indiana.

All three of the assessment techniques used in this study (chemistry, biology, bioaccumulation) agree that water quality in the South Fork of Griffy Creek is the most impacted of the three tributaries draining into Griffy Lake. If water quality of the lake is to be protected, nonpoint source control measures are most immediately needed in the rapidly urbanizing South Fork.

II. Geographical Information Systems Watershed Mapping

Geographical Information Systems (GIS) mapping was used to delineate the Griffy Lake watershed, subwatersheds, map land uses, parcel sizes, slopes, inventory significant and potential sources of contamination to the extent practical. In addition, the GIS mapping was utilized to perform a susceptibility analysis for each identified existing and potential source of contamination.

Most of the Griffy Lake watershed is within the City of Bloomington incorporated areas and the City Engineering Department had relatively good GIS coverage of most watershed areas, at least to coarse resolutions, for most watershed natural features. For areas of the Griffy watershed not already covered by GIS mapping, the City Planning Department had an intern complete a Watershed Inventory Map in GIS to depict the major land uses and features in the watershed. These land uses and features include:

- Topography
- Land use, land cover, zoning and planning restrictions
- The various types and locations of agriculture in the watershed
- The types and locations of manufacturing and commerce in the watershed
- Residential development patterns noting the unsewered areas, and wildlife habitats and areas of special interest
- A 1984 study conducted on the limitations and erodibility of soils in the Griffy watershed

The overall watershed and sub-watershed base maps for each of the three Griffy Creek sub-watersheds are presented as Exhibits 1 through 4.

Information from the City and from several other sources was converted the mapping data into ARC/Info. The ARC/Info data was refined to five square meter resolution for analytical purposes and in order to utilize a modified version of the Universal Soil Loss Equation (USLE) variable data was mapped for predictive modeling of soil loss scenarios in the watershed. Based on the results of previous studies, field observations of the nature of the watershed land uses and the types of nonpoint source pollutants apparently entering the watershed, it was decided the most effective nonpoint source (NPS) model would focus on sediment transport to estimate existing and potential sediment transport from the Griffy watershed, since it is not yet a fully urbanized watershed. The USLE and its derivatives are presently the most widely used NPS pollution management predictive NPS pollution models in use in the United States.

A. GIS Mapping Methods and Geo-Spatial Databases for the Lake Griffy Watershed

GIS maps were prepared by using existing geo-spatial databases for the Griffy Creek watershed, as shown in Table 1. The table shows the variables used, where the information was obtained, the dates for which the data apply, and the scale. Certain types of data were considered "model drivers" because much of the soil loss modeling depends on these data sets. Other types of data were considered in "scenario development" because they are dependent on individual land use decisions. Other types of land use data were also available and were included in several of the maps. All of the information shown below is available in an electronic version for future use by the City of Bloomington Planning Department.

Table 1 - Geo-Spatial Databases for Lake Griffy Watershed Project

Probable Use	Database	Key Variable(s)	Source	Date	Scale
Main Model Drivers	Hypsography	Slope %, landscape position (i.e., accumulated flow, etc.)	COB (most of watershed)	1991/92	1:1200
			USGS		1:24000
	Landuse	Cover type, % cover, % impervious	County	1993	1:4800
			County (revised)	1998	1:4000
	Soils	k-factor	County (NRCS)		1:15840
	Plat Maps	Property boundaries	County	1993	1:4800
For Scenario Development					
	Jurisdiction	Who	COB	1991/92	1:1200
			County	1993	1:4800
	Zoning	Zoning class	COB	1991/92	1:1200
			County	1993	1:4800
	Sewer lines	Presence, proximity, capacity, present use	COB	1991/92	1:1200

Other Available Databases	Roads	Same as above	TIGER INDOT COB	 1991/92	1:100000 1:24000 1:1200
	Hydrology	Lake boundaries, Streams as lines, Streams as polys	TIGER USGS County	 1993	1:100000 1:100000 1:4800
	National Wetlands Inventory (NWI)	"Attribute"	USFWS		1:24000
	Building footprints	Additional source of impervious surface data	COB	1991/92	1:1200

B. Production of the Digital, Geo-spatial Land Use Database

Of all the databases listed above, the way individual pieces of land are used is among the most useful for this project. The following land use classes were developed for this project and used in the development of the GIS maps:

Residential
- Multi-family (r-mf)
- Single family (r-sf)

Open Managed
- Frequent Mow (om-fm)
- Infrequent Mow (om-im)
- No Mow (om-nm)
- Unmanaged (om-u)

Agricultural
- Pasture (ag-p)
- Row Crop – Till (ag-rct)
- Row Crop – No-Till (ag-rcnt)
- Crop No-Row (ag-cnr)
- Fallow (ag-f)

Transitional (trans)
- Sites under construction

Commercial/Industrial (ci)

Forested
- Mature Grazed (f-mg)
- Mature Ungrazed (f-mug)
- Secondary Grazed (f-sg)
- Secondary Ungrazed (f-sug)
- Old field (f-o)

Waterbodies
- River/Stream (wb-rs)
- Lake (wb-l)
- Pond (wb-p)
- Other (wb-o)

Specific Procedures for Creating the New Land Use Database:

The Griffy watershed was subdivided into 48 equal area sections. For each section, maps which included Monroe County's 1993 digital, geo-spatial landuse database and COB hypsography were printed. These maps were updated in the field and with aerial photography using the above classification system during the summer of 1998.

Visual estimates of percent cover (cover + bare soil = 100%) and percent impervious surfaces were recorded for each distinct land use unit (polygon). The updated land use information on the maps was transferred to stable-base mylar and scanned. The resultant images were geo-referenced. All new information was then used to update the original (1993) County database. New label points with unique identification numbers were added.

Attribute data was entered and joined to the geo-spatial information via the new identification numbers. Accuracy was visually field confirmed by Commonwealth Biomonitoring, Inc.

C. Production of the Digital, Geo-spatial Hypsography Database, and Associated Slope Percentage Database

City of Bloomington hypsography is not available for a large area in the northeast portion of the watershed. This area totals a little over a quarter of the entire Griffy watershed. Specifically, this data was absent for about 75% and 33% of the North and Middle Fork sub-watersheds, respectively. While the COB contour interval resolution increases to 2 feet for some limited areas of the watershed, 4-foot contours were available for about half, and 10-foot for another quarter. These 10-foot contours largely bounded the data gap area.

USGS 1:24000-scale hypsography was used to fill in the northeast hypsographic data gap for complete hypsographic coverage of the watershed. The USGS contours also have a 10-foot interval. The USGS data matched the COB data reasonably well at adjoining boundaries.

1. Processing Steps for Converting the USGS Analog Data:

- Scan the Unionville Quadrangle topographic map in 256-bit color.
- Select only the contour lines by color, delete the extraneous geographic information, and change contours to “black”.
- Geo-reference, and convert image to rectified grid.
- Convert grid (raster) to lines (vector).
- Generalize (smooth) lines.
- Select contour lines and add elevation information.

2. Processing Steps for Production of the Surface Model and Slope Polygons:

- Append all COB contour databases (4-feet intervals and above) and the USGS data.
- Convert elevation (z) units from feet to meters to match (x, y) UTM coordinate system units.
- Create Triangular Irregular Network (TIN) surface model from nodes and vertices of contour lines.
- Convert to polygons with slope percentage as a continuous variable.
- Classify polygons according slope percentage classes, and dissolve borders between like polygons.

3 Processing Steps for Production of a Digital Elevation Model (DEM) to Be Used as Input for LS-factor Estimation:

- Use all contour, sinks location, lake pool level, and streams databases to generate a hydrologically correct DEM.
- Run macro program described in the following article:

  Hickey, R., Smith A., and P. Jankowski. 1994. Slope length calculations from a DEM within ARC/INFO GRID. *Computers, Environment and Urban Systems* 18(5):365-380.

4. Adjustment of the Digital, Geo-spatial Soils Database:

County soil survey data derived from non-ortho aerial photographs for areas with mature topography usually requires a rubber-sheeting procedure to match other, planimetrically-correct geo-spatial databases (e.g., the COB hypsography). Visual inspection of Monroe County's digital soils database indicated that this adjustment procedure had not been performed, at least for the area of the Griffy Lake watershed. Hence, rubber-sheeting was required in order to perform overlay analysis or simulation modeling that included soil attribute information, considered to be a fundamental component in such analyses.

5. Processing steps for soils database adjustment:

- Display County soils data along with COB building footprint, roads, and all hypsography data in background.
- Link distinct, known locations (e.g., road intersections, houses, etc.) and topographic positions (e.g., ridgetops, foot of toeslopes, etc.) from the soils data to matching locations found on the other reference databases.

6. Adjust Spatial Data:

- View adjusted data with original data and reference data.
- Edit the links, adding, moving, or deleting as required.
- Repeat steps 3-5 until desired adjustment is attained.

7. Other Processing Information

- All other digital, geo-spatial databases obtained from the COB or Monroe County (as indicated in Table 1) were transferred in ARC/INFO export format. The data was exported from the COB and Monroe County's GENASYS software.
- The Universal Transverse Mercator coordinate system (zone 16) was used in the analysis. All geo-spatial processing and analysis were performed using ARC/INFO software.

8. Printing of Base Maps

Four base map exhibits were produced as a result of the GIS data processing.

- Exhibit 1 - Overall Griffy Creeks Watershed Base Map
- Exhibit 2 - North Fork Griffy Creek Sub-watershed Base Map

- Exhibit 3 - Middle Fork Griffy Creek Sub-watershed Base Map
- Exhibit 4 - South Fork Griffy Creek Sub-watershed Base Map

Exhibit 1 - Overall Base Map of Lake Griffy Watershed

Exhibit 2 - North Fork Griffy Creek Subwatershed Base Map

Exhibit 3 - Middle Fork Griffy Creek Subwatershed Base Map

Exhibit 4 - South Fork Griffy Creek Subwatershed Base Map

D. Modeling Soil Loss Rates in the Griffy Watershed

Our project goals were to identify and quantify the magnitude of existing and potential nonpoint source (NPS) locations of pollution in the three main sub-basins of the Lake Griffy watershed via mapping and modeling. The GIS-based modeling portion of this effort focused on sediment resulting from water-based soil erosion. Previous studies indicated that sediment and sediment associated nutrient loading were the NPS pollutants of concern (Monroe County Water Quality Study, 1997). The primary source of non-sediment associated nutrients is failing septic systems in the watershed. Only the Browncliff Street neighborhood is known to have a significant number of failing septic systems. The volume of nutrient release from failing septic systems could not be quantified and is beyond the scope of this project. Therefore, the USLE was used in lieu of other watershed models to determine existing soil loss rates to the watershed, identify areas of NPS concern, and to model the impacts of land clearing scenarios with regard to soil loss rates.

A modified version of the USLE (Wischmeier and Smith 1978) was employed for the analysis of both the existing and potential sources. This model is considered quite robust for this type of estimation, and has been widely used in several forms. All forms of the USLE are based upon the following:

the soil loss rate (A) = $R * K * LS * C * P$ (equation 1)

where: A is in tons of soil per acre per year

R = rainfall erosivity factor	(200 for the study area)
K = soil erodibility factor	(0.17 to 0.43 for the study area)
LS = topographic factor	(0 to 138.6 for the study area)
C = cropping management factor	(0 to 1 for the study area)
P = erosion control practice factor	(0.55 to 1 for the study area)

Note that all of the terms on the right hand side (*rhs*) of the USLE equation (i.e., R, LS, K, C, and P) are unitless.

1. Factors and Data Sources

Modeling soil loss rates (SLR) across the three sub-watersheds required geo-spatial databases for all spatially variable factors. Of the five factors constituting the *rhs* of the USLE, all but R are considered spatially variable for our study region. The following hierarchical set rules were imposed for data acquisition, modification, and use:

1) After evaluating data sources for quality, data with the largest scale or highest resolution was used.

2) COB data was preferred over that from other data sources. This rule was followed to maximize the potential for future use of the set of databases resulting from this project. In addition, all non-COB data sets were adjusted to fit the COB base hypsographic data layer. In all cases, the non-COB databases were less highly-resolved and likely less accurate of all those data sets produced for the COB (see Table 1).

A. The rainfall erosivity factor, R

R-factor values for Indiana range from 220 in the extreme southwestern portion of the state to 140 in the northeast (Brentlinger et al. 1979). These values represent mean annual conditions for the region to which they are assigned. They are a summary measure describing the rainfall event parameters, including frequency, intensity, and duration, occurring in that area, on average given the information on record. In any one year the actual rainfall erosivity value might vary considerably from this average. Monroe County lies in the region of the state assigned an *R*-factor value of 200.

It is quite likely that rainfall event parameters vary spatially within the study area on shorter time scales but data on this do not exist. However, when considering the relative future erosion potential of a given location in the watershed , a constant *R*-factor value of 200 is adequate and appropriate.

B. The soil erodibility factor, K

For undisturbed soils, *K*-factor values can be considered static for human time scales. Within a soil profile in our region of the country and specific study area, *K*-factor values either remain constant or increase higher in the vertical soil profile at a given point. Hence, for many of the soil types in this area, the maximum *K*-factor values exist for the A-horizon. Values for the upper profile range from 0.24 to 0.43, and from 0.17 to 0.43 for the deeper subsoil horizons.

The soils database obtained for this analysis was a digital version of the County Soil Survey produced by the Soil Conservation Service. County soil surveys are produced from a combination of aerial photo interpretation and field verification. Because the aerial photographs used are not planimetrically correct, the boundaries of the soil types can contain considerable spatial and taxonomic errors for areas with mature topography. As much of the Griffy watershed contains ridge/ravine topography, considerable spatial adjustment of this database was necessary. Some taxonomic errors, such as mismatch of soil type names with soil polygon boundaries, were also corrected.

C. The topographic factor, LS

The *LS*-factor is a combined term, with values dependent on both the slope gradient, and slope length. In general, the steeper the slope and the greater the uphill distance, the greater the *LS*-factor value. The values for the study region were generated from the *LS*-factor equations as presented in the Revised USLE manual (Renard et al. 1997).

A digital elevation model (DEM) is very useful for automating the production of a LS value database. The DEM used here was generated from high-quality and high-resolution hypsographic information from the COB. The northeastern portion of the watershed required an alternative data source. The Unionville Quadrangle of the USGS 7.5 minute topographic map was the best available alternative.. A program was obtained from Hickey (1998) for the DEM _ LS-factor value conversion. As presented above, LS-factor values for the 3 sub-watersheds ranged from 0 to 138.6. The mean value for all 5 x 5 m areas was 2.31 with a standard deviation of 4.29. This large standard deviation points out the broad range of topography in the study area.

D. **The cropping system factor, C**

C-factor values are highly dependent on the amount of cover over the soil. In forests this includes the vegetative canopy, leaf litter, and coarse woody debris. In agricultural areas, this includes the crop canopy and crop residue. In residential areas this normally includes grass and grass litter. In transitional areas, this includes temporary or new grass and mulch (e.g. straw, sprayed composites, etc.).

Ground-level cover was estimated for all polygons in the landuse database. *C*-factor values for specific landuse classes were found in tables presented in Mitchell and Bubenzer (1980) and Brentlinger et al. (1979). These landuse-specific values were then modified according to the percent cover in each polygon of our landuse database. Of particular importance was the cropping system used in the agricultural areas involving crop rotation. A *C*-factor value of 0.25 was applied to these areas as specified in the Mitchell and Bubenzer (1980) tables.

It is also important to note that transitional areas with bare soil are assigned a value of 1.00. Hence, in these areas the potential Soil Loss Ratio is not modified by the *C*-factor. Consistent with the literature, this value drops to 0.70 with just 10% grass/mulch cover. The importance of high mulch rate and quick establishment of grass cover cannot be overemphasized, as indicated by these numbers which are based upon empirical field data.

E. **The erosion control practice factor, P**

P-factor values other than 1.00 were applicable only to those areas involving a cropping system. These values vary according to percent slope gradient as well as the erosion control practice used. Hence, both the topographic and landuse databases were required for assignment of these values. The erosion control practiced used in the areas with crop rotation was contouring with respect to both tillage and planting. To obtain accurate overall *P*-factor values for these areas, values specific to various slope percentages were weighted by the percentage areas for each slope class. These values can be found in Weischmeier and Smith (1978) or Mitchell and Bubenzer (1980), among other sources. This areal-weighting procedure resulted in *P*-factor values ranging from 0.55 to 0.89 for the agricultural areas using a crop rotation sequence.

Literature providing *P*-values for developing lands was extremely scarce, and not particularly useful. Hence, transitional areas were assigned a value of 1.00. Given our observations during land use database generation and other fieldwork concerning the limited use of temporary seeding or other cover, these values are reasonably appropriate and SLR overestimation is probably only slight.

2. Estimating Existing Source Locations and Magnitudes.

R-factor values were assumed to be a constant 200 over the study area (Wirschmeier et al. 1978).

Values for soil erodibility factors (*K*-factor) were assigned to the polygons in a corrected version of Monroe County's digital soils database. For undisturbed areas, the *K*-factor value associated with the upper soil layers was used. For transitional areas, with lower soil layers exposed by excavation, *K*-factor values were adjusted by averaging upper and lower soil layer *K*-factor values. For agricultural areas of this study area using crop rotation, tillage practices primarily just turn over the A-horizon. Hence, the *K*-factor value associated with the upper soil layers are used.

LS-factor values were obtained from a digital elevation model derived from COB and USGS hypsographic data. The Revised USLE model parameters were used to derive LS-values.

C-factor values were assigned on the basis of cropping systems in cultivated agricultural areas, and by percentage ground cover in other areas. Standard tables found in Mitchell and Bubenzer (1980) were used. Values of the P-factor were derived from those listed for contour tillage (Wirschmeier et al. 1978). Hence, these were applicable only to agricultural lands that included tillage in the cropping system.

Because values of P vary according to slope steepness class, values for tilled areas were calculated on the basis of the topographic composition of each particular field (i.e., by area-weighting the appropriate value for each slope class). P-factor values for construction sites were not derived, due to the limited data from literature and limited cover practices in the watershed.

A-value output was averaged by land use polygon. Areas where the model showed intolerable levels of existing or potential soil loss were identified. Intolerable soil loss rates were defined as those exceeding six tons per year, as recommended by the Soil Conservation Service. These areas were then ranked on the basis of average *A*-value. Land use polygons with the highest SLR's were assigned a #1 ranking. Ranking was sub-watershed specific. Field checking was performed to identify those areas where model output reflected current conditions, so as to allow a more focused follow-up effort. If field checking revealed that the potential problem area had disturbed land with ongoing erosion, it was placed in the hotspot category.

3. Estimating Potential Source Locations and Magnitudes

Potential SLR's were estimated by the following term.

$$A = R * K * LS \qquad \text{(equation 2)}$$

This simplified equation is a common approach for land use planning, most notably used by Brentlinger et al. (1979) for the State of Indiana. The solution of this equation for any land surface can be considered the maximum SLR (SLR_{max}) under bare conditions, which in this area exist during land disturbing activities and often for some period after the grading phase of landuse conversion activities . It should be noted that the particular yearly SLR_{max} values may not be strictly accurate for long term estimation, as some grass establishment would be expected over the course of a year. However, the relationships of values from one land area to the next do hold. Hence, it is thought that the R*K*LS values, or the maximum surface erosion potentials, are useful for as a planning tool (See Section E, below).

Model and Data Considerations / Discussion

Interestingly, in Monroe County the soil types associated with steeper slopes possess lower *K*-factor values relative to soil types associated with ridgetops or bottomland. Of course, the steeper slopes and, as mentioned above, the lower portions of long, steep slopes have much higher *LS*-factor values than the ridgetop uplands or bottomland areas. Still, *K*-factor values vary almost by a factor of two in this area.

Applicability of the Results

The specific spatial configuration, or patterns of SLR_{max} values, could be used at several times within the planning and zoning enforcement processes:

- For <u>long-range planning</u>, the resultant geo-spatial database could be used for overlay zoning.
- At the time of <u>site plan review</u>, the database could serve as useful information in evaluating proposed erosion control measures. Specifically, maps derived from the database could be given to developers or erosion control subcontractors to show particular locations of concern or areas identified for higher or lower mulching rates.
- During enforcement <u>site visits</u>, maps derived from the database could be used for prioritizing or focusing field efforts where erosion has the highest probability of occurring.

III. Watershed Contamination Threats and Hotspots

Based on the GIS watershed inventory, maps of existing watershed threats hotspots and potential areas of concern were developed. These maps prioritize and illustrate the position of the potential problem areas in the watershed that should be addressed with remedial or corrective measures. In addition the potential threats are illustrated and depicted in different markings than the existing threats in the watershed. For each of the respective sub-watersheds there is a brief general discussion of the existing NPS threats corresponding to a map exhibit for each subwatershed as well as a table to present the watershed mapping data for each polygon hotspot or area of concern. The tables present the following data: Hotspot or area of concern priority ranking and GIS polygon location, a site description, the percentage of impervious surface on the polygon, the percentage of vegetative ground cover on the polygon, the C (cover) Factor and P (conservation practice) Factor assigned the polygon for USLE modeling purposes, the total calculated soil loss from the given polygon in tons/acre/year, and the area of the hotspot within the polygons in square meters. After the hotspots and areas of concern are identified, recommendations for fixing them will be given in Section IV.

North Fork NPS Threats

The field investigations and GIS mapping data were compiled to develop Exhibit 5. The individual hotspots and areas of concern are also presented in tabular form in Tables 2 and 3.

Table 2 - Hotspots in the North Fork of Griffy Creek Watershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Imperv-ious Surface	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat (m^2)
1-Polygon 89	Residential - Single Family	30	75	0.05	1	16.3	1037
2-Polygon 87	Agricultural Row Cropped - Tilled	0	25	0.25	0.66	12.6	407

Description of the Individual Hotspots

- #1 - Polygon 89 - This site is a residence that has poor cover on a steep lawn area.
- #2 - Polygon 87 - An agricultural field with patches of steep HEL (highly erodible land) throughout the field.

Table 3 - Areas of Concern in the North Fork of Griffy Subwatershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Imperv-ious Surface.	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat (m^2)
3-P 67	Residential - Single Family	30	75	0.05	1	16.3	9975
4-P 85	Agricultural Row Cropped - Tilled	0	25	0.25	0.66	12.6	3828
5-P 74	Ag Row Cropped No-Till	0	25	0.25	0.63	12.5	29085
6-P 51	Ag Row Cropped No-Till	0	65	0.25	1	10.6	19809
7-P 27	Residential Single Family	33	70	0.06	1	8.6	6943
8-P 26	Residential Single Family	40	75	0.05	1	8.4	2195
9-P 34	Residential Single Family	33	70	0.06	0.66	7.8	642
10-P 90	Residential Single Family	0	65	0.065	0.63	7.7	2620
11-P 41	Residential Single Family	33	70	0.06	0.61	7.4	443
12-P 77	Residential Single Family	15	80	0.03	1	7.4	821
13-P 78	Residential Single Family	40	60	0.07	1	7.2	226
14-P 73	Residential Single Family	60	75	0.05	1	7.2	743
15-P 54	Agricultural -fallow	0	75	0.055	1	7.2	1774
16-P 32	Residential Single Family	25	80	0.03	1	6.9	107
17-P 66	Residential Single Family	40	80	0.03	1	6.6	825
18-P 19	Residential Single Family	25	70	0.06	1	6.5	371
19-P 75	Residential Single Family	35	80	0.03	1	6.5	470
20-P 20	Agricultural Cropped - No Row	0	95	0.02	0.7	6.4	974
21-P 80	Residential Single Family	30	85	0.02	1	6.4	111
22-P 8	Open Managed - Infrequently Mowed	0	95	0.007	1	6.4	881
23-P 7	Open Managed - Infrequently Mowed	30	75	0.05	1	6.4	1813

Exhibit 5 - Hotspots in North Fork Ranked By SLR

Middle Fork NPS Threats

The field investigations and GIS mapping data were compiled to develop Exhibit 6 - Hotspots in Middle Fork SW Ranked by SLR. The individual existing and potential areas of concern are presented below in Exhibit 6 and Tables 4 and 5.

Table 4 - Hotspots in the Middle Fork of Griffy Creek Subwatershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Impervious Surface	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat (m^2)
1-P 143	Transitional	0	0	1	1	60.1	846.3
2 -P 97	Residential - Single Family	55	70	0.06	1	39.7	1245.1
3- P 215	Agricultural - Fallow	0	10	0.35	0.76	29.4	2233.4
4- P 89	Transitional	0	0	1	1	27.5	3408.9
5- P 176	Transitional	20	40	0.2	1	20.7	4238.0

Description of the Individual Hotspots

- #1 - Polygon 143 - This site is no longer a problem from the perspective of soil erosion. At the time of GIS mapping it was a building lot with a septic mound system being constructed on it. The mound system is now complete and the site has been stabilized with good vegetative cover.
- #2 - Polygon 97 - There was recent excavation at this site and the cover is still very sparse. Attempts were made to establish turf in subsoil conditions, rather than on topsoil.
- #3 - Polygon 215 - This Hotspot is a fallow agricultural field on a relatively steep slope, with sparse cover. Cattle were recently removed from grazing this field and it is presently in recovery.
- #4 - Polygon 89 - This is a construction site that needs seed, mulch, and appropriate soil amendments for the establishment of good vegetative cover.
- #5 - Polygon 176 - This was a construction site that has since been stabilized with good vegetative cover.

Table 5 - Areas of Concern in the Middle Fork of Griffy Creek Subwatershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Imperv-ious Surface	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat - (m^2)
6 - P 87	Open Managed Frequently Mowed	0	80	0.03	1	18.7	342.7
7- P 111	Old Field	0	95	0.011	1	15.7	910.2
8- P 159	Commercial/Industry	30	25	0.2	1	14.8	4336.4
9- P 122	Residential - Single Family	60	75	0.05	1	14.5	1040.3
10- P 131	Residential - Single Family	35	70	0.06	1	12.7	4246.7
11 - P 85	Ag - Row Crop - Tilled	0	25	0.25	.66	12.6	8648.0
12- P 125	Residential - Single Family	30	80	0.03	1	12.3	1251.5
13- P 175	Ag - Row Crop - Tilled	0	30	0.25	.61	11.2	17359.3
14- P 171	Open Managed Infrequently Mowed	0	90	0.01	1	11.1	436.7
15- P 157	Residential - Single Family	50	75	0.05	1	10.9	1818.0
16- P 88	Open Managed Frequently Mowed'	0	80	0.03	1	10.8	267.7
17- P 120	Residential - Single Family	20	70	0.06	1	10.6	5092.0
18- P 138	Residential - Single Family	40	70	0.06	1	10.3	580.1
19- P 182	Ag - Row Crop - No Till	0	15	0.25	.59	10.1	12727.0
20- P 164	Transitional	45	65	0.1	1	10.0	1180.0
21- P 124	Residential - Single Family	35	65	0.065	1	9.8	6495.9
22- P 223	Ag - Row Crop - No Till	0	30	0.25	.61	9.2	375.7
23- P 174	Residential - Single Family	25	60	0.07	1	9.1	805.9
24- P 183	Residential - Single Family	20	75	0.05	1	9.0	2283.5
25- P 119	Residential - Single Family	70	70	0.06	.58	8.9	609.5
26- P 284	Ag - Row Crop - Tilled	0	10	0.25	1	8.8	18348.4
27- P 170	Open Managed Infrequently Mowed	0	75	0.05	1	8.7	1440.7

28- P 93	Open Managed Infrequently Mowed	0	80	0.03	1	8.7	1425.8
29- P 184	Ag - Fallow	0	75	0.055	1	8.6	466.2
30- P 99	Open Managed Frequently Mowed'	30	85	0.02	.84	8.5	338.4
31- P 156	Residential - Single Family	50	75	0.05	1	8.4	1021.8
32- P 161	Ag - Row Crop - Tilled	0	25	0.25	1	8.2	3084.0
33- P 216	Transitional	45	65	0.1	1	8.2	699.9
34- P 209	Transitional	45	65	0.1	1	8.1	1049.5
35- P 158	Open Managed Infrequently Mowed	0	90	0.01	1	8.0	281.7
36- P 192	Transitional	45	65	0.1	1	7.9	3415.5
37- P 117	Ag-Crop - No Row	0	80	0.03	1	7.8	4347.4
38- P 90	Open Managed Infrequently Mowed	0	65	0.065	1	7.7	779.1
39- P 220	Residential - Single Family	45	60	0.07	1	7.5	778.2
40- P 276	Open Managed Infrequently Mowed	0	65	0.065	1	7.4	6819.3
41- P 108	Residential - Single Family	35	80	0.03	1	7.3	1782.8
42- P 103	Residential - Single Family	30	80	0.03	1	7.1	539.1
43- P 104	Residential - Single Family	10	90	0.01	1	7.1	125.0
44- P 227	Open Managed Infrequently Mowed	0	85	0.02	1	7.0	1898.8
45- P 190	Transitional	45	65	0.1	1	6.9	456.3
46- P 86	Residential - Single Family	30	80	0.03	1	6.9	1140.2
47- P 94	Residential - Single Family	25	75	0.05	1	6.7	1163.2
48- P 281	Residential - Single Family	30	85	0.02	1	6.7	208.2
49- P 283	Open Managed Frequently Mowed'	0	85	0.02	1	6.6	234.5
50- P 283	Open Managed Frequently Mowed	0	85	0.02	1	6.6	234.5
51- P 146	Residential - Single Family	10	85	0.02	1	6.4	788.5
52- P 118	Residential - Single Family	30	80	0.03	1	6.2	404.1
53- P 84	Residential - Single Family	35	80	0.03	1	6.1	197.1

54- P 127	Open Managed Frequently Mowed	0	85	0.02	1	6.1	325.0
55- P 178	Open Managed Infrequently Mowed	0	75	0.05	1	6.1	183.4
56- P 101	Ag-Pasture	0	85	0.014	1	5.9	1876.0
57- P 98	Residential - Single Family	30	85	0.02	1	5.8	96.5
58- P 172	Open Managed Frequently Mowed	0	75	0.05	1	5.7	57.8

Exhibit 6 - Hotspots in Middle Fork Ranked By SLR

South Fork NPS Threats

The field investigations and GIS mapping data were compiled to develop Exhibit 7 (NPS Areas in the South Fork Ranked by SLR). The hotspots and areas of concern are presented individually in Tables 6 and 7.

Table 6 - Hotspots in the South Fork of Griffy Creek Subwatershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Imperv-ious Surface	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat (m^2)
1- P 376	Transitional	0	0	1	1	108.4	9779
2- P 350	Transitional	0	0	1	1	80.7	1019
3- P 378	Transitional	80	0	1	1	52.6	1542
4- P 282	Commercial-Industrial	10	0	1	1	36.3	8803
5- P 355	Transitional	0	0	1	1	22.2	13044
6- P 277	Forested - Secondary Ungrazed	0	90	0.016	1	13.7	123
7- P 258	Transitional	40	40	0.2	1	12.8	1272

Descriptions of Hotspots Ranked by SLR - South Fork Subwatershed

- 1 - P 376 - This is a construction site along 10th Street that was bare at the time of mapping. Presently there is some sparse vegetative on the site that is still inadequate to prevent soil erosion. The area needs soil amendments as per soil test and reseeded and mulched appropriately.
- 2 - P 350 - This is a soil borrow pit on Indiana University property along Range Road behind the I.U. warehouse. It needs vegetative cover and sediment control measures such as silt fence installed to prevent migration of sediments from the site.
- 3 - P 378 - This was an INDOT construction project along 10th Street (St. Rd. 45) which was bare throughout the GIS watershed mapping period. This site has since been stabilized with sod, and is no longer a Hotspot to be managed.
- 4 - P 282 - The I.U. Coal pile on Range Road was identified by the GIS mapping and USLE modeling as a Hotspot, due to a lack of vegetative cover and using K values for the soil types beneath the coal pile. The coal pile itself is not highly erodible and the NPS pollution effects of the coal pile are being monitored by I.U. SPEA on an ongoing basis.

- 5 - P 355 and 6 - P 277 - Fill area behind I.U. Warehouse and associated ditch draining the I.U. warehouse property. There are severe erosional problems associated with these two sites, and there have been for several years. **This is the erosion problem with most immediate needs of all those identified in the watershed inventory,** because sediment has direct flow access to the South Fork of Griffy Creek via the drainage ditch along Range Road. The ditch needs to be regraded and lined with erosion control blankets over a prepared seed bed utilizing a sod waterway mix. The fill area should, at a minimum, have silt fence immediately, and areas that are to a final grade or are not actively being filled should be hydroseeded.
- 7 - P 258 - This is a new home construction site with a bare lot during the GIS inventory. It presently has some sparse cover on the lot but is in need of additional seed and mulching to further prevent erosion. Other lots in the vicinity are now being developed and are bare. Erosion control ordinances should be strictly enforced in this subdivision.

Table 7 - Areas of Concern in the South Fork of Griffy Creek Subwatershed

Hotspot Priority Rank & GIS Location Polygon (P) #	Site Description	% Imperv-ious Surface	% Cover	C Factor	P Factor	Calculated Soil Loss (tons/acre/yr)	Area to Treat (m^2)
8- P 333	Open Managed - Infrequently Mowed	0	40	0.15	1	12.5	11868
9- P 388	Open Managed - Frequently Mowed	15	60	0.07	1	12.4	609
10- P 354	Open Managed - Infrequently Mowed	0	40	0.15	1	12.1	2212
11- P 275	Commercial-Industrial	0	60	0.07	1	11.8	388
12- P 242	Transitional	0	0	1	1	11.0	1700
13- P 370	Residential - Multi Family	80	50	0.08	1	10.2	116
14- P 270	Open Managed - Frequently Mowed	0	60	0.07	1	9.9	13568
15- P 357	Open Managed - Infrequently Mowed	0	60	0.07	1	9.6	1109
16- P 266	Open Managed - Infrequently Mowed	0	75	0.05	1	9.3	1044
17- P 284	Ag - Row Crop Tilled	0	10	0.25	0.59	8.8	5025
18- P 191	Open Managed - Frequently Mowed	0	60	0.07	1	8.6	1470
19- P 319	Open Managed - Frequently Mowed	0	60	0.07	1	8.6	717
20- P 294	Open Managed - Frequently Mowed	8	70	0.06	1	8.3	9765
21- P 363	Residential - Single Family	50	75	0.05	1	8.0	207

22- P 312	Open Managed - Frequently Mowed	0	60	0.07	1	8.0	504
23- P 206	Transitional	45	65	0.1	1	7.8	1765
24- P 306	Open Managed - Frequently Mowed	0	75	0.05	1	7.7	1628
25- P 235	Commercial-Industrial	10	60	0.07	1	7.5	1023
26- P 384	Residential - Single Family	55	60	0.07	1	7.4	598
27- P 342	Residential - Single Family	50	75	0.05	1	7.2	2566
28- P 320	Residential - Single Family	25	75	0.05	1	7.2	2850
29- P 331	Residential - Single Family	25	75	0.05	1	7.1	1321
30- P 279	Residential - Single Family	33	75	0.05	1	7.1	818
31- P 218	Transitional	45	65	0.1	1	6.9	1605
32- P 404	Residential - Multi Family	65	55	0.075	1	6.9	233
33- P 267	Forested - Secondary Ungrazed	0	100	0.011	1	6.7	413
34- P 407	Residential - Single Family	25	70	0.06	1	6.7	518
35- P 335	Open Managed - Infrequently Mowed	0	60	0.07	1	6.6	560
36- P 285	Forested - Secondary Ungrazed	0	90	0.016	1	6.6	85
37- P 269	Open Managed - Frequently Mowed	0	60	0.07	1	6.6	99
38- P 399	Open Managed - Frequently Mowed	0	70	0.06	1	6.6	181
39- P 173	Commercial-Industrial	30	65	0.065	1	6.5	2651
40- P 295	Open Managed - Frequently Mowed	0	60	0.07	1	6.4	1240
41- P 155	Open Managed - Frequently Mowed	0	80	0.03	1	6.4	801
42- P 382	Residential - Single Family	40	85	0.02	1	6.4	100
43- P 325	Open Managed - Infrequently Mowed	0	70	0.06	1	6.3	334
44- P 420	Commercial-Industrial	20	30	0.2	1	6.3	198
45- P 381	Residential - Single Family	40	85	0.02	1	6.3	324
46- P 334	Open Managed - Infrequently Mowed	0	60	0.07	1	6.2	456
47- P 340	Ag - Row Crop - No Till	0	50	0.25	.56	6.2	705
48- P 297	Open Managed - Infrequently Mowed	0	80	0.03	1	6.1	191
49- P 375	Residential Multi-Family	70	70	0.06	1	6.0	313
50- P 336	Forested - Mature Grazed	0	85	0.05	1	5.7	208

51- P 296	Residential - Single Family	50	80	0.03	1	5.6	65

The Bare Soil Scenario

Exhibits 8 - 11 show potential soil loss rates expected to occur within each segment of the watershed if the soil is allowed to remain bare or if vegetative cover is not quickly reestablished. These maps may be useful to the Bloomington Planning Department to demonstrate why certain highly erodible pieces of property in the watershed should not be unnecessarily disturbed.

IV. Pollution Control - Most Feasible Alternatives for Treatment

For each hotspot or area of concern identified in the watershed, a set of control alternatives have been proposed. These alternatives focused on low cost, low maintenance solutions. Both nonstructural and structural controls are possible. However,structural controls are expensive. Preference in this project was given to controls with lower required capital and maintenance costs. Major capital improvement projects were not further evaluated because there is little likelihood that they would be implemented. Non structural controls reduce implementation problems such as poor subsurface conditions, easement, access, and land rights problems, possible drainage impairment on upstream properties. The establishment of vegetative cover to hold soil in place was considered the most likely alternative to be implemented.

Three cover establishment alternatives considered. The advantages and disadvantages of each alternative were as follows:

A. Blown straw mulch, seeding, soil amendment

Benefits - Lowest Cost

Limitations - Not suitable for slopes greater than 3:1. Mulch lost to wind and sheet flow of stormwater.

B. Hydroseeding

Benefits - Best germination rates. One step process. More complete coverage.

Limitations - Not suitable for slopes greater than 2:1

C. Erosion control blankets with seed, soil, and amendments

Benefits - More suitable for steep slopes.

Limitations - Must be professionally installed. Highest expense.

A planning level cost estimate was prepared for each proposed best management practice measure and has been tabulated on a per subwatershed basis, and presented in Tables 8, 9, and 10. Map locations are presented in each of the three subwatershed pollution control implementation maps presented in Exhibits 5, 6, and 7 which have been developed from the GIS data mapping, and further described in Tables 5, 6, and 7.

Table 8 - Treatment Alternatives Existing North Fork Subwatershed Hotspots

Map Location and Priority	Site Description	NPS Pollution Treatment Strategy	Area - m^2 Cost
1 - Polygon 89	Residential - Single Family	Poor Cover on Steep Slopes - Cover Enhancement w/ turf grass or native perennial planting, Proper Fertilization - Hydroseeding is the most effective @ $0.60/S.Y.	9975 $7,150
2 - Polygon 87	Agricultural Row Cropped - Tilled	Allow to go fallow at the small portion of the field. No direct measures need to be applied. The only cost is an opportunity cost to the producer.	3828 $0.00

Discussion of Treatment strategies

The only measure necessary in the Middle Fork is application of seed, mulch and soil amendments via hydroseeding at Site 1 in Polygon 89.

Table 9 - Treatment Alternatives Middle Fork Subwatershed

Map Location and Priority	Site Description	NPS Pollution Treatment Strategy	Area - m^2 Cost
1- Polygon 143	Transitional - Under Construction - No Vegetative Cover	This site has been stabilized since the GIS inventory was performed. No treatment is necessary	846 $0.00
2- Polygon 97	Residential - Single Family	Enhance vegetative cover with seed, mulch and soil amendments via hydroseeding.	1245 $900
3- Polygon 215	Agricultural - Fallow	Allowing fallow ground to remain fallow will provide cover naturally. This is not even an opportunity cost to the farmer since it is presently out of production.	2233 $0.00
4- Polygon 89	Transitional - Under Construction - No Vegetative Cover	Seed, mulch, soil amendments via hydroseeding.	3409 $2450
5- Polygon 176	Transitional - Under Construction	Seed, mulch, soil amendments via hydroseeding.	4238 $3050

Discussion of NPS Control Strategies

The hotspots identified in the Middle Fork Subwatershed can simply be controlled via application of seeding with appropriate mulching and soil amendments to optimize vegetative cover establishment and growth.

Table 10 - Treatment Alternatives South Fork Subwatershed

Map Location and Priority	Site Description	NPS Pollution Treatment Strategy	Area - m^2 Cost
1 - P 376	Transitional Construction Site (inactive)	Apply Seed, mulch , soil amendments, via hydroseeding - Maintain silt fence (600 L.F.)	9780 $600
2 - P 350	Transitional Area - Borrow Pit - I.U. Property (active)	Apply Seed, mulch , soil amendments, via hydroseeding	1020 $915
3 - P 378	Transitional - St. Rd. 45 INDOT Project (completed - sodded)	none required	N/A
4 - P 282	Coal Pile Facility/Commercial Industrial Site (treatment strategies presently implemented)	This site is presently being managed by I.U. SPEA for NPS controls	N/A
5 - P 355	Transitional I.U. Warehouse fill area and eroded Ditch along Range Road	Apply Seed, mulch , soil amendments, via hydroseeding Grading ditch, Application of Seed, amendments, erosion control blankets.	13,045 $2000
6 - P 277	Forested - Secondary Ungrazed	No management needed Allow successional growth to occur	N/A
7 - P 258	Transitional - Residential Construction	Apply Seed, mulch , soil amendments, via hydroseeding	1272 $920

V. Biomonitoring of Aquatic Communities

Biological monitoring of the three primary tributaries of Griffy Creek was conducted using EPA's Rapid Bioassessment Technique for benthic sampling (Protocol III). This technique compares the benthic community of the study streams to a reference stream. Potential impacts measurable by this bioassessment method are toxic substances, nutrient enrichment, low dissolved oxygen, and sedimentation.

Biomonitoring of the incoming streams gives baseline information on the biological impact to the streams from environmental conditions within the respective subwatersheds. As problems in the watersheds are corrected, follow up biomonitoring can be done to measure the impairment or improvement in the tributaries.

Methods and Materials

Seven sites were sampled twice, once in the spring of 1998 and again in the late autumn of 1998. The sample sites were as follows:

	Sample Site #	Site Description
●	NF 1	At the end of Baugh Road
●	NF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
●	MF 1	In Griffy Nature Preserve, 200 yards west of the end of Lana Rd.
●	MF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
●	SF 1	Sycamore Valley adjacent to former gun club firing line.
●	SF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
●	Reference Stream - Jacks Defeat Creek near Ellettsville, Indiana	

Originally, three upstream sites within the South Fork of Griffy Creek were in the sampling plan to attempt to identify which sub-basins which might have greater risks for biological impairment. However, all major tributaries of the South Fork are ephemeral and are not capable of hosting a permanent benthic community. In addition, between the flood conditions of the first half of 1998 and the drought conditions of the last half of 1998, the environmental conditions of the sub-tributaries did not allow for representative sampling of sub watersheds of the South Fork of Griffy Creek.

The methods used for bioassessment were from the U.S. EPA technical Support Document Rapid Bioassessment Protocols for Use in Streams and Rivers (EPA/444/4-89-001). Protocol III for benthic macroinvertebrates was used. Data collected from the biosurveys was analyzed using the following metrics: (1) taxonomic richness, (2) Hilsenhoff Biotic Index, (3) functional feeding group ratios, (4) ratio of EPT and chironomid abundances, (5) percent contribution of the dominant taxon, (6) EPT Index, (7) Community Similarity Index, and (8) percent shredders in coarse particulate organic matter. The metrics were composited to obtain a single "biotic score" for each site. The scores range from 0 (no benthos present) to 48 (reference conditions). In addition, a habitat evaluation of each site was conducted using Ohio EPA's protocol. The habitat scores were correlated to the biotic scores to help separate water quality from habitat effects.

A reference stream draining an area of less than 20 square miles, but having a relatively forested watershed with limited channel alterations is required for comparison. This site selected was Jacks Defeat Creek near Ellettsville. This stream was shown in an earlier study to have a very healthy benthic community, with metrics representative of some of the best streams in the Eastern Corn Belt ecoregion of Indiana.

Results of Watershed Biomonitoring

Benthic samples were collected in July and December 1998. The raw data for each sample are presented in Appendix B.

There was a marked decline in the aquatic community of Jacks Defeat Creek during December 1998. Three of the eight metrics were much lower than normal, perhaps due to wastewater treatment problems in the Town of Ellettsville. Therefore, this station could not be used as a reference for the December sampling period. Instead, the values obtained from Jacks Defeat Creek in November 1996 were used as the reference .

For three of the stations studied, the Biotic Index Values did not change by more than 10% between sampling periods. Conditions at the following stations remained relatively constant during the summer and late autumn of 1998.

	July	December	Impairment Category
MF2	26	30	Slight
NF1	28	28	Slight
NF2	32	34	Slight

In contrast, the other three sites showed greater than 10% declines in Biotic Index Values between the July and December sampling periods.

	July	December

SF1	38	22
SF2	38	22
MF1	34	24

All six study sites were considered only slightly impaired in July, but the three sites listed above were considered moderately impaired in December.

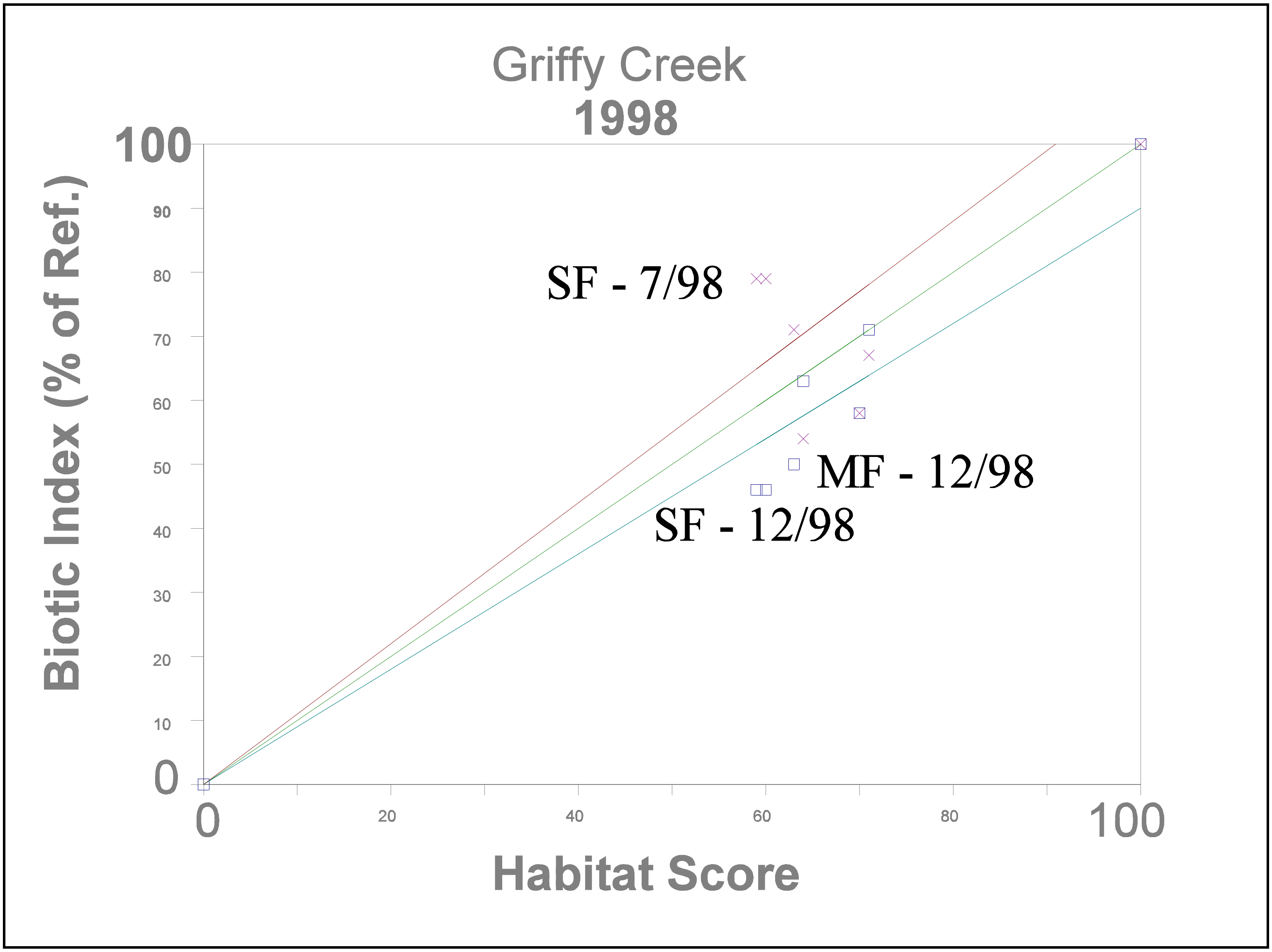
Diagnosis of Biomonitoring Results

The largest changes in the Biotic Index Values at these sites occurred in the following metrics:

- The percentage of shredder organisms declined (SF1 and SF2)
- One group became more dominant (SF2 and MF1)
- Scraper organisms declined (SF1 and MF1)
- Number of environmentally sensitive organisms declined (SF2)
- Total number of kinds of organisms declined (SF1 and MF1)

Lower dissolved oxygen may have been present during the December sampling period. Hilsenhoff Biotic Index values indicative of organic enrichment occurred at several sites, especially at SF2. In addition, sediment-related degradation may have occurred at SF1 and SF2. The percentage of sediment-intolerant organisms at these sites (10-30%) was much lower than at other locations (40-70%). Meanwhile, sediment tolerant organisms at SF1 were much more abundant (18% of the fauna) than at the other sites (1-3%).

The graph below shows the normal relationship between biological integrity and habitat quality. Where water quality is similar, the relationship is directly proportional, as represented by the solid line through the middle of the graph. A 10% deviation from the mean, to account for potential measurement error, is represented by the dotted lines. If water quality declines at a particular site, the biotic values begin to deviate from the normal relationship. The graph suggests that water quality impacts occurred at both South Fork sites during both study periods and at one of the Middle Fork sites. None of the sites on the North Fork had impacted water quality. An especially interesting result was the higher than expected biotic index values occurring on the South and Middle Forks during July (represented by the solid boxes above the upper dotted line). This phenomenon is often indicative of nutrient enrichment (EPA, 1989) associated with recent excessive influxes of nitrogen and phosphorus.


Griffy Creek
1998
Biotic Index (% of Ref.)
100
90
80
70
60
50
40
30
20
10
0
SF - 7/98
MF - 12/98
SF - 12/98
0
20
40
60
80
100
Habitat Score

VI. Watershed Water Quality Sampling

Water chemistry information was collected at eight sites in the Griffy Creek watershed:

	Sample Site #	Site Description
•	NF 1	At the end of Baugh Road
•	NF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
•	MF 1	In Griffy Nature Preserve, 200 yards west of the end of Lana Rd.
•	MF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
•	SF 1	Sycamore Valley adjacent to former gun club firing line
•	SF 2	Approximately 300 yards upstream of the confluence of the three forks of Griffy Creek
•	Combined	Griffy Creek below the confluence of the three forks
•	Spillway	Griffy Creek downstream from Griffy Lake

The water at each of the first six sample stations was tested once for pH, dissolved oxygen (D. O.), conductivity, and temperature. Samples for total suspended solids (TSS) were collected under four different flow regimes at one site on each fork, at the confluence of all three forks, and at the Griffy Lake spillway. E. coli bacteria samples were collected at one site on each fork during base flow conditions.

Table 11 - Water Quality Analyses in the Griffy Creek Watershed

		Suspended Solids (mg/l)				
Date	Flow Conditions	NF2	MF2	SF2	combined	spillway
4/23/98	Base flow condition	<5	<5	<5	<5	
5/22/98	High Flow Condition	1	31	27	3	6
6/5/98	Base Flow Condition	1	2	20	10	6
6/22/98	Very High Flow Condition	30	141	33	70	

Additional water quality data

Date	Site	Temp. (C)	pH SU	D.O. mg/l	Conductivity uS	Coliforms CFU/100 ml	E. coli CFU/100 ml
7/6/98	NF 1	21	7.9	8.6	210		
6/5/98	NF2					706	106
7/6/98	NF 2	19	7.7	8.9	170		
7/6/98	MF 1	18	7.6	7.4	260		
6/5/98	MF2					278	152
7/6/98	MF 2	19	7.8	7.0	230		
7/6/98	SF 1	20	7.8	9.1	320		
6/5/98	SF2					>1000	>450
7/6/98	SF 2	19	7.7	7.7	390		
6/5/98	Combined					>1000	>450

The dissolved oxygen concentrations, pH, conductivity, and temperature fell within the ranges required by freshwater aquatic life at all sites. During baseflow conditions the suspended solids concentrations at all sites in Griffy Creek upstream from the lake were extremely low, indicating good water when no runoff is occurring.

Suspended solids concentrations typically rise during stormflow conditions. In the North Fork, the thick vegetative cover present throughout the watershed (see Exhibit 2) appears to be effective in keeping sediment particles in the subwatershed from running off into the lake during storm events. Even during very high flow conditions following an intense storm on June 22, 1998, suspended solids in the North Fork did not rise above 30 mg/l. In contrast, the Middle Fork has more disturbed ground and less vegetative cover than the North Fork. Suspended solids concentrations up to 141 mg/l were recorded there during a severe storm event.

Suspended solids in the South Fork increased only slightly during storm events and levels associated with harm to aquatic life (greater than 100 mg/l) were not measured during this brief study period. Grab samples collected during storm events can be misleading. The volunteers collecting stream samples on June 22, for example, think they missed the worst part of the storm and that suspended solids were much higher as the storm began.

Suspended solids concentrations in Griffy Creek at the lake spillway were low at both baseflow and stormflow conditions. Sediment settling appears to be occurring in Griffy Creek during storm events..

A single sample for bacteria at four sites in the watershed during baseflow conditions found the water satisfactory for swimming. E. coli concentrations were less than the Indiana water quality standard of 234 CFU/100 ml in the North and Middle forks. However, unsafe levels were present in the South Fork. The bacteria levels were still very high as Griffy Creek flowed into the upper end of the lake. The source of the bacterial contamination could not be determined by this single sampling event. Possible sources include both human (e.g. failing septic systems) and animal fecal contamination.

II. Semi-Permeable Membrane Device Bioaccumulation Simulation

Semi-Permeable Membrane Devices (SPMD) are membranous bags filled with purified oil. As water containing bioaccumulatory chemicals passes over an SPMD, the chemicals pass through the membrane and accumulate in the oil. SPMDs act like a kind of artificial fish and are very useful in monitoring low concentrations of potentially harmful chemicals in water (Huckins et al, 1990. Chemosphere 20:533-552). One SPMD was installed in a strategic location in the North and South Forks of Griffy Creek. This was to provide a method of passive remote sampling that will simulate the bioaccumulation of urban runoff pollutants in aquatic organisms. Due to intense urbanization in the South Fork, it was hypothesized that this tributary would contain more urban runoff pollutants than the North Fork. SPMDs were set instream on July 6, 1998 and retrived on July 30, 1998. A blank was also run as part of the quality assurance program, to provide evidence that pollutants were not present in SPMDs before exposure to environmental conditions.

PCBs were analyzed because they have been commonly found in other Monroe County streams. Another class of chemical polycyclic aromatic hydrocarbons or PAHs originate primarily from incompletely burned fossil fuels. They are commonly found in urban stormwater runoff, sometimes in concentrations which cause water quality problems through toxicity to aquatic life. They are also known to have high potential to bioaccumulate in tissues of aquatic animals and therefore are commonly detected in SPMDs.

Semi-Permeable Membrane Device Data Results

	PCBs ug/ml	chrysene ug/ml	fluoranthene ug/ml	phenanthrene ug/ml	pyrene ug/ml
North Fork of Griffy Creek	<0.5	<0.08	<0.17	<0.84	<0.08
South Fork of Griffy Creek	<0.5	0.23	1.1	0.36	0.44
Blank	<0.5	<0.08	<0.17	<0.84	<0.08

Despite their presence in other Monroe County streams, PCBs were not detected in SPMDs placed in Griffy Creek. Four PAH compounds were detected in the SPMD placed in the South Fork of Griffy Creek during a minimum three week exposure period. All of these PAH compounds are commonly detected in urban stormwater runoff samples (Pitt et al., 1995. Water Environment Research 67:260-275; Bright, 1997. Water quality study of the Yellow River in Marshall & Starke Counties of Indiana, IDEM Contract ARN 97-922). Total PAH concentrations of greater than 4 ug/ml in SPMDs were indicative of streams with highly impacted aquatic communities in Wisconsin (Villeneuve et al., 1997. Environmental Toxicology and Chemistry 16:977-984). Total PAH compounds in the South Fork of Griffy Creek were lower than 4 ug/l but still high enough to be of concern for potential toxicity to aquatic life. Of the PAH compounds identified, phenanthrene is probably the most toxic (Smith et al., 1988. J. Great Lakes Res. 14:394-404), while pyrene is the most highly bioaccumulatory (Miller et al. Environ. Sci. Technol. 19:522).

III. Existing Land Uses and BMPs in the Watershed

Golf Course Management

There is only one golf course in the Griffy Lake watershed. This golf course is the IU Golf Course located within the South Fork watershed. Overall the golf course in is good condition from an NPS pollution control perspective. There are plans to expand the course in the future. Several management recommendations to minimize NPS problems in the future are given below.

Existing Golf Course Management

Based on observations made during a field reconnaissance of the IU Golf Course, the fairways, tees and greens provide good vegetative ground cover for the prevention of NPS pollution migration from the golf course. However, in rain events in early 1998, there was a considerable amount of muddy water running off of the golf course and into Griffy Lake. In tracing back the muddy flows, the sediment load was coming from diffuse sources, particularly the roughs on the hillsides of the course.

The roughs of the golf course in general only have approximately 60 - 70% areal vegetative turf coverage. The roughs are also on the sloping hillsides in the golf course and are in need of heavier vegetative cover to prevent runoff of sediments and associated nutrients.

The roughs should be over-seeded with a turf type dwarf tall fescue blend of varieties that require very little or no irrigation and less soil fertility for healthy growth. Soil pH should be tested to determine if pH is a limiting factor in growth. Soil fertility should also be tested to determine if a light application of a professional grade slow release, non-leaching fertilizer should be applied. In addition, some of the natural drainage ways in the roughs have developed eroding gullies. These gullies should be stabilized with straw/coconut blend erosion control blankets over a prepared seedbed with a native switchgrass planted in the waterway for permanent cover.

Proposed Future Golf Course Potential Impacts

There has been discussion of expanding the Indiana University golf course in the Sycamore Valley area adjacent to the South Fork Griffy Creek. Any type of construction which disturbs land adjacent to a stream flowing into a lake will cause sedimentation in the lake. In order to establish quality turfs in the valley, fertilizers will have to be applied to the ground. A large volume of forest clearing and earth moving would have to be done in the Sycamore Valley and surrounding hills in order to expand the golf course in this area. Griffy Creek would also be more vulnerable to degraded water quality from fertilizers and pesticides typically applied in high doses to golf courses.

In the event that the golf course is expanded in Sycamore Valley, vegetative buffer zones around the stream corridor should be established. Construction equipment should not be allowed to encroach on these buffer areas. Previous research on buffer zones suggests that they should extend at least 50 feet on each side of the stream. Vegetative buffer zones would also help protect against the harmful effects of nutrient and pesticide runoff into Griffy Creek. Such buffer strips, while helpful in protecting water quality during normal rainfall events, would not help during severe rainfalls. During high intensity rainfalls, Griffy Creek overflows its banks. During these events, which commonly occur in the small, steep valley, pesticides and nutrients associated with an expanded golf course would probably find their way directly into Griffy Lake.

Timber Management and Harvest

Previous Timber Harvests

There have been previous timber harvests in the Griffy watershed and, given the amount of timbered land in private ownership, there will continue to be timber harvest in the Griffy watershed. Most of the timbered land is located outside of City of Bloomington jurisdictional boundaries. Indiana University owns substantial timbered acreage adjacent to the Griffy Nature Preserve and on the south shore of the east end of Griffy Lake. This timbered property is not likely to be harvested in the near future. In fact, due to the steepness of the slopes and the highly erodible nature of the land, a land swap or donation of the land as part of the Griffy Nature Preserve is recommended, if feasible.

The Monroe County Planning Department is charged with issuing permits for timber harvest activities in most of the Griffy watershed to ensure proper erosion control BMPs are utilized. There was a major timber harvest in the North Fork Griffy Creek subwatershed in 1995 that proceeded unpermitted. When a county inspector arrived at the scene, considerable unmitigated damage had been done the land and several tons of fugitive soil erosion was contributed to the North Fork of Griffy Creek. The creek had flushed itself when field inspected in 1998, meaning the sediment and associated nutrients was transported downstream to Griffy Lake.

Future Timber Management on Public and Private Lands

The areal extent of timbered land in the watershed is the primary factor in Griffy Lake being preserved in a relatively good condition for over 50 years. Timbered land is the most protective cover factor against erosion and other types of NPS pollution. If more of the watershed cover is converted from forested to another land use or cover type, the lake can be expected to respond correspondingly in increased sedimentation and eutrophication.

Timber harvest activities should be monitored carefully to ensure that no sediment is released from a harvest site to any perennial or even ephemeral waterway in the watershed.

Agricultural Practices

Currently one farmer, Mr. Everett Kerr, farms nearly all of the agricultural land in the Griffy Watershed. Mr. Kerr is practicing extremely good conservation practices on the fields he has in production and his farm is having little adverse water quality effects. On nearly all of his production acreage he is employing contour planting and tilling, use of no-till or conservation tillage on nearly all acreage, extensive use of winter cover crops and legumes in the cropping rotation, heavy crop residue left on the fields after harvest, and grassed waterways and ditch checks are established in all swales and ditches.

Transitional (Construction and Development) Land Disturbing Activities

According to the USLE and empirical evidence, the single greatest factor that affects the generation and transport of NPS pollution is the cover factor. Changing the cover factor from forested or mature healthy field cover to bare land via excavation increases soil erosion and transport by a factor of roughly three orders of magnitude.

Vegetative cover in the form of temporary seeding, or limiting soil disturbance to only those areas being prepared for immediate construction are critical strategies for erosion control on transitional land under development.

Erosion Control Versus Sediment Control

Erosion control is the prevention of soil from being dislodged from its place in the landscape. The only practical way to prevent erosion is by covering and protecting the soil from the impact of rainfall and the erosive forces of the stress of concentrated flow of water. The covering of soil with vegetation is the only practical way to cover and insulate the soil from being dislodged and set in motion from its point of origin. Once soil particles are dislodged, the particles are referred to as sediment.

Sediment control is the practice of attempting to control the runoff of eroded soil particles. Generally the objective on transitional land is to prevent the sediment from being transported off site. A much more cost effective approach is to prevent the sediment from being generated in the first place with erosion control measures, i.e. protective vegetative cover.

Silt fence (particularly economy silt fence with stakes 10' on center) offer little substitute as a substitute management practice to erosion control with vegetative cover. In fact, silt fence is designed to be the last line of in sediment control rather than the primary method of sediment control.

Fugitive Sediment

Given the fine clay soil types prevalent in Monroe County, fugitive sediment is difficult to identify after it has left a transitional site. While several tons of sediment may actually leave a site in a storm event, typically there are only trace residues of sediment visible at the points where the sediment left the site. These are the heavier particles left behind after the velocity of the storm water runoff diminished enough to deposit sediment rather than transporting the sediment off site. A small fraction of the sediment that left the site in a storm event is evident in the proximity of the eroded site. The remainder gets deposited in a sediment sink downstream of the eroded site. Lake Griffy is the sediment sink for the subject watershed.

In each of the three forks of Griffy Creek, the stream velocity and gradient are such that sediment that enters the streams is flushed into Griffy Lake for deposition rather than accumulating in the stream beds.

The Importance of Topsoil

The terrestrial components of the biosphere essentially exist in the upper soil horizon of the earth's crust known as topsoil. In topsoil is all the nutrients, and microbes essential to the maintenance of healthy vegetative cover. Most developments sell off the topsoil from a transitional site after initial site excavation.

This makes reestablishment of vegetative cover problematic. The infertile, acidic, tight clay, subsoils of Monroe County are not conducive to growing vegetation without the addition of considerable amounts of soil amendments (lime, gypsum, myco bacteria, fertilizers) to make a functional root zone. Even with the application of mineral fertilizers, the mineral soils are lacking the microbial community that works to digest mineral soil particles into nutrients that can be taken up by the plant roots. A follow-up fertilization is typically required on all new stands of grasses established on mineral soils. Typically the grass does not receive this follow-up fertilization and the stand remains sparse for years to come.

Again, mineral fertilizers are typically used (e.g., 12-12-12) due to the perceived low cost of the fertilizer. This can be a false economy however, as the required application rates of the mineral fertilizers is so high (1200 pounds per acre). At \$6 per 50 pound bag, the cost is \$120 per acre. A slow release professional grade starter fertilizer on the other hand costs \$19 per 50 pound bag. However only 4.3 bags are required per acre at a cost of \$81.70 per acre. In addition, the mineral fertilizers get washed away in rain events, sometimes even before the grass seed germinates. In contrast, the slow release, professional grade fertilizers are more stable and slowly release nutrients to the root zone over an extended period of time.

Many examples exist throughout Monroe County where vegetation was re-established in topsoil as well as where re-vegetation was attempted on mineral subsoils. There is no comparison in the density of areal coverage and the amount of plant biomass between the two types of sites. Topsoil is a better growth medium than any subsoil with soil amendments.

IX Model Response to Land Use Changes

Eutromod is a lake eutrophication model developed by Duke University and distributed by the North American Lake Management Society. The model uses information on watershed size, land use, lake size, climate, and geography to predict the trophic status of a lake. For Griffy Lake, the following specific input was used:

Lake size	0.5 square kilometers
Mean depth	3 meters
Watershed size	1700 hectares
Annual rainfall	100 cm

Three different land use scenarios were used in the model:

100% forested. In this scenario, the entire Griffy Lake watershed is returned to its original pristine, forested condition. There are no agricultural or urban land uses. This scenario represents the land use conditions under which the lake would have the highest possible water quality.

100% urban. In this scenario, the entire Griffy Lake watershed is entirely urbanized. There are no agricultural or forest land uses. This scenario represents what Griffy Lake water qualitywould be like if residential and commercial development consumes the entire watershed.

50% urban/50% agricultural. This scenario represents a mixture of land uses. Residential and commercial development takes up half the watershed, while agriculture takes up the other half. Agricultural land uses in this scenario do not include conservation tillage practices.

With each change in land use, the model predicted the following changes in lake trophic status, clarity, and water column nutrient concentrations:

Table 12.

EUTROMOD PREDICTIONS OF LAKE TROPHIC STATUS

Scenario	P-Load kg/yr	TSI	Secchi meters	Chl.a ug/l	Total P mg/l	Total N mg/l
100% Forest	55	44	0.9	2.5	0.007	0.08
100% Urban	1000	66	0.6	19	0.08	0.8
Ag/Urban	2270	72	0.4	37	0.16	1.4

Next, the predicted responses were compared to recent in-lake data obtained by IDEM and SPEA to determine which land use most accurately predicted the present situation:

Table 13.

RECENT IN-LAKE DATA ON GRIFFY LAKE TROPHIC STATUS

	TSI	Secchi meters	Total P mg/l	Total N mg/l
1970s	47-75	2.3	0.3	no data
1990s	40-50	4.5	0.03	1.9

Eutromod predicts that the greatest nutrient loading will occur with a watershed which is half urban and half agricultural. This scenario is the one which most closely resembles the situation in the 1970s based on data collected by IDEM. More recent data collected by SPEA in the 1990s indicates that the quality of the lake has improved and now most closely resembles the 100% forested scenario.

There are large discrepancies between the model predictions and actual measurements of Secchi Depth and the corresponding TSI index value. Current water clarity, as measured by the Secchi Disk depth, is much greater than predicted by the model. This often occurs in lakes which have extensive macrophyte concentrations. The macrophytes outcompete the algae for nutrients, making the lake clearer than it normally would be.

Eutromod predicts that returning as much of the watershed as possible to a primarily forested condition could have a large positive impact on lake quality. Nutrient loading would be reduced about 10-fold below levels present when agricultural/urban land uses predominate. According to the model, Griffy Lake's trophic status will change from its present "mesotrophic" condition (TSI of about 45) to a "hypereutrophic" condition (TSI of about 65 to 70) if the worst case land use predominates in the watershed.

Bibliography

Brentlinger, J.L., J.B. Hays, R.L. Lauster, and C.S. Pierce. 1979. *Agricultural Erosion Assessment for the Nondesignated and Designated 208 Planning Areas of Indiana*. State Soil and Water Conservation Committee, Indiana Dept. of Natural Resources.

Hickey, R., 1998, Methods for Slope Angle & Slope Length Calculations within a GIS. *AURISA News* **76**:16-19.

Mitchell, J.K., and G.D. Bubenzer. 1980. Soil loss estimation. Pages 17-62 in *Soil Erosion*, M.J. Kirby and R.P.C. Morgan (eds). John Wiley and Sons, Ltd., Norwich, Great Britain.

Soil Conservation Service. 1981. *Soil Survey of Monroe County, Indiana*. USDA., Washington, D.C.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. *Predicting Soil Erosion by Water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)*. U.S.D.A., Agriculture Handbook No. 703, Washington, D.C.

Wischmeier, W.H., and D.D. Smith. 1978. *Predicting Rainfall Erosion Losses*. U.S.D.A. Agriculture Handbook No. 537, Washington, D.C.

Evaluation, Compilation, and Synthesis of Previous Studies

Natalie Saikaly, an intern with the City of Bloomington. prepared a synopsis of each of the former reports prepared for Lake Griffy and its watershed. Following is the summary of previous reports she prepared:

Griffy Lake has been studied for years by the students and faculty at Indiana University, including the departments of biology and SPEA, as well as other groups and members of the Bloomington community. The educational uses of this lake have resulted in various types of data, ranging from lists of notable plant species found in the surrounding preserve to limnological profiles. Unfortunately, a document compiling and summarizing all of the relevant characteristics and trends of Griffy Lake's water quality does not yet exist.

Thus far, previous studies on the water quality of Griffy Lake indicate a diverse habitat and healthy environment for flora and fauna. The Griffy Woods Nature Preserve compiled a list in 1996 of 170 vascular plant species found, including a segment of the property known as the "mature woods." towering Oaks, Tulip trees, Hickories, and Beeches represent the ecological niche known as the climax forest. Michael Tansey, I.U. biology professor, observed many different species of fungi in 1996, such as *Amanita citrina, Boletus badius, Morchella semilibera*, and *Stereum striatum.*

Previous research, indicates the past water quality at Griffy Lake has been good. The 1992 Fish Management Report stated that "as in previous studies, the water clarity was relatively high." This report concluded the Griffy Lake fishery was currently very good, as the dissolved oxygen in the lake was sufficient enough for game fish to survive at a depth of 20 ft. Results from a Griffy Reservoir study in 1995 called the summertime mean transparency in the lake *good* according to the U.S. EPA classification system. Similarly, a study on Griffy Reservoir in 1996 described a summertime mean transparency increase in the lake since 1992.

Another source of information on Griffy Lake's water quality is the 1984 Long-Range Use and Management Plan, produced by SPEA faculty and staff. The authors of this study attested to the lake's "good water quality", based ib low turbidity levels, neutral pH with good buffering capacity, and reasonable nutrient levels (nitrogen and phosphorous). Dissolved oxygen profiles showed ample oxygen for aquatic organisms.

However, the 1984 study also mentioned a potentially worsening problem to the water quality at Griffy Lake, that of trace metals. At the time, trace metal levels in Griffy Creek and the lake had not been examined thoroughly. The authors believed a potential source of the trace metals to Griffy Creek was the Indiana University coal and ash pile, located at the upper end of the watershed. Increased levels of iron, manganese, aluminum, lead, and zinc were observed in runoff waters at the coal/ash pile site, located on the south fork of Griffy Creek. The ultimate fate of these trace metals and their impact on Griffy Lake's water quality was unclear. Dusty Becker, a researcher and former I.U. professor, also attested to the potentially negative effects of the coal plant on Griffy Lake.

While the exact impacts of trace metals on Griffy Lake has yet to be determined, another concern for the lake's water quality lies in the recent development around the south fork. Concerns that Griffy Lake is threatened by sedimentation from development within its watershed may be an underlying reason why Indiana University is working with this particular lake. An article in the *Hoosier Times* on December 27, 1997 quoted Steve Cotter, natural resources coordinator for the city parks department, saying, "There's quite a bit of bare soil along the south fork of Griffy Creek. We believe a lot of the soil has already been deposited in the lake and with it any chemicals it has in it." As a result of this sedimentation, problems in Griffy Lake range from nutrient loading to boating difficulties.

Keith Clay, an I.U. biology professor, echoed Cotter's concerns. Although Clay said he was unable to document anything, through ten years of ecological research in the surrounding forested areas of Griffy Lake, he has made two main observations. First, the east end is rapidly silting up where the creek enters, and that each year the marsh expands and the remaining lake gets shallower. Second, there has been an increased frequency of explosions of aquatic macrophytes (mainly *Myriophyllum*) that makes boating difficult. Clay asserts that this "certainly reflects nutrient inputs into the water." The 1984 Long-Range Use and Management Plan gave similar thoughts on increases on macrophytes , namely *Potamogeton.*

Contacts:

Bill Jones, I.U. Professor, SPEA 855-4556

Michael Tansey, I.U. Professor, Biology 855-2914

Keith Clay, I.U. Professor, Biology 855-8158

Nathan Murphy, I.U. Ph.D. Student, Biology nmurphy@indiana.edu

Jeff White, I.U. Professor, SPEA 855-0731

Steve Cotter, Bloomington Parks & Recreation

Dusty Becker, Researcher/Local Contact 323-9214

The Internet

Various fellow graduate students at SPEA

Materials - Bibliography:

- Data from Indiana Clean Lakes Program (7/27/97 and 7/24/90)
- Newspaper article from Hoosier Times (site: http://www.hoosiertimes.com)
- Fungi observations from Michael Tansy (list of 1996 collection)
- 1992 Fish Management Report on Lake Griffy (IDNR - 1993)
- Griffy Woods Nature Preserve List of Vascular Plants Species (1996)
- Griffy Woods Nature Preserve List of Notable Plant Species (1996)
- I.U. Limnology Class E455's Report on Fall Overturn and Late Summer Stratification of Griffy Lake (November 25, 1997)
- Griffy Reservoir - 1996 Results
- Baseline Environmental Survey of Griffy Reservoir (John Thiele Jr, 1982)
- Griffy Lake Long-Range Use and Management Plan (Environmental Systems Application Center, SPEA, August 1984)

Appendix B

Biomonitoring Results Raw Data

Rapid Bioassessment Results - Upper Griffy Creek

July 1998

	Site #							
	JD1	SF1	SF2	MF1	MF2	NF1	NF2	NF2d
Chironomidae (Midges)								
Polypedilum convictum	14	3	4	7	2	1	4	4
P. illinoense		1		2	2		2	1
P. fallax				9	28	9	16	19
Cryptochironomus fulvus			1					
Tanytarsus glabrescens								1
Eukiefferiella spp.	1			1	6		1	1
Thienemannymia gr.	1		4	1	9		2	5
Simuliidae (Blackflies)	18	1	1	12	3	5	7	3
Tipulidae (Craneflies)								
Tipula sp.	1	1				2	1	
Plecoptera (Stoneflies)								
Perlesta placida		1			2	2	5	4
Allocapnia vivipara				1			1	
Ephemeroptera (Mayflies)								
Heptagenia spp.							2	1
Stenonema vicarium					1			
S. femoratum			7	1				
S. integrum	2							
Stenacron interpunct.	2						1	2
Baetis flavistriga	18		4	13	8	2	6	5
B. brunneicolor		1	2	3	5	2		1
B. amplus				2			3	
Isonychia sayi	8							
Trichoptera (Caddisflies)								
Cheumatopsyche spp.	5	10	11	20	14	12	10	7
Ceratopsyche sparna				2	1	1		1
Chimarra obscura		1						
Polycentropus spp.					1			

July 1998 (cont.)

Rapid Bioassessment Results

Site #

	JD1	SF1	SF2	MF1	MF2	NF1	NF2	NF2d
Coleoptera (Beetles)								
Psephenus herricki		4	30	3	1			1
Ectopria spp.			1					
Optioservus sp.		1	1	5		1		2
Stenelmis bicarinata	14	3			2			
Berosus spp.	2							
Megaloptera (Dobsonflies)								
Chauliodes spp.	3	2	2	3		1	1	
Sialis spp.	1							
Odonata (Dragonflies)								
Cordulegaster spp.								1
Decapoda (Crayfish)								
Orconectes immunis	2	4	1					1
Amphipoda (Scuds)								
Hyalella azteca		1				3	2	2
Isopoda (Aquatic Pillbugs)								
Lirceus fontinalis		42	30	15	14	57	36	36
Gastropoda (Snails)								
Elimia livescens	3	1						
Gyraulus spp.		1						
Pelecypoda (Clams)								
Sphaerium spp.	5		1					
Hirudinea (Leeches)						1		2
Oligochaeta (Worms)								
Lumbricidae						1		
Tubificidae		3			1			
Total	100	81	100	100	100	100	100	100

Data Analysis for 7/98 Samples

METRICS

Site #

JD1	SF1	SF2	MF1	MF2	NF1	NF2	NF2d

# of Genera	17	17	14	13	14	13	14	18
Biotic Index	5.6	6.4	5.5	5.9	6.3	7.0	6.6	6.6
Scrapers/Filterers	0.6	0.8	2.0	0.1	0.2	0.0	0.2	0.4
EPT/Chironomids	2.2	3.3	2.7	2.1	0.7	1.9	1.1	0.7
% Dominant Taxon	18	42	30	20	28	57	36	36
EPT Index	5	4	3	5	6	4	6	6
Community Loss Index	0.0	0.4	0.6	0.6	0.7	0.8	0.6	0.5
% Shredders (CPOM)	23	37	19	8	1	28	19	3

SCORING

	Site #							
	JD1	SF1	SF2	MF1	MF2	NF1	NF2	NF2
# of Genera	6	6	4	4	4	4	4	6

Biotic Index	6	4	6	6	4	4	4	4
Scrapers/Filterers	6	6	6	0	2	0	2	6
EPT/Chironomids	6	6	6	6	2	6	4	2
% Dominant Taxon	6	0	4	6	4	0	2	2
EPT Index	6	4	2	6	6	4	6	6
Community Loss Index	6	6	4	4	4	4	4	4
% Shredders (CPOM)	6	6	6	2	0	6	6	0
TOTAL	48	38	38	34	26	28	32	30
% of Reference	100	79	79	71	54	58	67	63
Impairment Category	N	S	S	S	S	S	S	S

N = NONE   S = SLIGHT   M = MODERATE   Sv = SEVERE

Duplicate Results

Metric Values

NF Griffy Creek Site 2, Monroe Co.

Sample 1 collected by Steve W. Chafin

Sample 2 collected by Andy Ruff

Samples collected 7/98

	Sample 1	Sample 2
Total Genera	14	18
EPT Genera	6	6
Scrapers/Filterers	0.2	0.4
% Dominant Taxon	36	36
EPT/Chironomids	1.1	0.7
Community Loss Index	0.6	0.5
Hilsenhoff Biotic Index	6.6	6.6
% Shredders (CPOM)	19	3

Site Scores in Relation to the Reference (JD1)

	Sample 1	Sample 2
Total Genera	4	6
EPT Genera	6	6
Scrapers/Filterers	2	6
% Dominant Taxon	2	2
EPT/Chironomids	4	2
Community Loss Index	4	4
Hilsenhoff Biotic Index	4	4
% Shredders	6	0
	32	30

Mean Site Score = 31

Each duplicate is within 10% of the mean

Both scores indicate "slight impact"

Rapid Bioassessment Results - Upper Griffy Creek

December 1998

Site #

JD1 SF1 SF2 MF1 MF2 NF1 NF2

Chironomidae (Midges)							
Polypedilum convictum	1						
Dicrotendipes neomodestus			6				
Glyptotendipes lobiferus					1		
Tanytarsus glabrescens			1				
Cricotopus bicinctus	1						1
Heterotrissocladius spp.	2						
Parakiefferiella spp.	3					1	
Parametriocnuemus spp.	5	5				1	
Orthocladius obumbratus	1						
Ablabesmyia spp.					1		
Thienemannymia gr.	3						
Simuliidae (Blackflies)	1						
Tipulidae (Craneflies)							
Tipula sp.	1	3				2	
Antocha sp.							1
Plecoptera (Stoneflies)							
Haploperla sp.		2					
Allocapnia vivipara			2	3	6	6	1
Taeniopteryx parvula				7	10	14	5
T. nivalis			1	5			
Isoperla confusa				3	7	20	8
Nemoura spp.				2			
Ephemeroptera (Mayflies)							
Ameletus sp.			1				
Stenonema vicarium	6						
S. femoratum	7		25		2		
Stenacron interpunct.	41						1
Isonychia sayi	7						

December 1998 (cont.)

Rapid Bioassessment Results

	Site #						
	JD1	SF1	SF2	MF1	MF2	NF1	NF2
Trichoptera (Caddisflies)							

Cheumatopsyche spp.		6				1	2
Hydropsyche betteni		12					
Chimarra obscura		16					1
Neureclipsis sp.							1
Micrasema sp.			1				
Coleoptera (Beetles)							
Psephenus herricki	1	3					
Megaloptera (Dobsonflies)							
Nigronia sp.		1					
Amphipoda (Scuds)							
Hyalella azteca		10	7	23	12	31	28
Gammarus sp.						1	
Isopoda (Aquatic Pillbugs)							
Lirceus fontinalis		42	43	55	49	12	29
Caecidotea spp.	1		8		12	4	22
Gastropoda (Snails)							
Elimia livescens	17						
Physa spp.			4				
Ferrissia sp.	1						
Pelecypoda (Clams)							
Sphaerium spp.	1						
Turbellaria (Flatworms)						6	
Oligochaeta (Worms)							
Lumbricidae			1	2		1	
Total	100	100	100	100	100	100	100

Data Analysis for 12/98 Samples

METRICS

	Site #							
	JD	JD1	SF1	SF2	MF1	MF2	NF1	NF2
# of Genera	18	18	11	13	7	10	14	12

Biotic Index	5.4	5.5	6.4	7.6	7.1	7.1	6.1	7.4
Scrapers/Filterers	1.0	8.2	0.1	29	0.0	2.0	0.0	0.7
EPT/Chironomids	9.3	3.8	7.2	4.3	20	13	20	19
% Dominant Taxon	20	41	42	43	55	49	31	29
EPT Index	7	4	4	5	5	4	4	7
Community Loss Index	0.0	0.6	1.3	1.2	2.6	1.6	1.1	1.2
% Shredders (CPOM)	47	1	3	4	17	16	22	6

SCORING

	Site #							
	JD	JD1	SF1	SF2	MF1	MF2	NF1	NF2
# of Genera	6	6	6	4	4	4	4	4
Biotic Index	6	6	4	2	4	4	6	4
Scrapers/Filterers	6	6	0	6	0	6	0	6
EPT/Chironomids	6	2	6	2	6	6	6	6

% Dominant Taxon	6	0	0	0	0	0	2	4
EPT Index	6	2	2	4	4	2	2	6
Community Loss Index	6	4	4	4	2	4	4	4
% Shredders (CPOM)	6	0	0	0	4	4	4	0
TOTAL	48	26	22	22	24	30	28	34
% of Reference	100	54	46	46	50	63	58	71
Impairment Category	N	S	M	M	M	S	S	S

N = NONE   S = SLIGHT   M = MODERATE   Sv = SEVERE

Habitat Scores

	NF1	NF2	MF1	MF2	SF1	SF2
Substrate	11	11	9	9	7	7
Cover	11	11	9	9	9	9
Channel	14	14	14	14	14	14
Riparian	16	16	15	15	14	14
Pool/Riffle	12	12	10	10	9	9
Gradient	2	2	2	2	2	2
Drainage Area	4	5	4	5	4	5
TOTAL	70	71	63	64	59	60