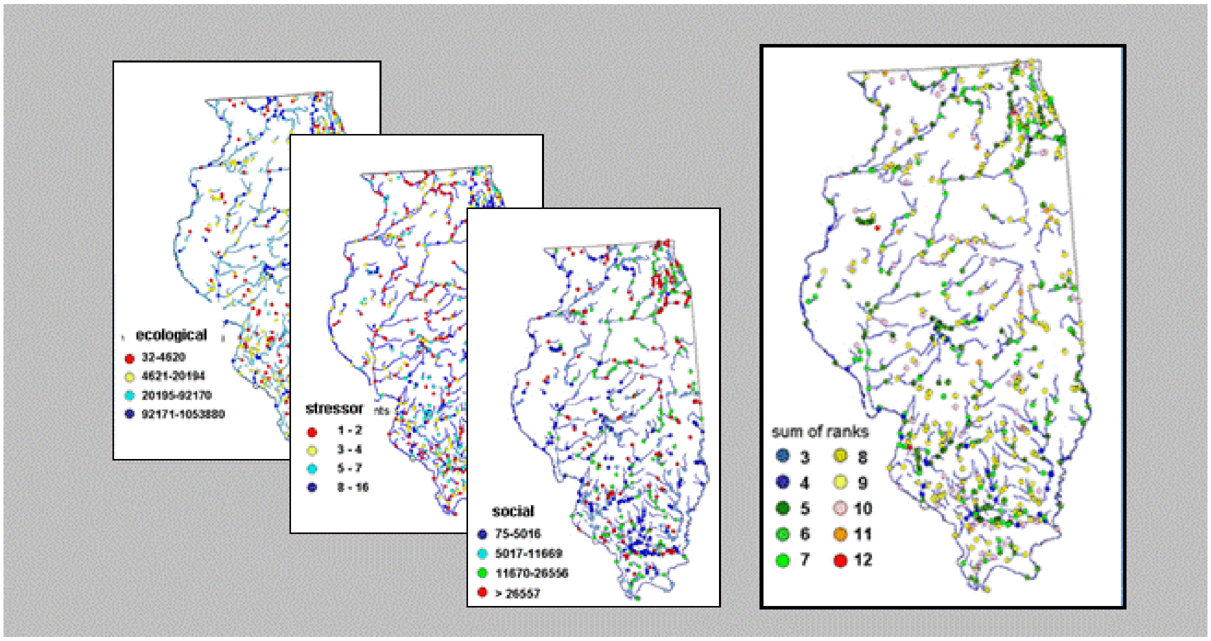

Project Summary

Comparing the Restorability of Illinois Impaired Waters: A Recovery Potential Pilot Study

Background. States across the US face enormous challenges in restoring their impaired waters. Under Section 305(b) of the Clean Water Act (CWA), states assess the condition of their waters biennially and place pollutant-impaired waters that do not meet Water Quality Standards on a Section 303(d) list. To guide restoration actions, states then develop Total Maximum Daily Loads (TMDLs) that quantify necessary pollutant loading reductions for each 303(d)-listed water body. States are required to develop schedules that prioritize the order of impaired waters for TMDL development (USEPA 2005). Implementation of completed TMDLs also involves prioritizing among numerous waters.

Prioritizing occurs because state capacity and resources typically cannot accommodate TMDLs, restoration plans, and implementation at a rate that supports action on all impaired waters every year. However, there is little in the CWA regarding prioritization. Priority-setting to optimize recovery (i.e., re-attainment of WQS) is a near-universal water program need, yet the *relative potential to recover* is not commonly assessed or factored into prioritization of the order of TMDL development from the 303(d) list at statewide scale. A 2005 analysis of impaired waters priority-setting in seven of ten EPA regions revealed prioritization was typically being done on a case-by-case, often ‘worst-first’ basis without considering all impaired waters systematically. Noting that better tools and data for comparing relative restorability might aid state priority-setting in their 303(d) schedules and TMDL implementation, EPA carried out an exploratory study of recovery potential assessment concepts and methods using the State of Illinois 2002 303(d) list. The study explored recovery-relevant measures, suitable data sources, and comparison techniques. Altogether, 104 metrics were identified, tested and demonstrated with multi-metric indices in measuring recovery-relevant properties of 303(d)-listed waters in Illinois.

We defined recovery potential in this study as:

> *the likelihood of an impaired water to re-attain Water Quality Standards or other valued attributes, given its ecological capacity to regain lost functionality, its exposure to stressors, and the social context affecting efforts to improve its condition*.

Illinois Impaired Waters. The 2002 303(d) list for Illinois included 723 waterbodies, of which 580 were streams or rivers, 119 were lakes, and 24 were labeled as channels, ditches or canals. Up to 16 impairment causes were identified per listed water, with a mean of 4.3 causes. The most common cause was nutrients, followed by oxygen depletion, ammonia, metals other than Mercury, and habitat alteration (channelization), among others (see Table 1).

Table 1. Relative abundance of impairment causes in the 2002 State of Illinois 303(d) list. Percent indicates the proportion of total impairments reported in the Illinois 2002 cycle.

NUTRIENTS	24.7%
ORGANIC ENRICHMENT/OXYGEN DEPLETION	8.5%
AMMONIA	8.2%
METALS (OTHER THAN MERCURY)	8.2%
HABITAT ALTERATION	6.9%
SEDIMENT	6.8%
TURBIDITY	6.0%
PCBS	5.5%
PATHOGENS	4.6%
ALGAL GROWTH	4.0%

The Illinois 2002 303(d) information also included a nominal prioritization of sites as low (7), medium (657), or high (59), indicating relative schedule timing for TMDL development. There was no documentation in the 303(d) data set on how the nominal priority ranking was determined.

Approach. The primary purpose of this pilot study was to explore the possibility of measuring indicators of impaired waters recovery potential and using these measurements as a basis for comparing their relative restorability. In order to develop indicators and methods in one state, yet useful across a broad variety of other states, several constraints were evident. A prioritization method for working with large numbers at statewide scales would need to be based on highly efficient, rapid screening tools and available data sources. For recovery potential to guide the process, factors linked to recovery in the literature would need to be measurable using these data and tools. Further, the measures relevant to a given state's waters and impairments would likely vary from state to state and thus flexibility and professional judgment would be needed to select from an array of recovery metrics.

To meet these conditions, we intentionally limited the study to commonly available data sources of two types: GIS datasets and water quality monitoring datasets. Widely available geospatial data like land cover, surface hydrography, and census information provide for measuring numerous attributes statewide. Monitoring data, including 303(d) list attributes compiled in state and EPA data systems, complement the landscape data with a variety of water body-specific attributes reflecting condition. Only one new dataset needed to be constructed – watershed boundaries for the listed waters – in order to measure recovery-relevant indicators on a watershed as well as water body or corridor basis.

Candidate indicators of recovery potential had been accumulated during a broad-based literature search for recovery-relevant attributes. Indicators that presented evidence of consistent association with an effect on recovery likelihood in literature and practice were examined and, if measurable using available data, were included in test analyses. Groups of successfully-measured indicators were then used in demonstrating alternatives for estimating relative recovery potential on a multi-metric basis.

Indicator development and measurement. Candidate indicators sorted out naturally into three classes representing significantly different influences on restorability. These recovery-relevant groupings are also reflected in the working definition above: 1) ecological (biotic and abiotic) capacity to regain lost functionality; 2) past, current and future exposure to stressors; and 3) social context and organizational or program process factors affecting restoration efforts. The ecological and stressor factors together define current and projected condition of the ecosystem, which undeniably has a strong influence on its ability to recover. Social context factors are not attributes of ecological condition, but also provide an essential dimension for assessing recovery potential that can and should be evaluated.

Candidate indicators were measured using GIS in the majority of cases. Monitoring data from EPA data tables contributed several additional measures. In total, 104 indicators (see Table A1, Appendix) were initially defined and test-measured successfully (i.e., consistently for all waters being evaluated and compared) on a statewide basis for the Illinois 303(d)-listed waters. Subsequently, 64 indicators (12 ecological, 20 stressor, and 32 social context: bolded in Table A1) were used in differing numbers and combinations to demonstrate example methods for analyzing multi-metric indices.

Demonstration of analytical approaches. As an exploratory study, a preferred method for analyzing the indicators had not been pre-selected. We carried out several analyses to demonstrate alternative techniques and evaluate the performance of each approach. These include single-indicator data display, cluster analysis, sum of ranks, and other methods.

The most simple, initial approach was to compare recovery potential based on single indicators believed to have a significant influence in the area under study. For example, impairment severity as a factor of numbers of impairment causes is a useful single measure of the likely complexity, difficulty and expense of restoration. Impervious cover percent in the watershed, or in a defined corridor, similarly presents a single factor that may be among the most important to consider in the urbanized sectors of the state. For agriculturally-dominated regions, the percent channelization was a potentially important factor although difficult to measure other than manually. Among specific impairment types, nutrients and ammonia (figure 1) were reputedly more difficult to restore. We worked with State agencies on developing an indicator of tile drained

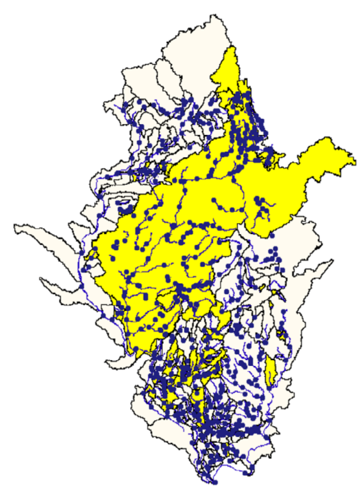

Figure 1. A single-indicator display of 236 ammonia-impaired waters and their watersheds (in yellow). Blue dots represent all IL 2002 impaired waters.

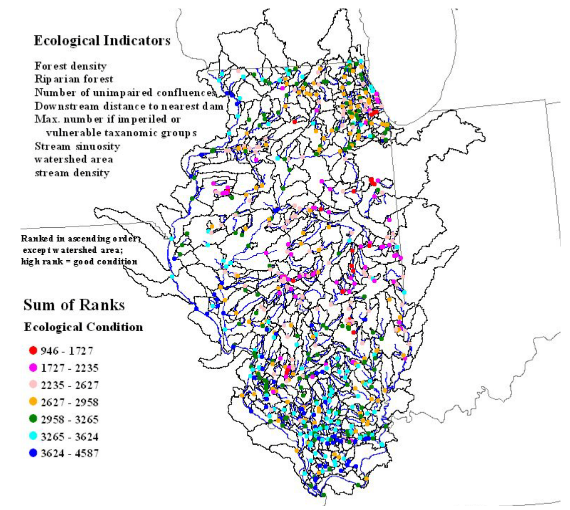

Figure 2. Ecological Recovery Potential sum of ranks index for the Illinois 2002 impaired waters list, based on 8 indicators (upper left).

croplands based on cropland percentage, slope, and selected soil types, because this factor was believed to reduce the success of buffers and other common restoration techniques in cropland settings. The single-indicator information was generally made available as statewide GIS plots, but could also be used as tabular information that enabled rank-ordering or establishing quantiles.

The second method involved combining selected indicators as a sum-of-ranks index within a single class (ecological, stressor, or social context) and plotting out the comparative values for the impaired waters (figure 2). In this case indicators were equally weighted, but weighting was recognized as a viable option for specific purposes. This kind of analysis enabled focusing on the ecological capacity factors alone, without considering the major roles also played by stressor and social factors. Similar stressor and social indices were created and mapped for the impaired Illinois waters.

A cluster analysis method demonstrated more complex alternatives for integrating multiple indicators from all three classes (figure 3). This method merged the systematic measurement of the indicators with the subjective, judgement-based recognition of clusters that may display recovery potential similarities. The cluster analysis results revealed a geography that could be exploited to prioritize action on more restorable waters. Cluster 1 sites appear to have the greatest recovery potential. Sites in cluster 1 contain greater amounts of forest, tend to be smaller watersheds with higher streams and confluence densities and fewer cited causes for impairment. Cluster 4 sites are similar to those in cluster 1, and we would rank these sites second in prioritization for TMDLs. Agriculture is more dominant in Cluster 4 sites, but the sites are also characterized by a tendency toward few cited causes of impairments, higher stream and confluence densities, and a large number of watershed groups.

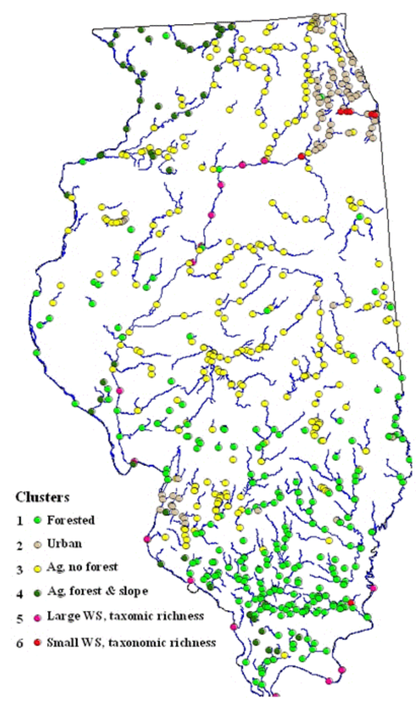

Figure 3. Cluster analysis of Illinois impaired waters based on recovery potential indicator scores. Clusters 1 and 4 appear to have more elevated recovery potential than the others.

A fourth method of combining multiple metrics to assess recovery potential used a logic modeling, multi-step approach. The goal in this demonstration was to identify waters with a difficult impairment type that yet had good recovery potential characteristics for other reasons. The first step selected all waters that were streams or rivers with a nutrient impairment (see figure 4A). This step narrowed the focus from 580 linear listed waters to 340 that had nutrient problems. This subset was further analyzed for proportion of riparian forest (90 meter buffer) and the top 10 percent was selected (figure 4b), reducing the subset to 34 waters. Finally, a mix of additional factors (watershed size, road density and stream density) was unioned with the preceding factors, identifying 19 waters (figure 4c). The combination of factors used in this analysis was not comprehensive but rather simplistic as the primary purpose was demonstrating the method.

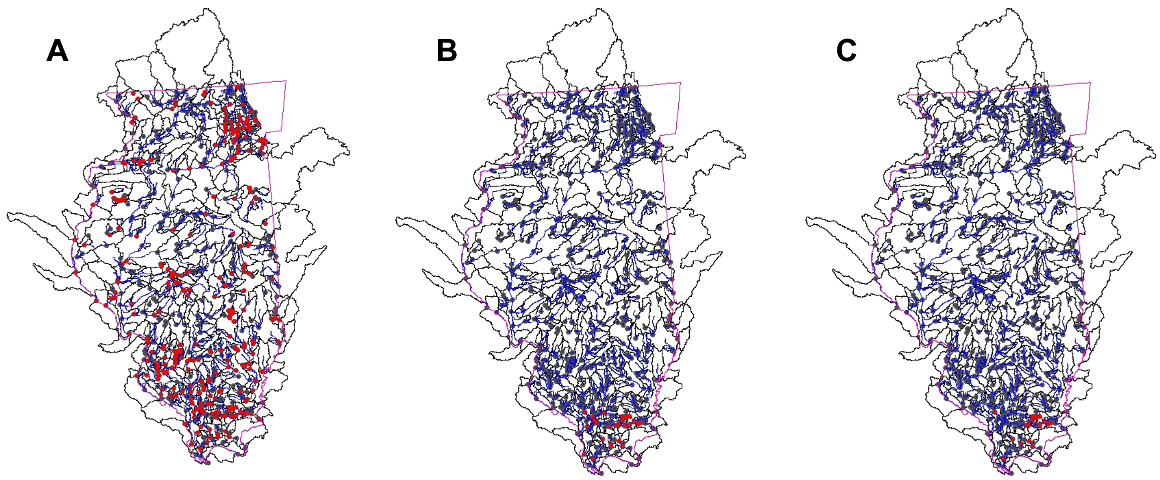

Figure 4. A logic modeling approach to comparing recovery potential among nutrient-impaired streams and rivers (A, red dots) that first considered waters with more riparian forest (B, red) and then favored lower road density, higher stream density per watershed, and smaller watershed size as positive factors (C). The method targeted 19 higher-potential waters from a total of 580 waters.

Discussion. This pilot project explored the concept of comparing impaired waters on the basis of recovery potential and demonstrated indicator development and measurement as well as several analytical approaches. We verified that recovery-relevant factors evident in the literature or in restoration practice could be translated into measurable indicators, although we did not evaluate the strength of specific indicators' association with recovery likelihood. The project demonstrated that recovery-relevant factors are numerous, and many are measurable in some way using commonly available datasets. It is noteworthy that these activities were completed using a statewide 303(d) list dataset of hundreds of impaired waters that were measured and compared on a consistent basis.

The large number of candidate indicators, the identification of the ecological, stressor and social context indicator themes, and the several alternative methods for assessing single and multi-metric indices of recovery potential all forecast the opportunity for recovery potential assessment to be a flexible approach. Given the range of different restoration priorities, decisions needing informational support, and variable environmental circumstances from state to state, such flexibility in indicator selection and analytical method is essential. On the other hand, too many indicators and options for interpretation could cause confusion. Indices with too many mixed indicators from all three classes can lose valuable signals in the noise. The opportunity to view ecological, stressor and social considerations separately is valuable, but challenging in the sense of data interpretation and communication. Overall, this exploratory study has demonstrated that comparative assessment of recovery potential appears feasible and its challenges worthy of further development efforts.

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Appendix

Table A1. The 104 recovery potential indicators that were defined and test-measured in the Illinois Impaired Waters Recovery Potential Study. **Bolded** indicators were used in demonstrating recovery-based priority-setting methods. Indicator types (left column) include B: baseline data; E: ecological; S: stressor; C: social context.

Type	RP Indicator name	Description
B	**303(d) list ID**	Numerical ID for tracking impaired water
B	**waterbody name**	Name of impaired water
E	**watershed mean slope**	Area weighted average slope for watershed using NED data
E	watershed stddev slope	Standard deviation of slope for watershed using NED data
E	watershed slope range	Difference between minimum and maximum slope values in watershed using NED data
E	watershed land area	Area of watershed for 303d waterbody excluding water
E	**watershed % forest**	Percentage of forest for 303d watershed from NLCD 1992
E	watershed # forest patches	Number of forest patches in each 303d watershed
E	watershed # forest patches per sq km	Number of forest patches in each 303d watershed per km2
E	largest forest patch as area	Size of the largest forest patch map units (usually m2)
E	largest forest patch as %	The size of the largest forest patch expressed as a percentage of watershed area
E	**watershed % legacy forest**	Land use legacy; proportion of forest per watershed from ca. 1970 LUDA data
E	**bank stability/woody vegetation**	Percentage of watershed streamlength with riparian forest, where riparian radial distance = 0 m
E	**corridor % forest 30**	Percentage of watershed streamlength with riparian forest, where riparian radial distance = 30 m
E	**corridor % forest 90**	Percentage of watershed streamlength with riparian forest, where riparian radial distance = 90 m
E	**recolonization access**	Number of (unimpaired) confluences for each impaired waterbody
E	**recolonization access**	Same as Recoloni but ignoring any confluences with dams
E	**sinuosity1**	Impaired stream length divided by straight-line (eculidean) distance between upstream and downstrean ends
E	**sinuosity2**	Same as Sinuosity1 but adjusted for breaks (e.g., lakes) by averaging all sinuousity1 values for each "unbroken" segment

E	**rare taxa presence1**	Max of the rank-ordered number of broad taxonomic groups represented by G1,G2, G3 species (heritage data), EPA R5 CrEAM
E	**rare taxa presence2**	Mean of the rank-ordered number of broad taxonomic groups represented by G1,G2, G3 species (heritage data), EPA R5 CrEAM
E	rare taxa presence 3	Std of the rank-ordered number of broad taxonomic groups represented by G1,G2, G3 species (heritage data), EPA R5 CrEAM
E	**watershed size**	Area (ha) for watershed defined by downstream most point of impaired waterbody
E	**watershed wetlands condition**	Land use legacy; proportion of wetland per watershed from ca. 1970 LUDA data
S	**watershed % U index**	Percentage of anthropogenic land cover classes per watershed from NLCD 1992 (ag, urban, barren)
S	**watershed % urban**	Percentage of urban for 303d watershed from NLCD 1992
S	**watershed % agriculture**	Percentage of agriculture for 303d watershed from NLCD 1992
S	**watershed % steep slope agriculture**	Percentage of watershed in agriculture on slopes > 9%
S	**shoreline % linear U index**	Percentage of watershed streamlength with anthropogenic cover, where riparian radial distance = 0 m
S	**corridor % U index30**	Percentage of watershed streamlength with anthropogenic cover, where riparian radial distance = 30 m
S	**corridor % U index90**	Percentage of watershed streamlength with anthropogenic cover, where riparian radial distance = 90 m
S	**shoreline % linear urban**	Percentage of watershed streamlength with urban, where riparian radial distance = 0 m (possible bank armoring)
S	**corridor % urban30**	Percentage of watershed streamlength with urban, where riparian radial distance = 30 m
S	**corridor % urban90**	Percentage of watershed streamlength with urban, where riparian radial distance = 90 m
S	**shoreline % linear agriculture**	Percentage of watershed streamlength with agriculture, where riparian radial distance = 0 m
S	**corridor % agriculture30**	Percentage of watershed streamlength with agriculture, where riparian radial distance = 30 m
S	**corridor % agriculture90**	Percentage of watershed streamlength with agriculture, where riparian radial distance = 90 m
S	**watershed % impervious cover**	Area weighted average impervious surface for watershed using NLCD 2001 data
S	watershed % impervious cover stddev	Standard deviation of impervious surface for watershed using NLCD 2001 data
S	**aquatic barriers1**	Distance to nearest dam from downstream most point of impaired reach
S	**aquatic barriers2**	Percentage of Ds_Dist for 1st 10 miles that is not interupted by a dam
S	**watershed % legacy urban**	Land use legacy; proportion of urban land per watershed from ca. 1970 LUDA data
S	**watershed % legacy agriculture**	Land use legacy; proportion of agriculture per watershed from ca. 1970 LUDA data

S	**severity of 303(d) listed causes**	Number of impairments cited
S	**impaired waterbody magnitude**	Sum of total length of impairment for 303d data
C	**303(d) schedule priority**	Prioritization by state for TMDL development (low, medium, high)
C	**watershed % protected land1**	Hectares of land in protected status 1 from GAP stewardship data
C	**watershed % protected land2**	Hectares of land in protected status 2 from GAP stewardship data
C	**watershed % protected land3**	Hectares of land in protected status 3 from GAP stewardship data
C	**watershed % protected land4**	Hectares of protected land from all 3 GAP stewardship data (classes 1 and 2 restrict land use changes)
C	**watershed % protected land5**	Hectares of protected land in GAP classes 1 and 2
C	**funding eligibility**	Sum of 4 presence-absence measurements (EQIP, CREP, CSP, WRP); values ranges from 0 to 4
C	**jurisdictional complexity**	Sum of number of cities, counties, town and other populated places in a watershed
C	**watershed organizational leadership**	Sum of number of watershed groups in a 303d watershed from EPA's ADOPT database (double counting used)
C	**local socio-economic distress1**	Sonoran; area-weighted 1970-2002 total long-term employment change, from county level data, scaled btw 0 and 100
C	**local socio-economic distress2**	Sonoran; 2003 unemployment rate, scaled between 0 and 100
C	**local socio-economic distress3**	Sonoran; 2002 income per person, area-weighted by county for transfer to 303d watersheds, scaled btw 0 and 100
C	**local socio-economic distress4**	Sonoran; # of families under poverty threshold from 2000 Census, by county - area-weighted to wshd, scaled btw 0 and 100
C	**local socio-economic distress5**	Sonoran; Percentage w/ college degree? by county - area-weighted to wshd, scaled btw 0 and 100
C	**corridor residential**	Number of housing units w/in 1/2 km of impaired waterbody
C	**corridor owner-occupied residential**	Number of owner-occupied housing units within 1/2 km of impaired waterbody
C	**watershed real estate value**	Average housing value from 2000 census in 1999 dollars; area weighted from county-level data
C	**corridor real estate value**	Average housing value units w/in 1/2 km of impaired waterbody
C	**recreational resource**	Sum of 4 presence-absence measurements (St_consv, St_frst, St_fwa, St_park); values ranges from 0 to 4
C	new residential 1980-85	New residential construction permits (1980 - 1985), total units
C	new residential 1986-90	New residential construction permits (1986 - 1990), total units
C	new residential 1991-95	New residential construction permits (1991 - 1995), total units
C	new residential 1996-2000	New residential construction permits (1996 - 2000), total units
C	new residential 1980-90	New residential construction permits (1980 - 1990), total units
C	new residential 1980-95	New residential construction permits (1980 - 1995), total units
C	**new residential 1980-2000**	New residential construction permits (1980 - 2000), total units
C	**total local indebtedness**	Total indebtedness of local governments (may be several in a watershed) (end of FY2002)
C	**local govt general revenue**	Total revenue of local governments (all sources, local taxes charges, fees and transfers from other unit of government)

C	**own local revenue**	Amount of local government revenue less federal and state sources, and transfers from other local governments
C	**debt/revenue ratio**	Total debt/Annual Own Source Revenues
C	**tax revenue**	Local government revenue from taxes
C	**sewer expenditures**	Local government expenditures on sewer treatment facilities
C	**park expenditures**	Local government expenditures on parks and recreation
C	**utility revenue**	Total revenue from public utilities
C	**water utility expenditures**	Local government expenditures on water ulitilities
C	**watershed population**	Estimate of watershed population
C	watershed population foreign born	Estimate of watershed population originating in another county, 1995
C	watershed population born out of state	Estimate of watershed population originating in another state, 1995
C	pers annual income total	Total annual personal income
C	**watershed population below fed poverty level**	Population living below the federal poverty level
C	**watershed residential**	Number of residential units
C	# housing units 1990-2000	Housing units built btw 1990 and 2000
C	# pre-1990 housing units	Housing units built prior to 1990
C	# pre-1970 housing units	Housing units built prior to 1970
C	# pre-1950 housing units	Housing units built prior to 1950
C	aggreg owner value	Aggregate Value of Owner Occupied Residential Units
C	aggregate income	agginc/pop
C	debt per capita	Debt/pop
C	general revenue per capita	Gen_rev/pop
C	out of state revenue per capita	Ownsrce_re/pop
C	tax revenue per capita	Tax_rev/pop
C	sewer expenditures per capita	Sewr_exp/pop
C	utilities expenditures per capita	Expenditures on utilities per capita
C	water utilities expenditures per capita	Wautut_ex/pop
C	% foreign born	othco/pop
C	% out of state born	ohhsta/pop
C	% pre WWII res units	preWWII/resunits
C	% 1990s res units	blt1990s/resunits
C	% pre 1970s res units	Pre70/resunits
C	% of population below poverty level	poppov/pop
C	**existence of TMDL or other plan**	whether or not approved/established TMDL is done for the waterbody