THE ASSEMBLAGE OF WATER QUALITY PARAMETERS AND URBAN FEATURE PARAMETERS, UTLIZING A GEOGRAPHIC INFORMATION SYSTEM MODEL FOR THE USE OF WATERSHED MANAGEMENT IN THE DARDENNE CREEK WATERSHED, ST. CHARLES COUNTY, MISSOURI.

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The Assemblage of Water Quality Parameters and Urban Feature Parameters, Utilizing A Geographic Information System Model For The Use Of Watershed Management In The Dardenne Creek Watershed, St. Charles County, Missouri

(Use of GIS to Integrate Multiple Sources of Disparate Environmental Data from a Small Watershed Undergoing Urban Development)

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DEDICATION

I dedicate this dissertation to my loving parents Mel and Alice Serrano, for their unwavering and devoted support and guidance.

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LIST OF ABBREVIATIONS

BMP	Best Management Practices
CARES	Center for Applied Research and Environmental Systems, University of Missouri, Columbia
CWC	Clean Water Commission
CDM	Camp Dresser & McGee, Inc.
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
GIS	Geospatial Information System
GRG	Great Rivers Greenway
HBA	Home Builders Association (of Greater St. Louis), Inc.
MoDNR	Missouri Department of Natural Resources
MSCI	Macroinvertebrate Stream Condition Index
MCWC	Missouri Clean Water Commission
NPS	Nonpoint source pollution
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Treatment Works
TMDL	Total Maximum Daily Load
USGS	U.S. Geological Survey
USGS LTRM	USGS Long Term Research Monitoring Program
WPP	Water Protection Program
WQS	Water Quality Standards

ABSTRACT

THE ASSEMBLAGE OF WATER QUALITY PARAMETERS AND URBAN FEATURE PARAMETERS, UTILIZING A GEOGRAPHIC INFORMATION SYSTEM MODEL FOR THE USE OF WATERSHED MANAGEMENT IN THE DARDENNE CREEK WATERSHED, ST. CHARLES COUNTY, MISSOURI.

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George Mason University, 2008

Dissertation Director: Dr. Lee M. Talbot

Water quality directly affects virtually all water uses. Fish survival, diversity and growth; recreational activities such as swimming and boating, municipal, industrial, and private water supplies, agricultural uses such as irrigation and livestock watering, waste disposal, and general aesthetics – all are affected by the physical, chemical, biological, and microbiological conditions that exist in watercourses and in subsurface aquifers. Water quality impairment is often a trigger for conflict in a watershed, simply because degraded water quality means that desired uses are not possible or not safe (Heathcote, 1998).

The human economy depends upon the services provided by ecosystems. The ecosystem services supplied annually are worth many trillions of dollars. Economic development that destroys habitats and impairs services can create costs to humanity over the long term that may greatly exceed the short-term economic benefits of the

development. These costs are generally hidden from traditional economic accounting, but are nonetheless real and are usually borne by society at large. Tragically, a short-term focus in land-use decisions often sets in motion potentially great costs to be borne by future generations. This suggests a need for policies that achieve a balance between sustaining ecosystem services and pursuing the worthy short-term goals of economic development. These ecological costs must be understood and harnessed as a variable in determining the long term effects to our communities at the local level.

The Dardenne Creek watershed is located in St. Charles County, Missouri, the fastest growing county in the St. Louis metropolitan area for three decades and one of the largest counties in metro St. Louis (St. Charles County Development, 2007). The central part of the watershed contains a large portion of the most rapidly developing belt of St. Charles County (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003). Dardenne Creek, selected for this study, and its tributaries drain almost 30% of the area of St. Charles County (U.S. Army Corps of Engineers, 2007). Many of the largest and quickest growing cities in the county contribute runoff to Dardenne Creek. Therefore, with more people moving into the area every year, there is a potential increase in the number of homes located within and near the floodplain of Dardenne Creek and its tributaries. This extreme increase of residential and commercial building is what some residents and agencies say is the cause of heavy sediment loads causing harm to the creek.

As such, the watershed has been studied by multiple stakeholders and governmental agencies which include detailed work gathering biological and chemical water quality parameters. The Army Corps of Engineers completed a three year watershed study in May 2007 -- that was ten years in the making -- compiling a hydrological assessment which included: land-use, land-cover, soil profiles, and updating the flood plain profiles.

Although this recent hydrological watershed study has been derived, and over 20 years of water quality data gathered, a Watershed Management Plan has not yet been adopted. This dissertation intends to show how the assembly and manipulation of watershed data into a GIS format could facilitate stakeholder understanding and development of a rational watershed management plan. To illustrate how this can be done, and to make a significant initial contribution to this objective, this dissertation includes the assembly of chemistry, biological, data water quality data sets from 1983 and 1993-2007, using a Geographic Information System (ArcGIS©), overlaying the St. Charles County, Missouri urban features data set. This work also summarizes the relevant EPA Clean Water Regulations and the St. Charles County Watershed Management studies that have been conducted to date. The scope of this study includes the complexities and solutions for the integration of science and policy. The primary focus of this paper is to exemplify the need for an interconnected, multi-variable, and multi-disciplinary system, which enables and facilitates enhanced, holistic watershed management decisions.

CHAPTER ONE

1. INTRODUCTION

This dissertation reviews the complexities associated with the integration of science and policy. The primary focus of this study is to suggest the need for the use of a geographic information system (GIS) to display the interconnection of multi-disciplinary and multi-variable data, which would allow for enhanced, holistic watershed management decisions.

A watershed is a geographical area defined by topography such that all tributaries and streams drain in an area defined by the U.S. Geological Survey. Each stream has its own watershed that demarcates all of the land that collects precipitation that drains into the stream. Collectively, these small watersheds provide critical natural services that sustain or enrich human lives: they supply our drinking water, critical habitat for plants and animals, areas of natural beauty, and water bodies for recreation and relaxation. Small streams are an important element of our local geography and confer a strong sense of place to a community (Center for Watershed Protection, 2008). The concept and terminology of a watershed management plan to maintain and preserve ecological health has been used for many years. However, surprisingly, there are few plans written or executed that balance two usually opposing factors: urban development and ecological health preservation. This dissertation will use a small watershed in St. Charles County, Missouri to review data collections performed to date, provide a summary of watershed planning activities that have been developed, and identify the dynamics of stakeholders associated with the watershed. A GIS platform will be proposed as the most useful means of integrating information about the watershed and clarifying the impacts of urban development for stakeholder groups.

1.1. Importance of a holistic watershed approach

The capacity of the watershed unit to provide many environmental values, goods and services is of prime interest to a variety of stakeholders in the area. However, it is often that the priorities of the stakeholders residing within the watershed are not known or communicated effectively to one another. Without a full understanding of the watershed as a system with the collective and integrated prioritization schemata, there will continue to be conflicts in land use master planning. By developing collaborations and partnerships among agencies, individuals, and organizations based on common understanding of the issues and problems, the full value of a watershed can then be viewed as a whole. This holistic watershed approach will allow the stakeholders to analyze and interpret that information that is pertinent to their interests and be able to conduct cumulative analyses.

1.2. Statement of the problem

The Dardenne Creek watershed, located within St. Charles County, Missouri, (Fig. 1) has undergone tremendous changes over the past 50 years and has suffered rapid ecological degradation that may be attributed to excessive development. In 1990 approximately 145,500 people lived within the watershed in approximately 52,000 housing units. The watershed was ranked first in growth rate for state of Missouri during the 1990s (St. Charles County, Missouri Profile, 2008). In 2000, approximately 283,883 people lived within the watershed in approximately 101,663 housing units. It is anticipated with a 2006 Census population estimate of 338,719 it will contain 131,191 housing units (U.S. Census Bureau St. Charles County, MO, 2008). The rate of development in the area has been increasing steadily since 1990, St. Charles County is ranked in the top 2% growth counties in the Nation (City of St. Charles, Missouri, Economic Development, 2007).

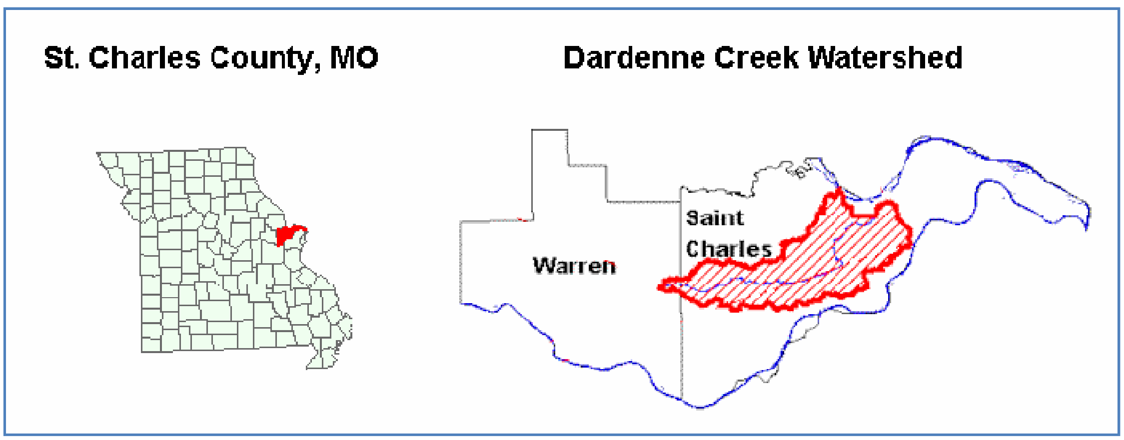


Figure 1 Dardenne Creek Site Location, St. Charles, Missouri
(U.S. Army Corps of Engineers, 2007).

Dardenne Creek, the stream selected for this study, runs throughout this watershed. Dardenne Creek and its tributaries drain almost 30% of the area of St. Charles County. Many of the largest and quickest growing cities in the county contribute runoff to Dardenne Creek (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003). Therefore, with more people moving into the area every year, there is an increase in the number of homes located within and near the floodplain of Dardenne Creek and its tributaries.

Ecological changes that have been noted in and adjacent to Dardenne Creek include: the stream has experienced heavy sediment loads; wetland degradation and loss; destruction and destabilization of riparian corridors; alterations in urban and agricultural runoff; and chemical contamination (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003).

Further, amplified incidents and magnitude of flooding may also be attributed to the increased rate of development in the stream floodplain. Residential and commercial building within the floodplain has been allowed and made possible by continuing augmentation of terrain levels. Water displacement during periods of high precipitation has, consequently, resulted in a higher frequency of flash-flooding events. In 1993 a major flood event caused extensive property damage and closed many roads in the flood zone.

In early 2008 there was more evidence of problems stemming from human land use within Dardenne Creek's flood plain. Officials from the Missouri Department of Transportation reported residents of this region have unfortunately become accustomed to the Dardenne Creek flooding the roadway, whenever there's significant rain. Developers in the area, who some blame for adding to the flooding issue by clearing and changing land, are donating land for an improvement project to help the flooding issue (NBC News St. Louis Affiliate, 2008).

Over the years, there have been numerous detailed and exhaustive data gathering efforts by several stakeholders, which include: biological, chemical, and hydrological, land-use, land-cover and soil and flood data. Some agencies have used geospatial systems and tools for displaying some of the data. Further, there is regulatory state-level water quality reporting that is ongoing, and two St. Charles County watershed management studies have been completed. This research is designed to explore the use of a GIS platform to enable stakeholders with divergent interests and scientific expertise to view the environmental data that are available and to use the GIS platform to create policy solutions for the watershed's environmental problems. This study is intended to demonstrate the interconnectedness of the multi-variable and multi- disciplinary factors necessary for sound and holistic watershed management principles and plans. Watershed management participation spans from the citizens and grass root support to the local- and state-level decision makers which will allow for an enhanced, dynamic, and operable watershed management plan.

1.3. Scope

The cumulative effect of landscape alterations in the Dardenne Creek watershed has resulted in increases in subsequent multiple effects on water quality for Dardenne Creek parameters, attributed primarily to high-level urban development for this region.

There are multiple agencies that collect vast amounts of disparate data sets, yet the assembly and analysis of these data for this watershed have not been accomplished. The limitations are often the result of lack of resources and expertise necessary for assembly and analysis, and the inadequacy of presenting spatial information by traditions means.

In order to be a viable solution for watershed planning, a watershed plan must allow for the dynamics of an ever-changing landscape, so as to ensure that urban development will complement preventative preservation and conservation principles and goals for watershed health.

A geographic information system (GIS) for watershed planning would assemble and display the relationships of many disparate data sets. The GIS would serve as a platform to assist with determining the watershed land use practices, priorities, and goals. This approach toward an interoperable data management system would enhance the understanding of the complexities of the interdisciplinary research. The display of all watershed attributes and geospatially-collected data display would serve as a powerful planning mechanism to identify interrelated watershed priorities and goals that would result in a comprehensive understanding of the whole system.

The first objective of this dissertation is to show the interconnectedness of the multi-variable and multi- disciplinary information that is required for sound and holistic watershed management principles and plans. The second goal is to display environmental data sets as a baseline for a Dardenne watershed management plan. The third goal, based on research and interviews of pertinent watershed players, is to provide an integrated solution that combines science, relevant programs, and policy, in a dynamic Graphical User Interface to complement the Dardenne watershed management plan.

1.3.1. Research Objective

The complexities and challenges of implementing a watershed management plan require the participation of all relevant stakeholders to provide the multi-disciplinary expertise necessary to design an interoperable management system.

Question 1: Will the geographic display of watershed parameters and attributes in a GIS the assist governmental, non-governmental organizations, and other watershed stakeholders to better understand the status and trends of the interrelations among them in the comparison of multiple-variable and different data sets?

Question 2: Will the geographic display of watershed parameters and attributes in a GIS facilitate adoption of watershed management plans by local governments?

1.4. Organization of Dissertation

This paper consists of ten chapters and covers three fundamental aspects: water quality science; relevant regulations and policy; and watershed management planning using a Geographic Information System (GIS) (Fig. 2).

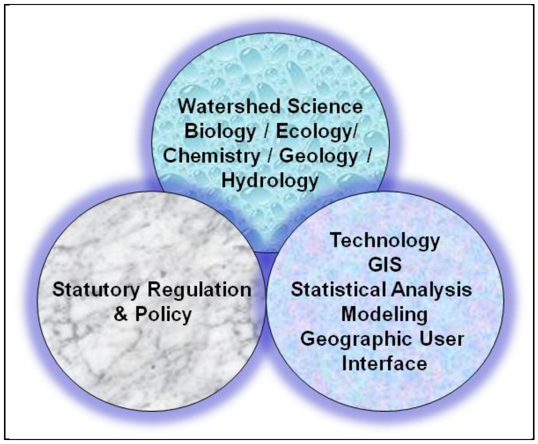


Figure 2 Watershed Science; Regulation and Policy; and GIS.

This dissertation is organized to describe the critical elements that are associated with implementing a GIS for holistic watershed management planning. To enable a better understanding of this study, the literature review is presented in the Chapter Two. Chapter Three, Four and Five provide the foundation of the study that includes the site description, the relevant law associated with the watershed management, and the associated stakeholders who live and work within the watershed. Chapter Six is an overview of the Dardenne Creek watershed historical studies conducted to date. Chapter Seven discusses the original GIS research analysis conducted for this study and provides an overview of the GIS display of the integration of various disparate data sets for the Dardenne Creek watershed. Chapter Eight is an overview of holistic watershed and

Chapter Nine discusses the benefits of GIS application for holistic watershed management planning. Chapter Ten is the conclusion and identifies areas of future work.

CHAPTER TWO

2. LITERATURE REVIEW

This paper has three fundamental aspects: water quality science, relevant regulations and policy, and community watershed management planning using a Geographic Information System (GIS). The quality of a stream's health can be determined by measuring and evaluating various parameters of a stream, including its physical, chemical and biological aspects. The data collected for these parameters can be used as a resource to help identify possible sources of water quality problems. This chapter categorizes published literature with respect to water quality monitoring approaches; studies of hydrological, chemical and biological stream measurement parameters; the modeling of hydrological, chemical and biological data sets; and watershed management and planning. The chemical and biological measurements are what the EPA and MoDNR, use to assess water quality. The Army Corps of Engineers study hydrological parameters for flood plain measurements and to help assess stormwater runoff that can relate to land use and impervious surfaces.

2.1. Water Quality Monitoring Approaches

The measurement of water quality is determined by the physical, chemical, and biological characteristics of water in relationship to a set of standards. Often these parameters are measured individually and do not assess the cumulative effects of the three parameters combined. Point source pollution is relatively easy to measure and is regulated by law. However, non-point source pollution is much more difficult to monitor and analyze. Non-point source monitoring methods rely on trend analysis and modeling. Further, the complexity of non-point source pollution is reflected in the many types of measurements of water quality indicators. The most basic monitoring method is done by sampling the water at a particular site location at a particular time and then comparing the readings against a standard. More complex measurements that must be made in a lab setting require a water sample to be collected, preserved, and analyzed at another location.

There are many types of monitoring. Two basic approaches often used in water quality monitoring -- the cause-and-effect monitoring and compliance monitoring (Nader et al, 1993), are discussed in this section.

The cause-and-effect monitoring method tries to prove or disprove a cause-and-effect relationship between a specific land activity and water quality degradation. There are three basic cause-and-effect designs for documenting water quality problems or changes in water quality due to changes in land use or management (Arnold et al, 1993). These designs attempt to separate natural geologic, weather, or upstream impacts from land management impacts.

1) The before-and-after design incorporates water quality monitoring before and after a change in management to determine if the changes alters water quality. Without associated long-term monitoring of water quality, weather, and stream flow, this method provides little insight.

2) The above-and-below design involves sampling water quality over time immediately above and below a potential source of nonpoint source pollution, such as monitoring immediately above and below where a road crosses a stream. The primary advantage of this design over the before-and-after design is that it allows for separation of nonpoint source pollutants contributed upstream. This advantage can be lost if the monitoring sites do not isolate the source of interest from other inputs to the stream. Also, changes to the channel may cause changes to upstream reaches. For example, a poorly designed bridge could cause bank erosion upstream (Nader et al, 1993).
3) The paired watersheds design involves monitoring water quality on two or more watersheds over time. The watersheds are initially under the same management. After a sufficient pretreatment time period (several years as a minimum), one watershed is selected as a control and the others are treated. The control watershed measures the year-to-year and seasonal climatic variation. This design is the most useful of the three methods for establishing cause-and-effect relationships. It is also the most technical and expensive method. (Nader et al, 1993). The challenge in this method is the selection of the control watershed.

Compliance monitoring evaluates whether water quality parameters measurements are within set minimum or maximum chemical values. State and/or Regional boards have set water quality standards based on “beneficial use categories” for each stream, river, and lake. “Beneficial use” is a term used by the Environmental Protection Agency (EPA) (MoDNR Water Quality Standards_2008) to describe different functions of water (EPA, Watershed Academy Web, 2008).

Most waters support several beneficial uses. The rationale for public regulation of water quality is to protect the existing and designated beneficial uses of water (Monitoring Guidelines, EPA Publication, 1991). Although the specific designated uses vary from state to state, they generally include agricultural use, industrial use, domestic water supplies, recreational use, and the propagation of fish and wildlife. Each state determines which use(s) should be applied to the water bodies or stream segments within the state. The numeric parameters for water quality are assigned to each beneficial use and then become minimum criteria for water quality. The specific water quality parameters to monitor will depend on the beneficial uses of the water.

Because direct measurements of water quality can be expensive, ongoing monitoring programs are typically conducted by government agencies. However, there are local volunteer programs and resources available for some general hydrological, biological, and chemical assessments. Yet the integration of the agency collections and the volunteer collections is not often cultivated.

2.1.1. Measuring the Hydrological Parameters of a Stream

The watershed is the basic land unit of the hydrologic cycle and thus is the source of nonpoint pollution generation and transport. Water quality at any point along a stream reflects all pollutants from all sources in the watershed above that point including natural geological processes and anthropogenic induced changes such as urban and industrial land uses. Urban and industrial land use and activity includes waste water transportation (i.e. sewage, septic tanks, stormwater runoff; new housing construction and road building; and livestock and crop agriculture. These land use activities may result in the loss of vegetation; increased paved areas; increased runoff; increased erosion; increased sedimentation and debris; point and nonpoint pollution of nutrients, herbicides, pesticides, human wastes, heavy metal, toxic substances; eroded stream banks; and increased streamflow fluctuations (Murdoch, 2001).

Since a watershed is an interconnected land and water system, changes made to the land surface or to vegetation within a watershed have the ability to change aspects of its hydrologic cycle. For example, constructing impervious surfaces, such as parking lots and streets in a watershed can have profound effects on the watershed's water storage capacity. When water storage capacity is reduced, the ability to accommodate rain water often results in flooding. The drying effects are much greater at times when it does not rain due to reduced water storage capacity.

Nonpoint source pollution (NPS) is driven by meteorological and hydrological events in a watershed. Nonpoint source pollution is caused by human activity that alters natural processes. The occurrence and magnitude of nonpoint source pollution is directly linked to the hydrologic cycle.

Nonpoint source pollution generation and transport are difficult to predict because they are strongly influenced by precipitation and individual watershed characteristics. Interacting climatic, hydrologic, geologic, soil, vegetation, and land-use factors cause a high level of natural variability in NPS generation and transport through time (duration of precipitation) and space (size of watershed) (Nader et al, 1993).

A debate on how to compare models of watershed behavior continues to stimulate ongoing research. It is argued that procedures presently used to compare the performance of rainfall-runoff models are unsatisfactory for several reasons. Principally this is because they provide no measure of the uncertainty (as measured by an estimate of residual variation between experimental units) in differences between measures of model performance (Clarke, 2008).

This states that present rainfall-runoff models procedures simply do not provide a sound basis for recommending any particular model for use by the hydrological community at large.

While the principles of good experimental design (replication, randomization) are widely practiced in other fields of applied science, they are not yet widely practiced in hydrology and other geophysical sciences where models are essential tools. It is argued that these principles can and should be applied where experiments are designed to compare the performance of hydrological models (Clarke, 2008).

2.1.2. Measuring the Chemical Parameters of a Stream

Water chemistry plays an important role in the health, abundance and diversity of stream aquatic life within a watershed. Typical chemical parameters of the stream that are measured include temperature, turbidity, pH, dissolved oxygen, and nitrogen and phosphorus compounds. Chemical analysis provides information about selected parameters at one moment in time.

The methods to collect chemical parameters are defined by the Environmental Protection Agency (EPA). The collections are carried out by the Missouri Department of

Natural Resources (MoDNR), U.S. Geological Survey (USGS) and volunteer monitoring teams.

USGS Berkas (1985) conducted a water-quality assessment of Dardenne Creek and determined that it failed to meet water-quality standards downstream of two point-source waste-water treatment plants. Corrective action was advised to increase the design-capacity and to be implemented by St. Charles County.

While the Missouri Department of Resources (MoDNR) data sets for this watershed have been collected periodically since 1983, no trend analysis of these water quality chemistry parameters has been preformed for years due to lack of resources (Ford, 2008).

2.1.3. Measuring the Biological Parameters of a Stream

The type and diversity of aquatic benthic populations are good indicators of general stream health (Mann-Edge, 2000). Benthic macroinvertebrates are a major food source for fish species (Jones et al, 1997). Since they move only short distances this makes them susceptible to any pollutants in the water (MoDNR, 2005). They also may serve as integrators of water quality over time.

Indices developed for stream bioassessment are typically based on either fish or benthic macroinvertebrate assemblages. These indices consist of metrics which subsume attributes of various species into aggregate measures reflecting community-level ecological responses to disturbance. However, little is known about the relationship between fish and benthic macroinvertebrate metrics, or about how ecological health assessments are affected by assemblage-specific responses to disturbance (Flinders, 2008).

Stream habitat quality assessment complements biological assessment by providing a mechanism for ruling out habitat degradation as a potential stressor and provides reference targets for the physical aspects of stream restoration projects (Frappier & Eckert, 2007). The Frappier and Eckert (2007) study analyzed five approaches for measuring habitat conditions based on discriminate function, linear regressions, ordination, and nearest neighbor analyses.

2.2. Watershed Modeling: Integrating Physical, Chemical and Biological Parameters

The dynamics of a watershed requires research of the unstable water compositions to combine physical, chemical, and biological parameters. The integration of hydrological, water chemistry, and stream fauna information might be accomplished by modeling efforts. For example, the work of Nirel and Revaclier (2003) used the Global Biological Index of macroinvertbrates to determine that unstable water compositions are less favorable to biological diversity. The study aimed to establish a physical-chemical indicator of freshwater quality with respect to biological quality in order to facilitate the modeling of aquatic systems with a management perspective. The input data were results obtained in rivers from the Geneva, Switzerland region consisting of 19 rivers, 30 sampling sites, sampled monthly for one year for physical-chemical parameters and four times a year for mean biological index determination. This study used the distribution of the conductivity/calcium ratio as a function of the flow with respect to the Global

Biological Index. The conductivity calcium index and its relationship with the flow can easily be modeled, thus allowing not only the modeling of the water quality response to watershed management, but also the determination of the critical flow ranges where inputs would have the worst impact on the biology of the receiving system. The study is in the process of applying the index to numerical modeling of the impact of urbanization on water quality in rivers from the Geneva, Switzerland region (Nirel & Revaclier, 2003).

2.2.1. Model Uncertainty

In watershed-level assessment and management, hydrologic and water-quality models typically are used to help understand and investigate complex watershed processes, predict receiving water response to changes in inputs and environmental conditions, and evaluate management alternatives (Wu et al, 2006).

The investigation of the effects of uncertainty on hydrologic and water-quality model outputs has been the topic of many studies (Cox, 2007). For instance, the application of coupled watershed and water-quality models involves substantial uncertainty as model parameters are sometimes estimated from inadequate data.

Most of the uncertainty analyses were conducted on individual watershed or water-quality models, and thus dealt with uncertainty from only one model used. The effects and propagation of uncertainty in coupled watershed and water-quality models have not been adequately explored. The problems arising from coupled models are that uncertainty in both watershed and water-quality models are propagated to the final results (Wu et al, 2006).

2.3. Geographic Information System Modeling of Watershed Parameters

A geographic information system can depict multiple parameters that have geo-referenced coordinates such that relationships of occurrences of events can be displayed and probabilities of patterns and temporal trends can be visually represented for the many variables that comprise a watershed. These geospatially referenced parameters denoting measurements taken in the field can be overlaid with pixilated photos (or raster data sets). This section highlights several recent studies that use the GIS platform for display and analysis of water quality parameters.

Kovacs and Honti (2008) described a distributed parameter method developed to calculate diffuse phosphorus emissions at the scale of small watersheds based on relative pollution potential and transmission coefficients. Pollution potential raster (pixel cell) maps of the main diffuse pathways were determined by utilizing digital base maps covering the whole territory of Hungary. These indicated the capability of each cell to contribute to the diffuse emissions. To check the accuracy of the emissions distribution procedure, the results for several sub-catchments were compared in order to measure river loads, including point sources and river retention. The results suggest that the method is capable of determining the spatial distribution of the main diffuse sources and of assessing the risk of eutrophication of small water bodies in the absence of local loading data (Kovacs & Honti, 2008).

In another study using GIS modeling, Anlauf and Moffitt (2008) assessed stream habitats. Habitat assessments were conducted in an intermountain watershed at three spatial extents to explore ways to predict the presence of tubificid oligochaetes likely to support the parasite *Myxobolus cerebralis*, the cause of salmonid whirling disease. Stream reaches with six different reach slope characteristics were selected using GIS. The aquatic habitat in 60 reaches selected at random was measured and classified into distinct habitat units. Within the habitat units, areas of microhabitat with depositional fine sediments were chosen, measured, and core samples were removed to characterize the sediments and benthic oligochaetes. Two tubificids, *Tubifex* spp. and *Limnodrilus hoffmeisteri*, were abundant and co-occurred in silt-clay and fine sand sediments in these habitats. GIS Models were posed and tested to predict the presence and relative abundance of tubificids using habitat characteristics from the three spatial extents: reach, habitat unit, and microhabitat. At the reach extent, tubificids were associated with low-reach slope and with slow water habitats. Within habitat units, tubificids were associated with higher percentages of fine sediments and higher stream width-depth ratios. In microhabitat cores, the presence of silt-clay sediments was positively associated with higher average stream width-depth ratios. Since ecological relationships are often scale dependent and stream systems have a natural hierarchy, predictive habitat models such as these that use measures from several scales may help researchers and managers more efficiently identify and quantify aquatic communities at highest risk of infection by the *M. cerebralis* parasite (Anlauf & Moffitt, 2008).

2.4. Watershed Management and Planning

There have been many specific strategies for water quality control to reduce pollutants that typically target land use activities, such as agriculture. There are also specific suggested best practices for land use including installation of grass buffer zone overland flow systems; construction sites and roads and the placement of detention pond or holding pond; and the installation of grass buffer zone. (Hsieh & Yang, 2006).

In the Lake (2007) study of widespread degradation of riverine ecosystems in Australia, it was recorded that government agencies increased efforts of stream restoration. This study sought to identify principles from ecological theory that have been, or could be, used to guide stream restoration.

In attempts to re-establish populations, knowledge of the species' life histories, habitat template, and spatio-temporal scope is critical. In many cases dispersal will be a critical process in maintaining viable populations at the landscape scale, and special attention should be given to the unique geometry of stream systems. One way by which organisms survive natural disturbances is by the use of refugia, many forms of which may have been lost with degradation. Therefore, restoring refugia may be critical to the survival of target populations, particularly in facilitating resilience to ongoing anthropogenic disturbance regimes (Lake, 2007).

A study was conducted on the northern Taiwan Fei-Tsui reservoir, considered to be the most important drinking water source for this region. The study monitored and investigated the pollution sources and found the water quality was impacted significantly by nonpoint sources of pollution such as runoff from different land uses, especially tea plantations. The analyses of Total Maximum Daily Load (TMDL) criterion using a Basin model was performed for the entire watershed in order to develop a strategy for allocating point and nonpoint pollution loads. The model was calibrated and verified using the data collected during the 1998–2000 period, and used to evaluate the effect of nonpoint source pollution on water quality. The results were intended to assist in developing best management practices for the Fei-Tsui Reservoir watershed. However, the final selection of the scenario for implementation was found to be based primarily on cost, as well as political and social considerations (Hsieh & Yang, 2006).

The goals of most literature cited in this section were to expand the understanding of these complex ecosystems and to provide technical guidance and information for land managers, organizations, and private citizens interested in maintaining or restoring ecological communities.

CHAPTER 3

3. DARDENNE CREEK WATERSHED DESCRIPTION AND SITE LOCATION

The Dardenne Creek watershed is comparatively small and is categorized as a sub- watershed (geological) unit that contributes to larger hydrological and geological watershed systems. As a component of the larger river system, the Dardenne Creek drains into the Mississippi River near the Mississippi-Illinois River confluence and the Mississippi-Missouri River confluence. This chapter provides the description of the Dardenne Creek watershed location and its proximity to the confluences, and defines the geological hierarchal watershed structure as classified by the U.S. Geological Survey. This chapter also discusses land use and distinct land use zones within the watershed.

3.1. The Mississippi-Illinois and Mississippi-Missouri River Confluences

St. Charles County, Missouri is located at the confluence of the Missouri and Mississippi Rivers, (Fig. 3) and this is well situated with respect to surface water supplies. These rivers transport large amounts of water and still provide an abundance of good surface water for major users, such as recreational boating and commercial barge operations. Rapid urbanization in the county has introduced substantial amounts of sediment into some of the smaller streams (St. Charles County Government, 2008).

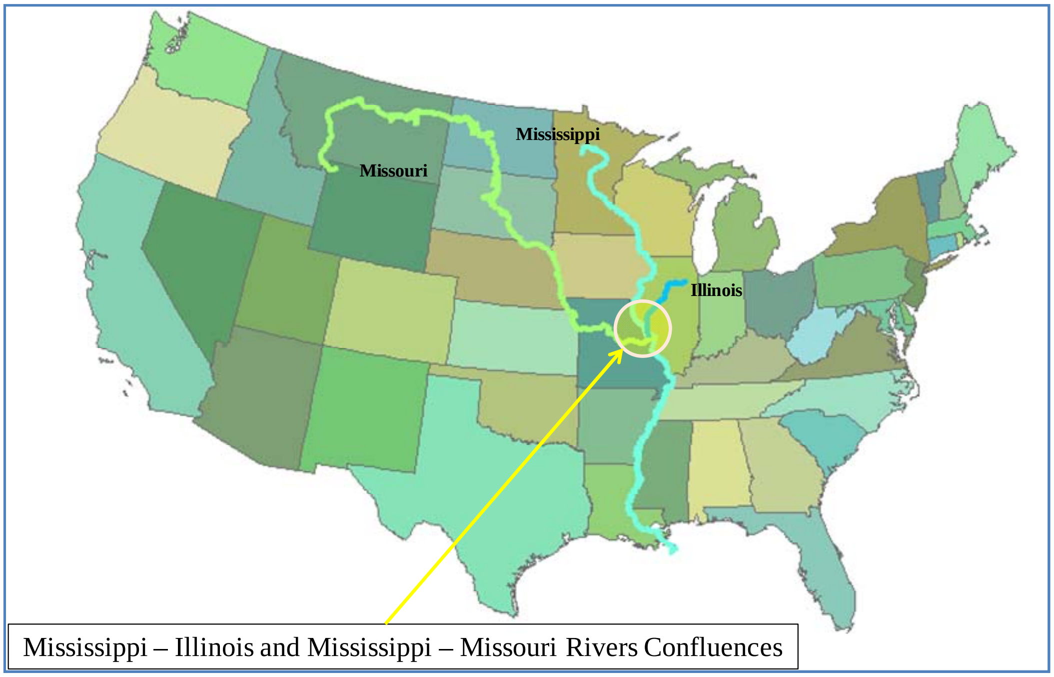
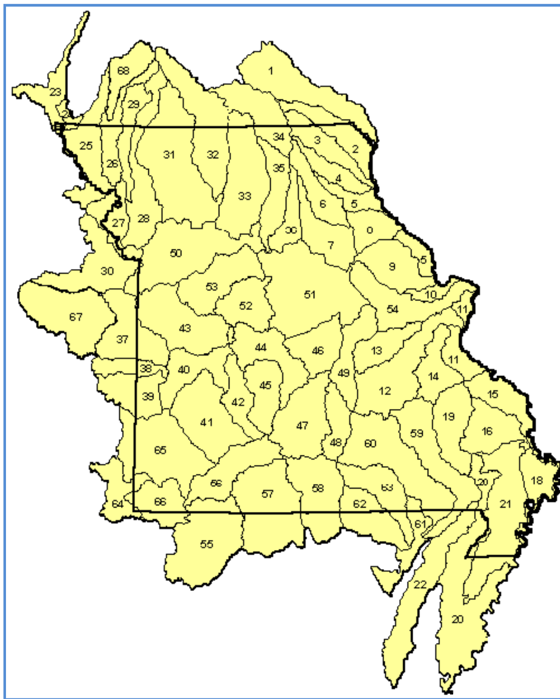


Figure 3 Map of Mississippi, Missouri and Illinois Rivers, USA (Serrano, ESRI Shapefiles, 2008).

3.2. Missouri and St. Louis Metropolitan Area Watersheds

In the state of Missouri, there are 68 watersheds in the 115 counties (Appendix A). The watersheds are listed by the USGS 8-digit hydrologic unit listing and mapped in Figure 4.



1. 07100009	2a. 07110001 2b. 07110001	3. 07110002	4. 07110003
5. 07110004	6. 07110005	7. 07110006	8. 07110007
9. 07110008	10.0 7110009	11. 07140101	12. 07140102
13.0 7140103	14. 07140104	15. 07140105	16. 07140107
17. 08010100	18. 08020201	19. 08020202	20. 08020203
21. 08020204	22. 08020302	23. 10240001	24. 10240004
25. 10240005	26. 10240010	27. 10240011	28. 10240012
29. 10240013	30. 10270104	31. 10280101	32. 10280102
33. 10280103	34. 10280201	35. 10280202	36. 10280203
37. 10290102	38. 10290103	39. 10290104	40. 10290105
41. 10290106	42. 10290107	43.10290108	44. 10290109
45. 10290110	46. 10290111	47. 10290201	48. 10290202
49. 10290203	50A. 10300101 50B. 10300101	51. 10300102	52. 10300103
53. 10300104	54. 10300200	55. 11010001	56. 11010002
57. 11010003	58. 11010006	59. 11010007	60. 11010008 60A. 11010008
61. 11010009	62. 11010010	63. 11010011	64. 11070206
65. 11070207	66. 11070208	67. 10290101	68. 10240009

Figure 4 Missouri Watersheds (Missouri Department of Conservation, n.d.).

In the St. Louis Metropolitan area, there are nine major watershed units which drain into the Mississippi River and the Missouri River (Figure 4). The Peruque Creek (MO) – Piasa Creek (IL) watershed unit is one of the nine major watersheds in the St. Louis region, which drain into the Mississippi River. The Dardenne Creek watershed study site resides within the Peruque Creek-Piasa Creek watershed unit (Fig. 5) (U.S. Environmental Protection Agency: Surf Your Watershed, 2005).

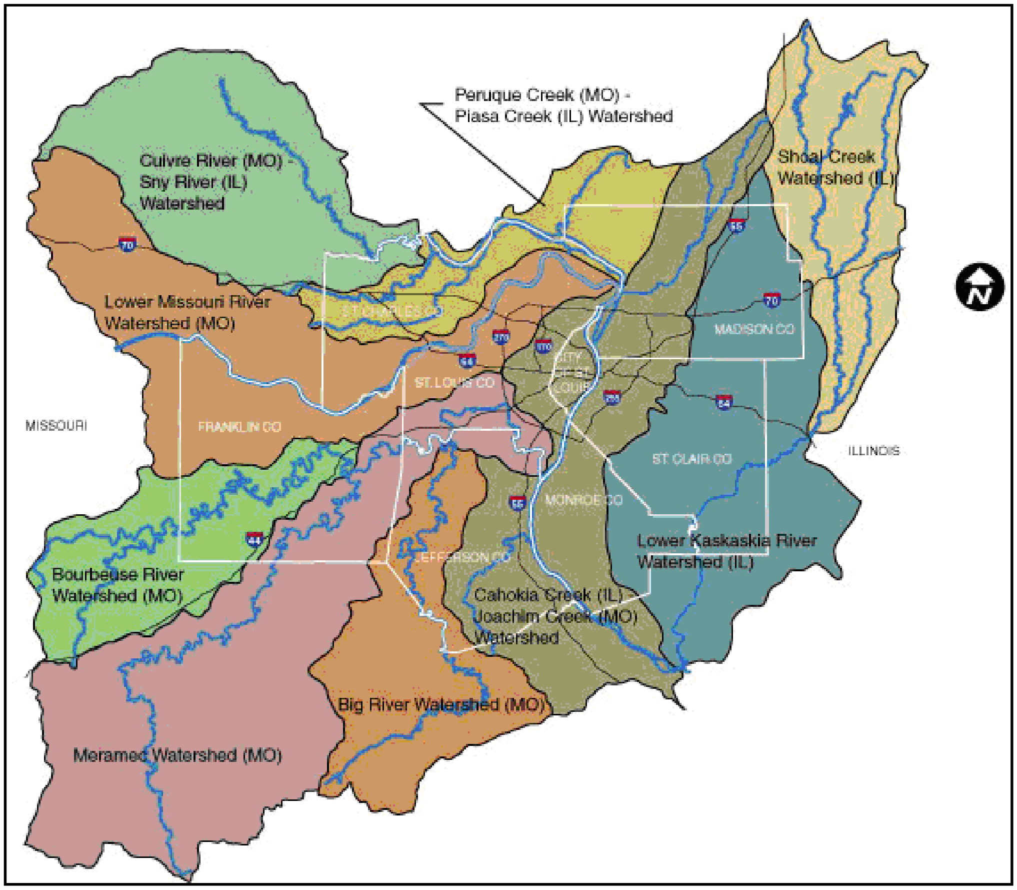


Figure 5 A Map of the Nine Major Watersheds in the St. Louis Region
(East-West Gateway Council of Governments, 2004).

3.3. St. Charles County. Missouri Watersheds

There are eleven watersheds in St. Charles County, Missouri (Fig. 6).

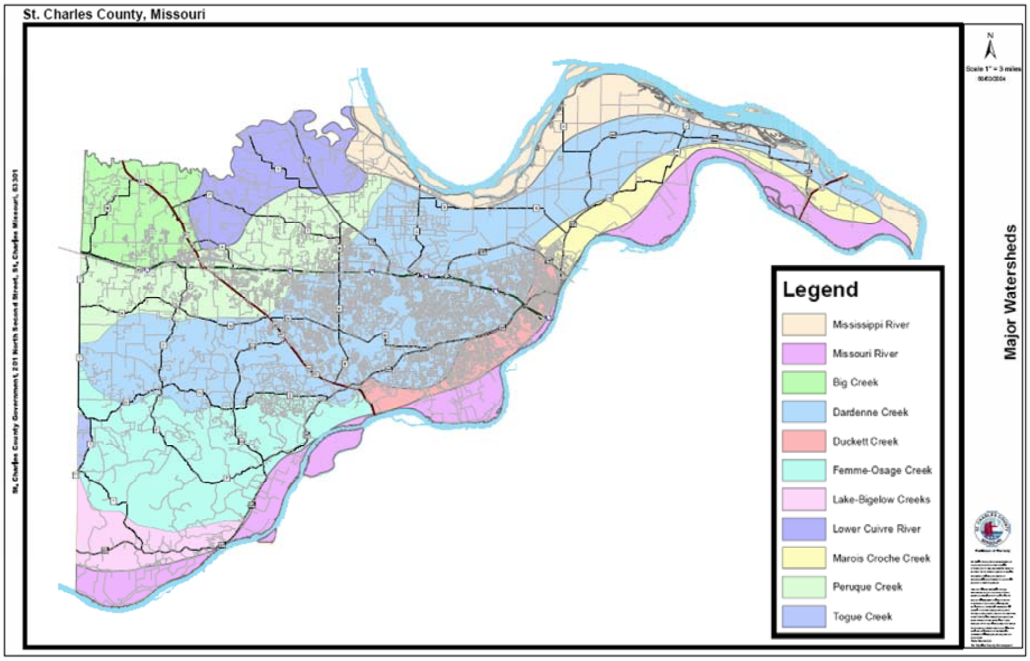


Figure 6 St. Charles County Watersheds (St. Charles County, Missouri: Division of Environmental Services, 2008)

3.4. St. Charles County Description

St. Charles County has an area of approximately 1450 square kilometers (560 square miles) of which over 101 square kilometers (39 square miles) are water surface. The extreme length of the triangular-shaped county is nearly 76 kilometers (47 miles) and the extreme breadth is approximately 40 kilometers (25 miles). The lowest elevation at the confluence of the Mississippi and Missouri Rivers (Fig. 7) is around 122 meters (400 feet) above sea level. The highest elevation is in the south-central part of the county and is around 274 meters (900 feet) above sea level (St. Charles County Government, 2008).

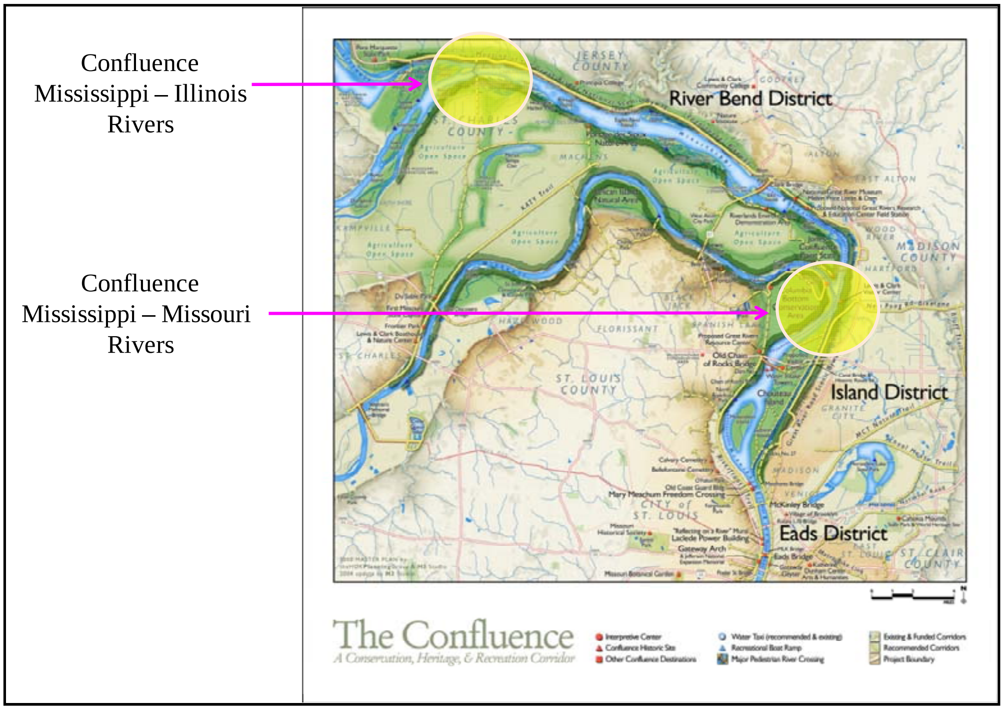


Figure 7 A view of the Mississippi-Illinois and Mississippi-Missouri Rivers Confluences and St. Charles County, Missouri.(Confluence Greenway Organziation, 2006)

The Dardenne Creek Watershed is located primarily in St. Charles County, which contains St. Charles city, the second largest city in the St. Louis metropolitan region. Approximately one percent of the headwaters area of the watershed lies adjacent Warren County. It is a mid-sized watershed, approximately 427 square kilometers (165 square miles), and is the largest watershed in St. Charles County, containing approximately 30 percent of the county's land area (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003).

3.5. St. Charles County 100 Year Flood Plain Description

Approximately 70 percent of the St. Charles County tributaries and streams drains into the Mississippi River, while the remaining southern 30 percent drains into the Missouri River. Approximately 43 percent of the county is within a 100-year floodplain.

Most of northeastern St. Charles County between the Mississippi and Missouri Rivers is within the flood hazard area. Other areas of the county having 100-year floodplain designations are along Cuivre River, Dardenne Creek, Peruque Creek, Femme Osage Creek, and Big Creek. Flood hazard zones are depicted in Figure 8

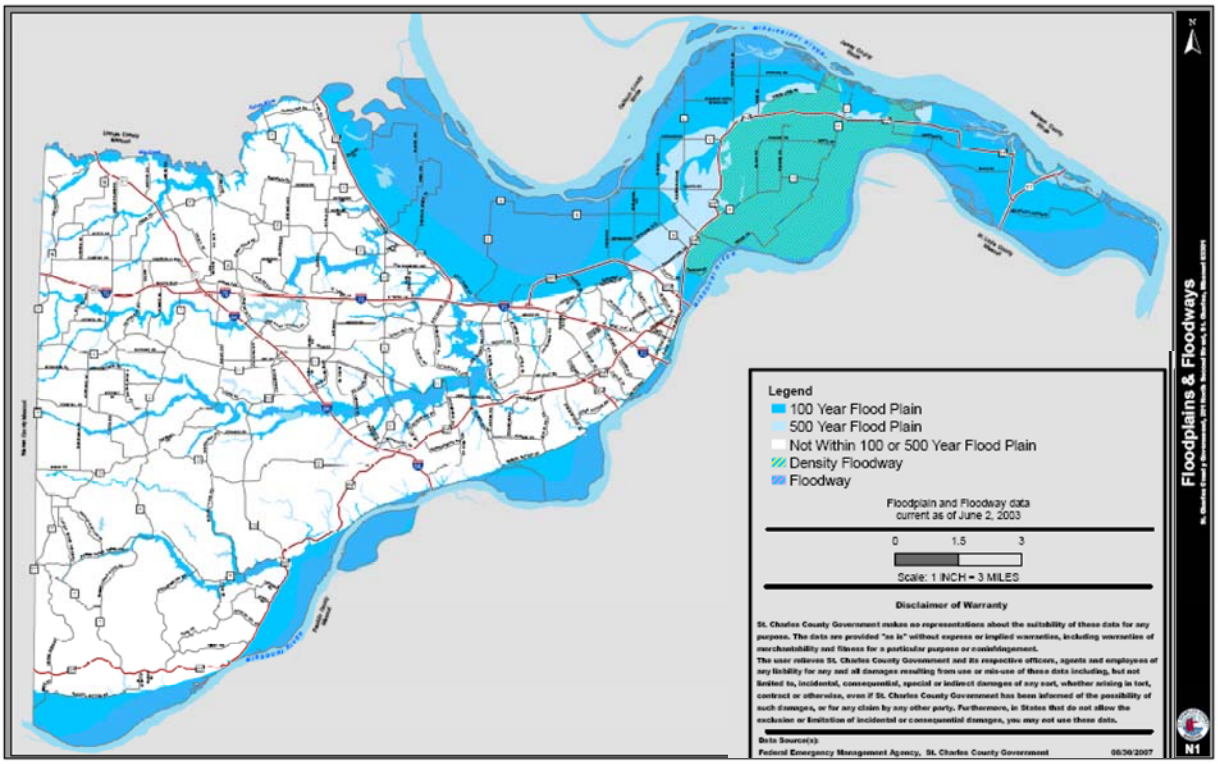


Figure 8 St. Charles County, Missouri Flood Plains and Flood Ways (St. Charles County Government, 2008) .

In addition to surface water sources, large amounts of water are stored in underlying bedrock and alluvium. Some of this water supply has a high content of minerals, but much is good quality. This quality varies depending upon the rock types present, water movement, and other factors. Various contaminants have been introduced into some groundwater resources by failing septic tanks, lagoons, and former landfills (St. Charles County Government, 2008).

3.6. Dardenne Creek Watershed

The study site selection for this research is the Dardenne Creek watershed, and is identified by the U.S. Geological Survey classification levels (Table 1) (Figure 9).

Table 1 U.S. Geological Survey Classification Levels

Level 1. Region: The Upper Mississippi Region [Region (07)]
Level 2. Subregion: The Upper Mississippi River Basin [Subregion (0711)]
Level 3. Accounting Unit: Bear-Wyanconda, Illinois, Iowa, Missouri [AU (071100)]
Level 4. Category Unit: Peruque Creek (MO)-Piasa Creek (IL) Watershed [CU (07110009)]

(See Appendix A. Watershed Description and USGS Region [07] Watershed Levels).

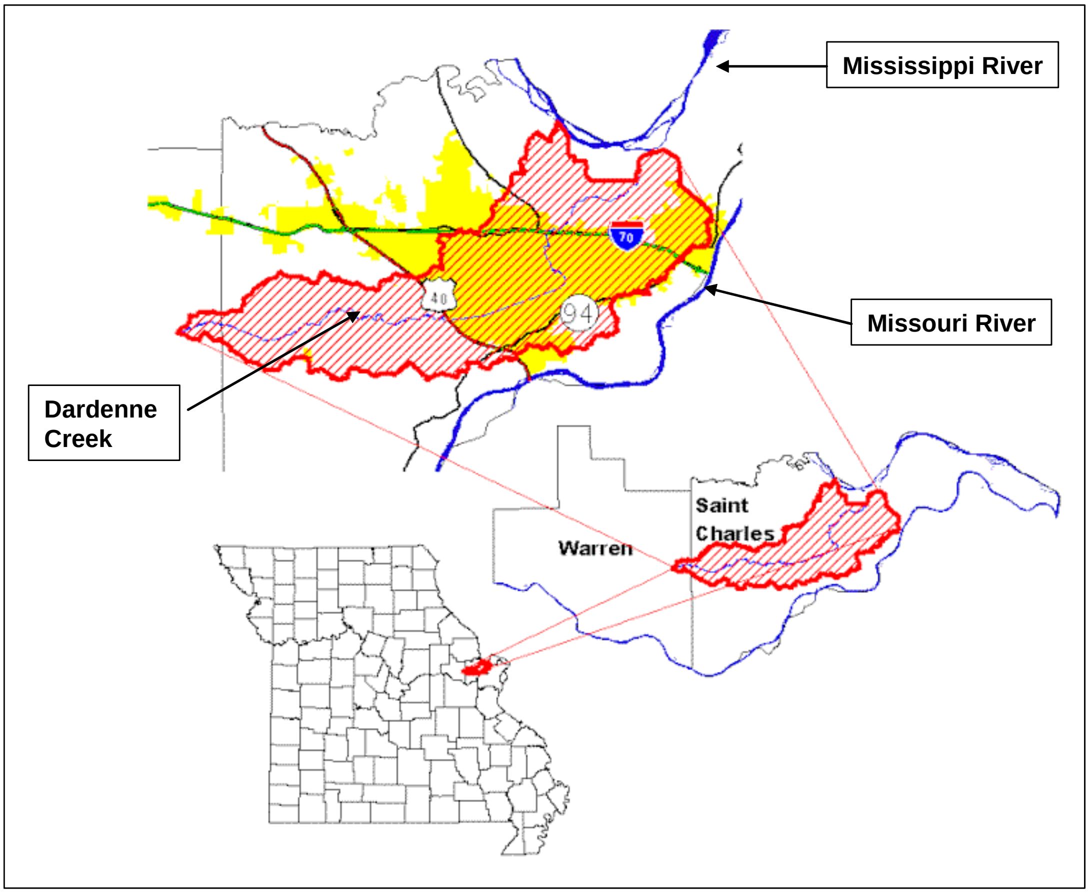


Figure 9 Dardenne Creek Watershed (Red Shaded Area) (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003)

St. Charles County. It is a mid-sized watershed, totaling an area of 427 square kilometers (165 square miles). It is the backbone of the county with the natural ambience that the creek offers as it winds through each community providing a green buffer from the heavy development, which is ever expanding.

Land use in the watershed ranges from rural and agricultural land to densely built-up areas in St. Charles County and surrounding municipalities. The Dardenne Creek watershed can be divided into three separate areas (Fig. 10). The headwaters is classified by the St. Charles County as the Upper Dardenne Creek and is primarily rural and contain less- developed agricultural land. The central part of the watershed, the Middle Dardenne Creek, which is also known as the middle reaches, is a heavily-developed residential area that contains a large portion of the most rapidly developing belt of St. Charles County. This triangle is bounded by Interstate 70, U.S. Highway 40/61, and Missouri Highway 94. The Lower Dardenne is in the Mississippi floodplain, which is presently being used primarily for agricultural purposes. However, there are currently proposals for commercial development to occur in that area of the floodplain.

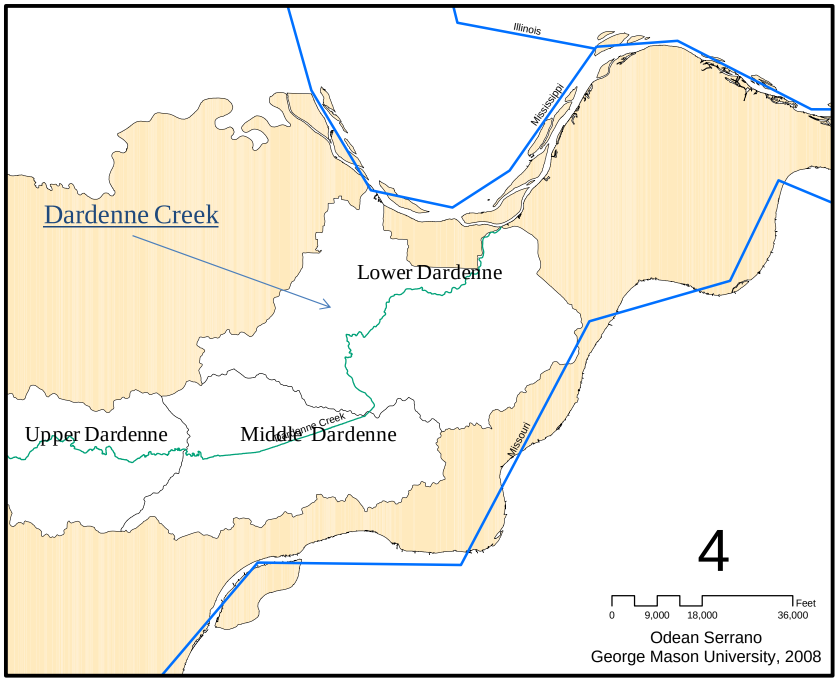


Figure 10 St. Charles County Missouri and the Dardenne Watershed
(Serrano, ESRI Shapefiles, 2008)

3.6.1. Dardenne Watershed Environmental Benefits and Corridor Protection

The most critical component of the watershed is the riparian zone, which includes the stream bank and surrounding areas that border the stream channel. Like all waterways, the Dardenne's riparian is not defined by a specific width. In some areas it spreads out hundreds of feet and in some areas it is a narrow strip along the creek. It is within this riparian zone that the many complex biological interactions take place. The riparian zone functions in the context of the surrounding ecosystem. Changes within the watershed will impact the physical, biological and chemical processes occurring within this corridor. Stream systems normally function within natural ranges of flow, sediment movement, temperature, and other variables. When development and riparian degradation go beyond the tolerable ranges of these variables, the alterations can result in major changes in the structure (species) and function (energy, flow, nutrient cycling) of the ecosystem (St. Charles County Government, 2008).

Shading of the riparian zone is a major control of water temperature, while maintaining the natural vegetation within the zone is essential to provide bank stability. A stable riparian ecosystem will help modulate stream flow and remove and filter run-off. It will help store water and provide a unique habitat for both aquatic and terrestrial plants and animals. Providing an adequate vegetated buffer zone along streams is fundamental for safe watershed management. The broader this vegetated corridor is, the greater the time it takes for rainwater to reach the creek. This is called lag time, which reduces the potential for flash flooding (St. Charles County Government, 2008).

3.6.2. Recreational & Educational Benefits

Since the Dardenne Creek watershed is experiencing some of the most rapid urban development in the state, citizens of St. Charles County recognize a certain urgency to protect and preserve the watershed. Recent data available from residents' surveys have indicated interest in preservation and protection of the water quality of these streams (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003). The heaviest public use is in the Busch Wildlife Reserve, which receives over 1,000,000 visitors per year for fishing, hunting, hiking, bird watching, and a variety of other outdoor activities. The interest in urban parks, natural areas, and trails is continually increasing (University of Missouri, Columbia: Center for Applied Research and Environmental Systems (CARES), 2003).

Where the Dardenne watershed was once used as a waterway for commerce and trade, it can now be used as an interlocking network of open space and trails that connect the people to the waters. This can be accomplished, while also preserving the diversity of wildlife in St. Charles County (Confluence Greenway Organziation, 2006).

Park settings providing riparian protection that would not only help to support wildlife diversity preservation and clean water throughout St. Charles, but also could provide economic and recreational opportunities. A regional park concept developed by the Confluence Greenway Organization is intended to provide hundreds of miles of public access and links within the protected natural areas in the state. Given proper access, the creek and the surrounding area can be used by residents for numerous recreational activities such as hiking, walking, biking, and nature exploring. The development of so called ‘eco’-parks along the creek could serve as outdoor classrooms for schools and colleges.

A goal within this regional park concept is to connect the Dardenne watershed with the Confluence Greenway Project, providing over 26 square kilometers (6,500 acres) of linear park and trails passing through the most heavily developed area of St. Charles County. It would also link trails carrying passengers between Missouri and Illinois, and thereby, connect with the Illinois trail systems (Confluence Greenway Organziation, 2006).

3.6.3. Dardenne Watershed Urban Expansion

The county has tremendous projections for major growth with regard to the Dardenne watershed. Urban activities occupy 34 percent of the watershed including residential, transportation, commercial and industrial uses. Other land use includes grassland (11%), cropland (17%), forest (13%) wetland (5%) water bodies (1%) and other agricultural lands (18%) (Fig. 11) (MoDNR: Cook, 2001).

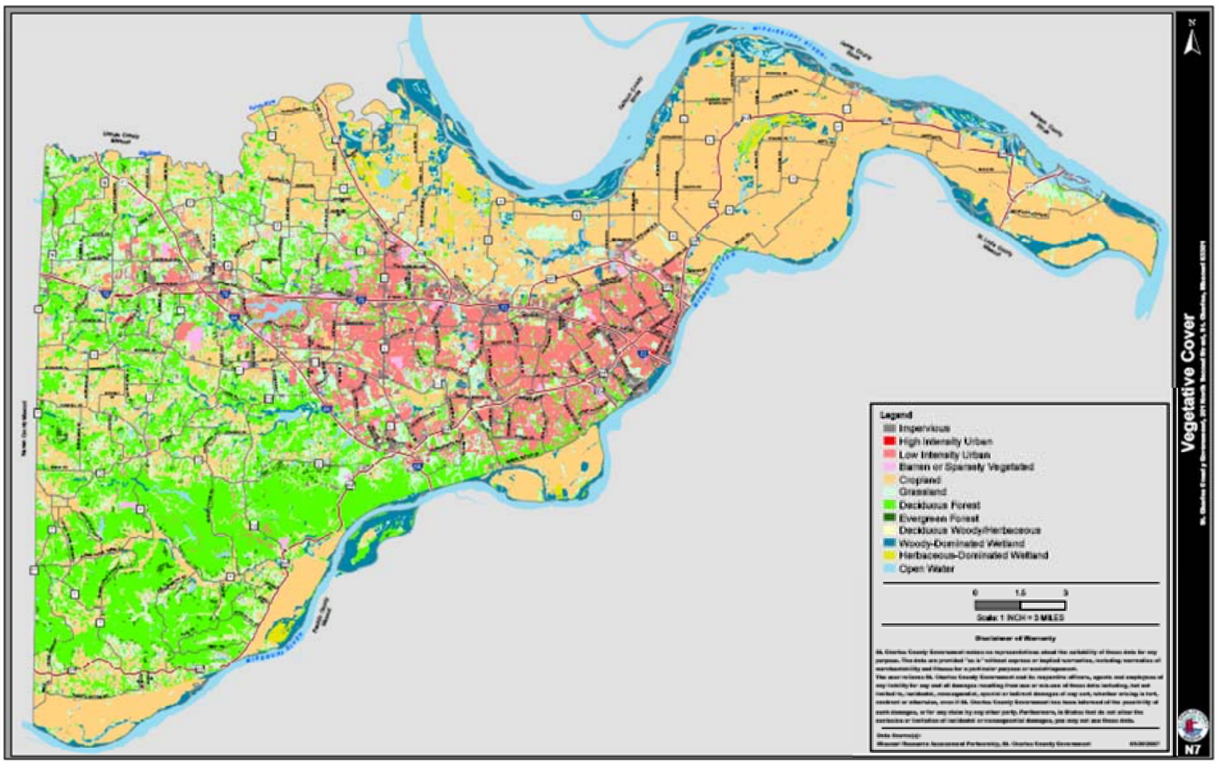


Figure 11 St. Charles County Vegetative Cover
(St. Charles County Government, 2008)

The amount of permeable land decreases as cities develop and as vegetated soils are replaced with buildings (impermeable rooftops), parking areas, and streets. Where rain was originally absorbed by the soil and then, through groundwater flow, seeped into local streams, (the rain) is now moved rapidly and efficiently into the local stream through surface flows (Westervelt, 2001). The increased stormwater flows attributed to the increased impervious surface areas resulting from urban development, transport nonpoint source pollutants and runoff into the local streams, thereby changing the water quality parameters.

Along the Dardenne Creek, the Missouri Department of Natural Resources (MoDNR) has collected water quality data, both chemical and biological, from the years 1993 to 2007, at specific locations. The MoDNR also instituted a Volunteer Water Quality Monitoring and Assessment Program in 1993 that teaches citizens how to collect chemical, biological, and visual data sets (MoDNR, 2008). The Volunteer program has collected data in the same corridor from the years 1993 to present.

The Army Corps of Engineers, St. Louis Hydrological Unit, conducted a Dardenne Creek watershed study which began in 2004 and was completed in 2007. A summary description and evaluation of each study will be discussed in Chapter Five. The Army Corps of Engineers has collected hydrological data and the USGS has collected hydrological soil group descriptions and topological data which help to define physical features of the watershed. However, to date there has been little trend analysis to depict the water quality parameters. Presently, there are very few commercial or residential building codes that address maintaining the State stream water quality standards.

CHAPTER 4

4. CLEAN WATER LAW REVIEW

Policy and regulation are fundamental components of this dissertation. This chapter provides an overview of the relevant regulation for water quality management for the Dardenne Creek watershed. It is important to understand the structure of the Clean Water Act and the role of the State in enforcing the law. This chapter will outline the pertinent aspects of Federal and State law and will discuss several cases that were filed against the EPA and State of Missouri regarding the water quality regulations related to the Dardenne Creek watershed.

4.1. Clean Water Act History

Federal water legislation dates back to the nineteenth century when Congress enacted the River and Harbor Act of 1886, recodified in the Rivers and Harbors Act of 1899. It is only within the last several years, however, that major water pollution legislation has been passed.

Recognizing the threat that polluted water posed to the public health and welfare, Congress enacted the original Federal Water Pollution Control Act (FWPCA), passed in 1948, in order to "enhance the quality and value of U.S. water resources and to establish a national policy for the prevention, control and abatement of water pollution." FWPCA and its several amendments set out the basic legal authority for Federal regulation of water quality.

The Water Pollution Control Act Amendments of 1956 strengthened enforcement provisions by providing for an abatement suit at the request of a State pollution control agency; where health was being endangered, the Federal government no longer had to receive the consent of all States involved. The Federal role was further expanded under the Water Quality Act of 1965. That act provided for the setting of water quality standards which are state and federally enforceable. It became the basis for interstate water quality standards. The Clean Water Restoration Act of 1966 imposed a $100 per day fine on any polluter who failed to submit a required report. The Water Quality Improvement Act of 1970 again expanded Federal authority and established a State certification procedure to prevent degradation of water below applicable standards. The 1973 Federal Water Pollution Control Amendments significantly expanded and strengthened this earlier legislation. As amended in 1977, this law became commonly known as the Clean Water Act (U.S. Environmental Protection Agency, Clean Water Act History, 2006).

The Clean Water Act (CWA) Title 33, United States Code (U.S.C.), is the overarching law for clean water issues within the United States governing water pollution. This includes the major amendments enacted in the Clean Water Act of 1977 by the 95th United States Congress and the Water Quality Act of 1987, enacted by the U.S. Congress.

The CWA established the symbolic goals of eliminating releases into the nation's waters of high amounts of toxic substances, eliminating additional water pollution by 1985, and ensuring that surface waters would meet standards necessary for human sports and recreation by 1983.

The Act established the basic structure for regulating discharges of pollutants into the waters of the United States. It gave EPA the authority to implement pollution control programs, such as setting wastewater standards for industry.

The Clean Water Act also required that States set water quality standards for all contaminants in surface waters. The Act made it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions. It also funded the construction of sewage treatment plants under the construction grants program and recognized the need to address the critical problems posed by nonpoint source (NPS) pollution (Los Alamos National Laboratory, 2008).

4.2. Clean Water Act Overview

4.2.1. Federal Titles:

The Clean Water Act has six major federal statutory provisions

Title I **Research and Related Programs**

Title II **Grants for Construction of Treatment Works**

Title III **Standards and Enforcement**

a. Technology-Based Standards Program
b. Water Quality Standards Program
c. National Water Quality Inventory
d. Enforcement
e. Federal Facilities
f. Thermal Pollution

g. Nonpoint Source Management Program

Title IV **Permits and Licenses**
NPDES Permits for Point Sources
Dredge and Fill Permits (Wetlands)
POTW Biosolids Management Program

Title V **General Provisions**
Citizen Suits
Employee protection

Title VI **State Water Pollution Control Revolving Funds**

4.2.1.1. Title III Technology-Based Standards Program

Under the 1972 Act, EPA began to issue technology-based standards for municipal and industrial sources.

Municipal sewage treatment plants, also called publicly-owned treatment works (POTW), are required to meet secondary treatment standards.

Effluent guidelines (for existing sources) and New Source Performance Standards are issued for categories of industrial facilities discharging directly to surface waters. Categorical Pretreatment Standards are issued to industrial users (also called "indirect dischargers") contributing wastes to POTW. These standards are developed in conjunction with the effluent guidelines program.

To date, the effluent guidelines and categorical pretreatment standards regulations have been published for 56 categories and apply to between 35,000 and 45,000 facilities that discharge directly into the nation's waters. These regulations are responsible for preventing the discharge of almost 700 billion pounds of pollutants each year. EPA has updated some categories since their initial promulgation and has added new categories.

The secondary treatment standards for POTWs and the effluent guidelines are implemented through the National Pollutant Discharge Elimination System (NPDES) permits discussed in Title IV of the CWA. The categorical pretreatment standards are typically implemented by POTWs through permits that they issue to their industrial users.

b. Water Quality Standards Program

Water quality standards (WQS) are risk-based (also called hazard-based) requirements which set waterbody-specific allowable pollutant levels for individual water bodies, such as rivers, lakes, streams and wetlands. States set WQS by designating uses for the waterbody (e.g., recreation, water supply, aquatic life, agriculture) and applying water quality criteria (numeric pollutant concentrations and narrative requirements) to protect the designated uses. An anti-degradation policy is also developed by each state to maintain and protect existing uses and high quality waters.

A Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet WQS. Over 60,000 TMDLs are proposed or in development for U.S. waters over the next decade and a half.

Following the determination that a waterbody is not meeting water quality standards, a TMDL strategy for that waterbody is developed for implementation of the requirements and may involve modification to NPDES permits for facilities discharging to the waterbody in Title IV.

While the effluent guidelines have been largely successful, because they apply to specific point sources and are enforceable, the WQS have been much less so. As of 2007, approximately half of the rivers, lakes, and bays under EPA oversight were not safe enough for fishing and swimming.

c. National Water Quality Inventory

Section 305(b) requires EPA and the states to compile a biennial Report to Congress on the nation's water quality.

d. Enforcement

Under section 309, EPA can issue administrative orders against violators, and seek civil or criminal penalties when necessary.

States that are authorized by EPA to administer the NPDES program must have authority to enforce permit requirements under their respective state laws.

g. Nonpoint Source Management Program

The Nonpoint Source management program is required to be carried out by the States.

4.2.1.2. Title IV Permits and Licenses

Water pollution degrades surface waters making them unsafe for drinking, fishing, swimming, and other activities. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Individual homes that are connected to a municipal system, use a septic system, or do not have a surface discharge do not need an NPDES permit; however, industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters (EPA, 2008).

In response to the 1987 Amendments to the Clean Water Act (CWA), the U.S. Environmental Protection Agency (EPA) developed Phase I of the NPDES Stormwater Program in 1990.

The Phase I program addressed sources of stormwater runoff that had the greatest potential to negatively impact water quality. Under Phase I, EPA required NPDES permit coverage for stormwater discharges from:

Medium and large municipal separate storm sewer systems (MS4s) located in incorporated jurisdictions or counties with populations of 100,000 or more;

Eleven categories of industrial activity, including construction activity that disturbs .02 or more square kilometers (5 or more acres) of land.

Operators of the systems, facilities, and construction sites regulated under the Phase I NPDES Stormwater Program must obtain permit coverage for the stormwater discharge leaving sites.

The Phase II Final Rule, published in the Federal Register on December 8, 1999, requires NPDES permit coverage for stormwater discharges from certain regulated small municipal separate storm sewer systems (MS4s) and construction activity disturbing between 1 and 5 acres of land (i.e., small construction activities). The Phase II Rule also established potential waivers for small construction activities. (See Table 2 for the Missouri NPDES program status as of March, 2008).

Table 2 Missouri NPDES Program Status
(U.S. Environmental Protection Agency, NPDES State Program Status)

State	Approved State NPDES Permit Program	Approved to Regulate Federal Facilities	Approved State Pretreatment Program	Approved General Permits Program	Approved Biosolids (Sludge) Program
Missouri	X	X	X	X	-

Title V - General Provisions

U.S. citizens may file suit against a CWA violator if EPA or a state fails to take enforcement action. This is the case of the Home Builders Association of Greater St. Louis verses the Missouri Clean Water Commission (CWC) and the Missouri Department of Natural Resources that is discussed in Chapter Five.

4.3. State of Missouri Clean Water Statutory Overview

Missouri state statutes address all of the elements of responsibility handed down from the Federal Clean Water Act (CWA) and Title 40 Code of Federal Regulations (CFR) that EPA requires to mitigate and prevent water pollution.

Missouri Revised Statutes, Chapter 644, Water Pollution, is Missouri's Clean Water Law (CWL). Title 10 Code of State Regulations (CSR) is utilized by the Missouri Department of Natural Resources (DNR) to apply requirements that address water pollution control. These two primary statutes codify Missouri's responsibilities, duties, actions, enforcement, reporting, fee collection, and project funding for meeting the various CWA section and EPA regulation requirements.

4.3.1. Chapter 644, Water Pollution

The Missouri Revised Statutes, Chapter 644, Water Pollution Overview has seven categorical elements:

I. Water Quality Standards (WQS)

The state is given the authority to develop and set WQS for the waterbodies within the state; establish effluent discharge regulations; identify prohibited acts; give the DNR Director authority to determine if the WQS is exceeded; and provide time allowances for certifications under CWA Section 401 permits. (EPA Water Quality Standards Designated Use Categoriesm 2008). The WQS address three basic elements:

A) Define Designated Uses for each waterbody commonly identified as:

- i. drinking water
- ii. water based recreation
- iii. fishing/eating
- iv. aquatic life
- v. agricultural water supply
- vi. industrial water supply

B) Water Quality Criteria addresses the levels of pollutants or water quality characteristics that, if not exceeded, protect the designated use of the waterbody:

1) narrative – referring to:
   - i. free of undesirable conditions
   - ii. balanced indigenous species

2) numeric – parameter specific referring to: magnitude/concentration regarding:
   - i. duration
   - ii. frequency/recurrence interval

3) biological – applying only to aquatic life, requiring field sampling and studies of fish, macroinvertebrates, plants, and comparing the study site to a relatively minimally impacted study site.

C) **Anti-degradation Policies** address the high quality water component of antidegradation that can be applied using one of two approaches:

1) identify and protect waters based on consideration of the level of each parameter to the criteria necessary to support propagation of fish, shellfish and wildlife, and recreation in and on the water.
2) use a variety of factors to judge a waterbody's overall quality.

II. Point Source Pollution Control

Point Source Pollution Control provides authority for Missouri Clean Water Commission (CWC) to establish procedures and regulations necessary to administer control of point source pollution; establishes and requires point source permits; identifies variances to point source regulations; and identifies unlawful acts.

III. Defines Nonpoint Source (NPS) Pollution

Defines water contaminant sources considered to be NPS; requires Water Pollution Control Projects shall have NPS identified in an NPS Control Plan developed by MoDNR; requires Waste Treatment Management Plans identify NPS.

A. CWA Pollution Control Strategy

The requirement for a pollution control strategy in the Clean Water Act addresses both Point Source and Nonpoint Source pollution.

Compliance monitoring evaluates whether water quality parameters are within (complying) set minimum or maximum chemical values. State and/or regional boards have set water quality standards based on “beneficial use categories” for each stream, river, and lake. “Beneficial use” is a term used by the EPA (Environmental Protection Agency) to describe different functions of water.   Most waters support several beneficial uses. The rationale for public regulation of water quality is to protect the existing and designated beneficial uses of water (EPA Circular Publication, 1991). Although the specific designated uses vary from state to state, they generally include agricultural use, industrial use, domestic water supplies, recreational use, and the propagation of fish and wildlife. Each state determines which use(s) should be applied to the water bodies within the state. The numeric parameters for water quality are assigned to each beneficial use and then become minimum criteria for water quality. The specific water quality parameters to monitor will depend on the beneficial uses of the water (Nader et al, 1993).

IV. Section 303 (d) of the Federal Clean Water Act

Section 303 (d) of the CWA requires that each state identify waters that are not meeting water quality standards and for which adequate water pollution controls have not been required. Any waterbody identified as impaired in the listing shall be adopted by the CWC and the impairment shall be publicly advertised by DNR   The 303(d) List helps state and federal agencies keep track of waters that are impaired but not addressed by normal water pollution control programs (MoDNR Water Quality Section 303(d), 2008).

A) Total Maximum Daily Loads (TMDL)

Under the Federal Clean Water Act, when a waterbody is listed by the state on the 303 (d) List as impaired, the state must undertake strategies to mitigate the impairment. A TMDL program provides a framework for identifying and cleaning up impaired waters. Section 303(d) requires states to list impaired waters for which the necessary pollution controls have not yet been required and for which a TMDL study has not been written. The state is required to develop a TMDL for all waters on the 303(d) List. The TMDL is a mathematical calculation of the amount of a specific pollutant a waterbody can absorb and still meet water quality standards. Each TMDL document will include allocations of the acceptable load for all sources of the pollutant. It will also include an implementation plan to identify how the load will be reduced to a level that will protect water quality (MoDNR TMDL Index, 2008).

V. Section 305 (b) of the Federal Clean Water Act

Section 305 (b) requires that each state report the status of the water quality of its waterbodies to EPA on a biennial basis. The 305(b) report provides a detailed look at a wide variety of impacts to water quality all across Missouri (EPA Water Quality 305(b), 2008) .

VI. Section 319 of the CWA

Section 319 of the Clean Water Act provides the basis for the Missouri 319 Nonpoint Source (NPS) Implementation Program.

Congress amended the Clean Water Act in 1987 to establish the section 319 Nonpoint Source Management Program because it recognized the need for greater federal leadership to help focus State and local nonpoint source efforts. Under section 319, Missouri receives grant monies supporting a wide variety of activities, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects (MoDNR NPS Index, 2008).

A) National Pollutant Discharge Elimination System (NPDES):

Water pollution degrades surface waters making them unsafe for drinking, fishing, swimming, and other activities. As authorized by the Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or man-made ditches. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters (U.S. EPA NPDES Index, 2008).

VII. State Revolving Funds (SRF)

In 1987, Congress voted to phase out the old construction grants program for funding of municipal sewer and wastewater treatment plant upgrades, replacing it with the Clean Water State Revolving Fund (CWSRF). Under the CWSRF, EPA provides annual capitalization grants to States. The States, in turn, provide low interest loans for a wide variety of water quality projects. States must match the federal funds with $1 for every $5 (20 percent match) (Missouri CWA Revolving Fund, 2008). Figure 12 shows the relationship between the CWA and the Missouri Clean Water Law.

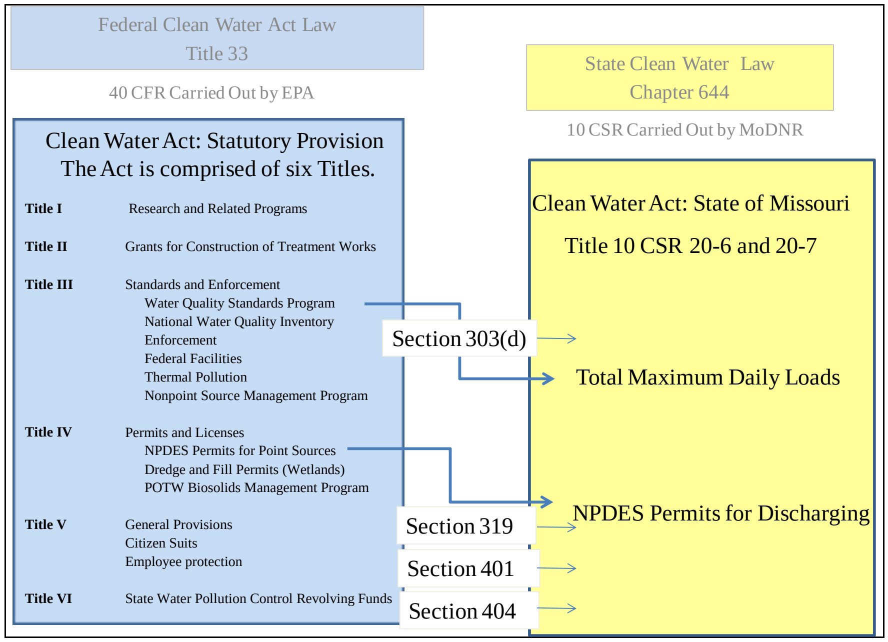


Figure 12 CWA v Missouri Chapter 644 (Serrano, 2008)

4.4. Clean Water Act Implemented

This section summarizes how the CWA is implemented with a flow diagram of (Fig. 13). First, the State must develop water quality standards (WQS) that are consistent with the statutory goals of the CWA. Then waterbodies are monitored to determine whether the WQS are met. There are five categories of water quality that range from category 1 - high quality water to category 5- impaired.

If all WQS fall within the range of category 1 - 4, then the antidegradation policies and programs are employed to keep the water quality at acceptable levels. Ambient monitoring is also needed to ensure that this is the case.

If the water quality for a waterbody is a category 5, it is not meeting any WQS, then a TMD as a basis for a water quality strategy to meet the standards, must be developed by law. The most common type of strategy is the development of a Total Maximum Daily Load (TMDL). TMDLs determine what level of pollutant load would be consistent with meeting WQS. TMDLs also allocate acceptable loads among sources of the relevant pollutants. Necessary reductions in pollutant loading are achieved by implementing strategies authorized by the CWA, along with any other tools available from federal, state, and local governments and nongovernmental organizations.

The CWA identifies strategies and programs that the State can follow once an impaired waterbody is identified on the 303 (d) List. NPDES is a Federal permit program that covers point sources of pollution discharging into a surface waterbody.

- **Section 319** - Addresses nonpoint sources of pollution, such as most farming and forestry operations, largely through grants.

- **Section 404 -** Regulates the placement of dredged or fill materials into wetlands and other Waters of the United States.
- **Section 401 -** Requires federal agencies to obtain certification from the state, territory, or Indian tribes before issuing permits that would result in increased pollutant loads to a waterbody. The certification is issued only if such increased loads would not cause or contribute to exceeding water quality standards.
- **State Revolving Funds** (SRF)

  Provides money in the form of loans for municipal point sources, nonpoint sources, and other activities that will assist in mitigating violations.

After implementation of the TMDL and NPDES strategies, ambient conditions are again measured by the state and compared to ambient water quality standards. If standards are met, only occasional monitoring is needed. If standards are still not being met, then a revised strategy is developed and implemented, followed by more ambient monitoring. This iterative process must be repeated until standards are met (EPA Watershed Academy, 2008).

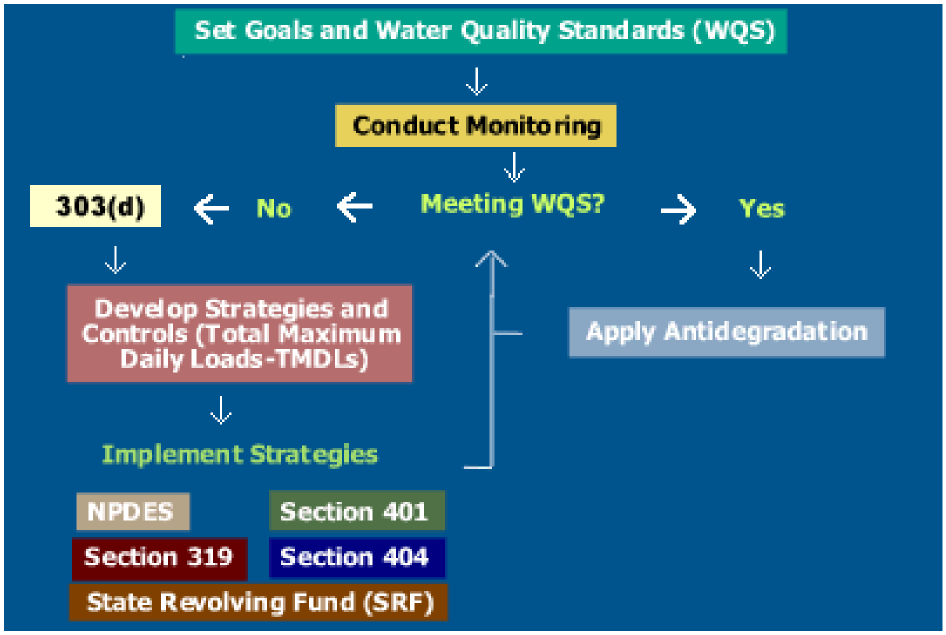


Figure 13 Clean Water Act Implementation (EPA Introduction to the CWA, 2008)

4.5. Clean Water Act: § 305 (b) for Dardenne Creek

The 2002 National Assessment Database addresses 305 (b) requirement for reporting the status of all State waterbodies. The database summarizes information submitted electronically by the states allowing public viewing of assessments for individual waterbodies.

The § 305 (b) report shows that Missouri electronically submitted status data to EPA for the years 2002, 2004 and 2006, indicating state awareness of the stream segment impairment for Dardenne Creek. Tables 3, 4 and 5 are the results of the § 305 (b) database entries for four segments of Dardenne creek that were submitted by the MoDNR to EPA for 2002, 2004, and 2006.

Table 3 Assessment Data for Missouri Peruque-Piasa Watershed, 2002
(EPA National Assessment Database 2002)

Dardenne Creek	MO_0219_R	Impaired
Dardenne Creek	MO_0222_R	Impaired
Dardenne Creek	MO_0221_R	Impaired
L. Dardenne Creek	MO_0223_R	Impaired

Table 4 Assessment Data for Missouri, Peruque-Piasa Watershed, 2004
(EPA National Assessment Database 2004)

Dardenne Creek	MO_0222_R	Impaired
Dardenne Creek	MO_0219_R	Impaired
Dardenne Creek	MO_0221_R	Good
L. Dardenne Creek	MO_0223_R	Good

Table 5 Assessment Data for Missouri, Peruque-Piasa Watershed, 2006
(EPA National Assessment Database 2006)

Dardenne Creek	MO_0222_R	Impaired
Dardenne Creek	MO_0219_R	Impaired
Dardenne Creek	MO_0221_R	Good
L. Dardenne Creek	MO_0223_R	Good

4.6. Section 303 (d) and TMDL Sequence

In Section 303 (d) of the Federal Clean Water Act, Congress directed each State to identify each impaired waterbody within its borders to submit a listing of impaired waterbodies on a 303 (d) List, to the EPA.

EPA adopted regulations, 40 CFR §130.7(d)(1) each State to identify for each impaired waterbody within its borders, the specific pollutants(s) that cause the impairment, and to submit the listing to the EPA.

EPA is required to review and approve, approve with modification, or disapprove the 303 (d) listing of impaired watersbodies submitted by the State.

Each State is required by 40 CFR § 130.7(b)(1) and (c)(1) to develop a proposed Total Maximum Daily Load (TMDL) for each pollutant, for each waterbody placed on that State's 303(d) List. A TMDL is a calculation of the maximum amount of a given pollutant that a body of water can absorb before its quality is affected.

After the State develops a TMDL for a particular pollutant, the State is then required by 40 CFR § 130.7(d)(2) to submit the proposed TMDL to EPA. EPA is required to approve or disapproved the proposed TMDL.

If a watershed is determined to be impaired such that it is placed on the 303(d) List, a State is required to develop a watershed management plan that will include the TMDL calculation.

4.7. Clean Water Act: § 303 (d) for Dardenne Creek

In August 2002, Missouri Clean Water Commission (MCWC) and the MoDNR submitted the proposed Missouri 2002 § 303 (d) List to EPA and did not identify Dardenne Creek on the List.

In December 2003, the EPA approved the Missouri 2002 § 303 (d) List and placed Dardenne Creek on the 2002 303(d) list for "unknown" pollutants (Fig. 14). EPA, and not the State of Missouri, made the decision to show Dardenne Creek as impaired on the 2002 303 (d) List. The State of Missouri did not show the Creek on the 2002, 303 (d) List due to the incomplete water quality sample data sets (MoDNR, 2004). EPA believed that the results and conclusions from the studies conducted by the Department of Natural Resources between 1998 and 2000 adequately demonstrated that Dardenne Creek was impaired (MoDNR, 2004). Additionally regulations do not exempt waters from the requirement to be included on the 303 (d) List where a specific pollutant is "unknown" (EPA, 2003). (See Appendices B and C).

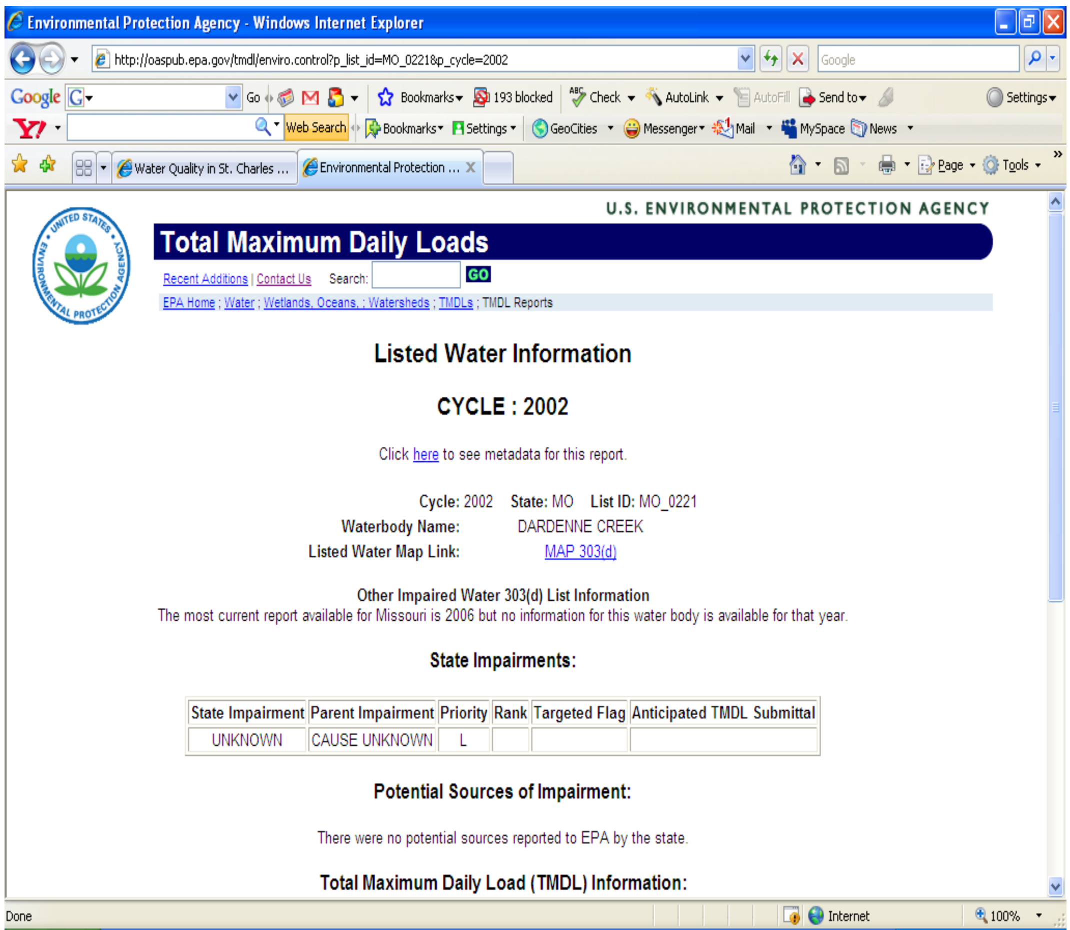


Figure 14 EPA 2002 Section 303(d) List Fact Sheet for Missouri

In 2004 the MoDNR revised the Missouri 2002 § 303 (d) List to include Dardenne Creek. The specific pollutant was described as "unknown".

4.8. § 305 (b) and § 303 (d) for Dardenne Creek Reporting Comparisons

The comparisons between the 305 (b) and 303 (d) Lists for the years 2002 through 2006 are incongruent (Table 6). This section outlines the disparities noted between the reports (Table 6).

EPA 305 (b) with EPA 303 (d) List Comparison for 2002 - 2006

The Dardenne Creek was listed by the EPA as impaired or partially impaired on the 305(b) Stream Status List for 2002, 2004 and 2006. However the Dardenne Creek was only on the EPA approved 303 (d) List for 2002, with the pollutant identified as "unknown".

EPA 303 (d) with Missouri 303 (d) List Comparison for 2002 – 2006

The EPA identified Dardenne Creek on the approved 303 (d) for 2002. The Missouri 2002 303 (d) List submitted to EPA, originally did not identify Dardenne Creek as impaired on the State 2002 303 (d) List. In 2004, the State of Missouri updated their 2002 303 (d) List. The State of Missouri has identified Dardenne Creek as impaired for 2002, 2004, and 2006. However, the EPA 303 (d) List indentifies Dardenne Creek only for 2002.

Table 6 EPA and Missouri 303 (b) and 303 (d) List Comparisons

	2002	2004	2006
EPA 305 B List	Y	Yes Partially	Yes Partially
EPA 303 (d) List	Y	N	N
MoDNR 303 (d) List	Y with 2004 Revision	Y*	Y*
*Mo DNR combined their 2004 and 2006 lists.			

EPA 303 (d) and TMDL

The EPA 303 (d) List was approved in 2002, identifying Dardenne Creek as impaired by an unknown pollutant. This listing generates the requirement for a TMDL calculation to besubmitted. In an interview with the MoDNR, TMDL Unit Chief, it was determined that a TMDL for Dardenne Creek has never been prepared by Missouri (Hoke, 2008). An incomplete water sampling set is the reason stated. It is anticipated that in September of 2008 the MoDNR will attempt to collect water samples to gain a better determination of the impairment and status of the Dardenne Creek.

4.8.1. § 305 (b) and § 303 (d) Comparison Summary

Comparison of the 305 (b) and 303 (d) Lists of EPA and MoDNR data for these lists indicate two apparent contradictions. One is that Missouri acknowledged the Dardenne Creek as impaired as evidenced in the 2002 305 (b) listing, however did not list the Dardenne Creek on the original 2002 303 (d) List. The second contradiction is the Dardenne Creek was listed on the Missouri 303 (d) List for the 2002 (as updated in 2004), 2004 and 2006 Lists, however, EPA only approved Dardenne Creek on the EPA 2002 303 (d) List.

The first contradiction may be due to Missouri's belief that while data collected indicated a lack of meeting the water quality standards of the 305 (b) List, the amount of frequency of the data collection was not sufficient to include the Creek on the 303 (d) List.

The second contradiction may be a result of EPA policy. The complete List may not have been reviewed to date and Dardenne Creek may be on the portion of the List not yet reviewed. Therefore, the portion of the List not reviewed cannot be approved. A second and possibly more plausible reason may be the fact that Dardenne Creek has been part of the focus of litigation at both Federal and State levels. Because of the delicate nature of the situation, EPA may want to verify Missouri's data before approving or disapproving the Creek's inclusion on the 303 (d) List for 2004 and 2006.

4.9. Litigation Regarding § 303 (d)

Since 1998 there have been three cases filed against the Missouri Clean Water Commission and the Missouri Department of Natural Resources for their lack of properly managing the §303 (d) List. Two of the cases were combined because the cases were similar in scope. In one instance the Petitioners' argument was that streams, which they believed should on the State Impaired Waters 303(d) List, were not included on the List. In another case the Petitioners argued that, while the Dardenne Creek was on the State 303 (d) List, the pollutant was designated as "unknown", and therefore, Dardenne Creek should not be on the List.

4.9.1. *American Canoe Association and Sierra Club v. U.S. Environmental Protection Agency*

On November 12, 1998, the American Canoe Association and Sierra Club filed a law suit against the U.S. Environmental Protection Agency in United States District Court for the Western District of Missouri. The plaintiffs alleged that the EPA failed to:

1. Approve or disapprove Missouri's 1998 Section 303 (d) List in a timely fashion and/or its approval of an inadequate Section 303 (d) List, and its failure to prioritize water

quality-limited segments (WQLSs) in Missouri;

2. Establish and implement TMDLs;
3. Propound a schedule for timely establishment of TMDLs by Missouri for all WQLSs;
4. Review, approve or disapprove of the State’s continuing planning process (CPP);
5. Revoke Missouri’s Title IV permit-issuing authority: and
6. All of the above constituted failures to perform nondiscretionary duties under the CWA, § 33 U.S.C. 1313 (d).

On January 25, 1999, the Federal District Court consolidated the Missouri Soy Bean Association (MBA) December 15, 1998 law suit against EPA with the American Canoe Association’s suit because of similar allegations regarding the Missouri 303 (d) List. The MBA suit contended that EPA should have disapproved Missouri's 1998 list of pollution-impaired waters because some of the listed waters lacked documentation of pollution.

The case was settled on August 18, 2000, where in a consent agreement and settlement agreement filed with the court, EPA agreed to certain commitments regarding CWA Section 303 (d) TMDL programs and the Continuing Planning Process (CPP) in Missouri. These agreements provided for a more active role by EPA to assist Missouri in improving its water quality assessment, plan development, and reporting programs. The settlement called for Missouri to update and maintain the 303 (d) Lists with closer scrutiny by EPA of reporting provided by the state of Missouri (MoDNR Case Litigations, 2008).

4.9.2. *Home Builders Association (St. Louis) vs. Missouri Clean Water Commission and Missouri Department of Natural Resources*

The Home Builders Association of Greater St. Louis (HBA) is a not for profit Missouri corporation, headquartered in St. Louis County with over 1,000 members comprised of builders, developers and others associated with the shelter industry in the St. Louis metropolitan area. On January 3, 2005, the HBA filed suit against the Missouri Clean Water Commission (MCWC) and MoDNR claiming that the both parties were imposing additional and regulatory requirements over and above those set forth in and authorized by 10 CSR 20-7.031, for certain permits that involved discharges into the Dardenne Creek watershed. These requirements include, but are not limited to, the additional or extra requirements to conduct water quality review and to intercept and treat stormwater. The imposition of these additional requirements also results in additional delays in the time normally required to issue permits. HBA argued that its members had incurred additional financial costs and lost project time as a direct result of the imposition of these requirements. (See Appendix D).

On February 6, 2008 a settlement agreement was reached between the two parties and HBA agreed to voluntarily dismiss its position in the pending case.
(See Appendix E).

Stipulations of the settlement were that each party will participate in the cooperative Biological Assessment of the segment of the Dardenne Creek included in the 2002 § 303 (d) List to determine the unknown pollutant.

4.10. Dardenne Creek § 303 (d) Summary

Since 1998, the EPA and MoDNR have experienced several laws suits with the CWA § 303 (d) Lists, brought forth by stakeholders of this watershed region. EPA has been accused of failing to approve or disapprove Missouri's 1998 Section 303 (d) List in a timely fashion. The EPA was also accused of failing to propound Missouri to establish TMDLs for all WQLSs in a timely fashion. Whereas, MoDNR has been challenged with the lack of response in identifying an "unknown" pollutant for Dardenne Creek, that was on the Missouri 303 (d) List, in a timely fashion, thereby the cause of extra burden and costs to the residential building association.

As a result, the U.S. EPA has given direct attention to the MoDNR 303 (d) listings. In two letters from EPA to the MoDNR, dated April 29, 2003 and September 27, 2007, EPA summarized and partially approved the State of Missouri's final 2004/2006 CWA Section 303 (d) impaired waters List and the Methodology for the Development of the List. However, EPA is continuing to review a portion of the State's submission and has requested additional documentation and supporting information. MoDNR is working to gather supporting information. Rather than delay a decision on the entire submission, EPA partially approves Missouri's 2004/2006 CWA Section 303 (d) List and deferred action on the remaining water bodies and associated pollutants pending additional water quality data collection.

The Dardenne Creek currently is one of the water bodies that is on the 2004 and 2006 Missouri 303 (d) List as impaired, submitted electronically to EPA on April 20, 2007. However, while EPA has approved a portion of Missouri's list, Dardenne Creek remains on a portion of the List that EPA has not yet reviewed for approval or disapproval for inclusion on the 303 (d) List. EPA is continuing to assess that portion of the List.

CHAPTER 5

5. DARDENNE WATERSHED STAKEHOLDERS

The coordination from local alliances to the State, Regional and Federal Governmental levels is a challenging and daunting task due to the dynamics of both the physical landscape and political realities. This section presents a sample of the stakeholders involved in formulating a unified perspective of the Dardenne watershed. (Tables 6-9).

A fundamental aspect of this dissertation is to understand the roles of the various shareholders, the work of each group of shareholders and the constraints they encounter to ensure a viable holistic watershed management plan. To better understand the system, interviews were held with various stakeholders within the community. The information obtained was by consensual agreement and the information provided in this dissertation is based on these personal interviews.

5.1. The Missouri Clean Water Commission (CWC)

The Missouri Clean Water Commission is a seven-member citizen's board that is appointed by the Governor and confirmed by the Senate. The responsibilities of the CWC include developing Missouri's Water Quality Standards, 10 CSR 20-7.031 and developing Missouri's list of impaired waters, 303(d) List required by the Clean Water Act. They are the governing body that issues permits limiting the discharge of pollutants into the state's waters and take enforcement action against those who violate the Missouri Clean Water Law and implementing regulations. The CWC also provide certification of operators for municipal wastewater facilities and the Concentrated Animal Feeding Operation waste management systems.   The CWC oversees financial assistance to protect and preserve water quality and is responsible for developing the Nonpoint Source Management Plan outlining Missouri's approach to addressing nonpoint source pollutant problems.   The CWC also maintains a 303(e) Continuing Planning Process that intended to bring together and coordinate all aspects of water pollution control in an effort to assure the state maintains progress toward protecting and preserving water quality (MoDNR, 2006).

5.2. Missouri Department of Natural Resources

For more than a decade, local authorities in St. Charles County have worked with various Federal and Missouri State agencies to create an updated flood model for Dardenne Creek and its tributaries. Beginning with a research grant provided by the Environmental Protection Agency in 1997, the Missouri Department of Natural Resources has been involved with city and county representatives in St. Charles County, in an effort to better understand the Dardenne Creek watershed (U.S. Army Corps of Engineers, 2007).

5.2.1. The MoDNR Water Protection Program

The MoDNR Water Protection Program is comprised of various branches including the Water Pollution Control Branch. The water pollution control branch oversees the monitoring and assessment of water quality data collected by MoDNR and provides the reporting of stream health status to the CWC for the development of the Section 303(d) List. The MoDNR was extremely helpful in readily providing the raw chemical and biological data that was used for this study. However, this dissertation research determined that the various watershed programs were based on specific missions of the individual departments' areas of interest. It was not clear that the programs were inter-related adequately within the scope of a watershed perspective.

5.2.2. The MoDNR Volunteer Water Quality and Monitoring Program

The MoDNR Volunteer Water Quality Monitoring Program is a partnership between the Department of Conservation, Department of Natural Resources, the Conservation Federation of Missouri and the citizens of Missouri (MoDNR, 2008). The goals of the MoDNR Volunteer Water Quality and Monitoring Program include:

- Informing and educating citizens about the conditions of our streams;
- Establishing a monitoring network;
- Generating water quality data;
- Enabling citizens to be active participants; and,
- Halting degradation of Missouri streams (MoDNR, 2005).

The volunteer program offers different levels of involvement and commitment that build on each other. Volunteers are expected to share the knowledge they gain with their community, periodically monitor a stream and submit collected data in a timely manner. Volunteers begin by mapping their watershed, submitting a visual survey of their selected sites and submitting benthic macroinvertebrate data. With further training volunteers learn to collect samples for chemical and microbiological parameters. Water quality volunteers often work in conjunction with Missouri Stream Teams. The Missouri Stream Team organization is a network of citizens who are concerned about Missouri streams.

5.3. St. Charles County Government

The St. Charles County governmental offices have three main divisions that pertain to this dissertation: Community Development; Information Systems and Environmental Services. Although the scope of their missions is not focused around a watershed perspective, each division contributes to the understanding and oversight of the Dardenne Creek watershed.

The Community Development Department is divided into four divisions consisting of: Building Code Enforcement, Development Review, Neighborhood Preservation (Code Enforcement), and Planning and Zoning. These four divisions provide services related to permitting and inspecting new construction, community planning, zoning and subdivision matters, neighborhood preservation inspections and, reviewing and approving development improvement plans (St. Charles County Divisions, 2008).

The Planning and Zoning Commission has the power to make, amend, and publish for later adoption by ordinance, an official Master Plan of the County to assure the coordinated development of the County in accordance with present and future needs.

Since 1959, the St. Charles County Master Plan has been amended several times to better reflect changing circumstances and policies of the fastest growing county in the state of Missouri. The Master Plan evaluates current conditions and future trends to provide a benchmark point of reference with regard to the effective implementation of public policy. The primary goal of the Master Plan is to balance, on a countywide basis, the competing issues and interests which affect future growth and development patterns within the county. It sets policies, as well as indentifying and evaluating community planning goals and areas of community concern. It is intended to provide a long-term vision with basic goals, strategies, policies, and recommendations to help guide the county's future growth and development to better serve its citizens.

The County Charter requires the review of the Master Plan at least every five years, with the next suspense date being June 30, 2008. In order to facilitate this review and drafting an updated the Master Plan, the County Executive has appointed a steering committee of sixteen citizens to oversee this effort. The Master Plan Steering Committee is composed of 2 council members, 3 members of the county administration, and 11 community members.

An important part of the Master Plan review process is providing opportunities for public comment and participation. Multiple opportunities for public comment and participation are being provided via the St. Charles County web site. The first public forum designed to encourage participation in a land use planning exercise was held in February 2008.

When adopted, the Envision 2020 Master Plan will be one of the primary tools used to assure the coordinated development of the county, promote the general welfare and prosperity of its people, and set policy regarding the social, governmental, economic, and physical development of the county (St. Charles County Government, 2008).

The Information Systems Division provides services in Geographic Information Systems and access to static GIS maps created by the county for the community public use. This division provided the original GIS infrastructure data set shapefiles for this research in 2004 at no cost upon request. Since this time, the updates to the 2004 St. Charles County GIS data set require a fee to be paid in order to acquire the updates. (See Appendix G).

The Community Development Division's primary focus is land development oversight in St. Charles County. The Division of Development Review analyzes all new development in unincorporated areas of St. Charles County to ensure that site improvements, including grading, erosion control, stormwater facilities, and street design comply with the Unified Development Ordinance (UDO), design standards and prudent engineering design practices. The review process is designed to minimize the impact of new development on properties outside of the development area and to ensure that all publicly dedicated facilities meet the county's standards for public maintenance. Development Review ensures that the UDO, Design Criteria for the Preparation of Improvement Plans, tree preservation, streambank protection, and flood plain encroachment regulations are adhered to when reviewing a proposed development.

The St. Charles County Division of Environmental Services' mission is to protect public health by minimizing pollution, providing environmental education, and by conserving natural resources. This division is also responsible for regulating solid waste storage, collection, transportation, and disposal within the unincorporated areas of the St. Charles County (St. Charles County: Divison of Environmental Service_2008) .

5.4. Army Corps of Engineers

Although individual streams have been studied with detailed hydrologic methods for the St. Charles County Flood Insurance Study, no comprehensive study had been undertaken for a major stream in the area, including all of its tributaries. The Army Corps of Engineers initiated the Dardenne Creek Watershed Study in 2004, noted as the first of its kind in St. Charles County. This three year project focused on analyzing the likelihood of flooding for Dardenne Creek, as well as for all of its tributaries greater than one square mile in drainage area. Various flood frequencies had been analyzed for the existing watershed conditions, and the future conditions had been estimated, to anticipate the frequency and magnitude of flooding in the future (U.S. Army Corps of Engineers, 2007). The summary of the methods of this study is discussed in Chapter Seven.

5.5. The USGS Long Term Research Monitoring Program

The Long Term Resource Monitoring Program was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The Long Term Resource Monitoring Program was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program (USGS LTRM, 2004). The USGS LTMR partnered with the MoDNR for water quality data gathering that resulted in some of the data sets presently being used in the analysis of this dissertation.

5.6. The Home Builders Association of Greater St. Louis, Inc.

The Home Builders Association (HBA) is a not for profit Missouri corporation, headquartered in St. Louis County with over 1,000 members comprised of builders, developers and others associated with the shelter industry in the St. Louis metropolitan area (Home Builders Association of Greater St. Louis, 2008).

As discussed in Chapter Four, in January, 2005, the HBA brought forth a legal petition for Petition for Declaratory and Injunctive Relief, against the Missouri Clean Water Commission (MCWC) and the Missouri Department of Natural Resources.

The HBA was seeking a determination that the MCWC and MoDNR were exceeding their legal authority by imposing additional and extra regulatory requirements over and above those set forth by State law, in certain permits that involved discharges into the watersheds of Dardenne Creek, Peruque Creek, Flat Creek and Mill Creek. These requirements included, but were not limited to, the additional or extra requirements to conduct water quality reviews and to intercept and treat stormwater. The HBA claimed the imposition of these additional requirements also resulted in additional delays in the time normally required to issue permits to develop or build in these watersheds.

This dissertation research involved multiple requests from MoDNR general counsel for progress and settlement status of this case.

Stipulations of the settlement agreement reached on February 6, 2008, state that each party will participate in the cooperative Biological Assessment of the segment of the Dardenne Creek included in the 2006 § 303 (d) List to determine the unknown pollutant.

The cooperative Biological Assessment may serve as a pilot for other similar cooperative solutions. The Department will prepare the scope of work for the study which may address macroinvetebrate, water chemistry, benthic fine sediment and other parameters. During an interview held for this dissertation with the MoDNR, it was found that the Department will conduct a bio-assessment in September 2008 consisting of sediment and macro-invertebrate surveys at several points in Dardenne Creek. Surveys will use a weighted evidence approach. No volunteers will be utilized. The surveys are said to take a couple of weeks.

HBA will have the opportunity to review the proposed scope of work and provide any comments. MoDNR will implement the scope of work, and HBA, as its option, may participate in the study, obtain split samples, or conduct its own sampling. The interview revealed that it is probable the HBA, at their own expense, will hire a consultant to review MoDNR's data or hire a consultant to conduct a simultaneous survey of their own for comparison purposes with MoDNR's survey data (Morrison, 2008).

HBA and the Department agree that any recommendation to place a stream on any § 303 (d) List will be based on the evidence analysis using scientifically obtained evidence as prescribed by the Commission's approved *303 (d) Listing Methodology Determinant* (Missouri Clean Water Commission, 2008) .

5.7. Private Organizations, Alliances and the University of Missouri. Columbia

There are many active organizations in the metropolitan area with blended watershed preservation and management goals. (See Appendix F).

The Greenway Network is a grassroots, volunteer-based organization whose mission is to conserve natural resources, encourage sound management of land and waterways and watersheds in the St. Louis Metro (Greenway Network. Inc. 2008). The Dardenne Creek Watershed Alliance was organized in 2000 however, it is currently being reorganized by the Greenway Network.

The Missouri Stream Team is a network of citizens who are concerned about Missouri streams, and provides an opportunity for all to become involved in stream conservation. Stream Team membership is free to any interested citizen, family or organization (Missouri Stream Team).

The Clean Stream Education Initiative is a current a statewide network of secondary school science teachers of watersheds in St. Charles, Boone, Cole, Audrain, Cooper, Lincoln, Pettis, Madison, Pemiscot, Jackson, Bolivar, Franklin, St. Louis, Osage, St. Louis City, and Howard Counties. Teachers are encouraged to implement a science curriculum based on water quality testing methods and fieldwork that meets the Grade Level Expectations of the Missouri State Standards. The goal of the project is to encourage students to participate in volunteer water quality monitoring on local streams, creating Stream Teams, organizing stream litter pick-ups, and making educational presentations about water quality in their communities (Greenway Network. Inc. 2008).

The charter for the Great Rivers Greenway District (GRG) is to promote the use of greenways near major waterways throughout the St. Louis metropolitan region. Greenways are created to maintain open space near creek channels, and to utilize that area for recreation, flood control, and/or ecosystem restoration purposes. To achieve their mission, the District is developing The River Ring that will encompass a 600-mile web of more than 45 greenways. The River Ring will cross in various areas across the region to include St. Louis City, St. Louis Count and St. Charles County, Missouri and Madison and St. Clair counties, Illinois. The River Ring will provide access to trail and greenways to provide economic, environmental and social benefits. Great Rivers Greenway District is funded by a 1/10th of 1 cent sales tax raised in St. Louis City, St. Louis County and St. Charles County, which generates $10 million annually (Great Rivers Greenway District, 2008).

The combination of the Dardenne creek watershed's stakeholders' roles and missions are both dynamic and complex. This section provided a sample review of several stakeholders for this watershed.   A fundamental challenge is that there is not one single defined leader or authority with a watershed management perspective in place to date.

The governance roles are defined by regulation while the private businesses and alliances are driven by a particular interest. Some businesses argue that environmental regulations entail excessively high compliance costs, restrict businesses and personal decisions that some businesses believe put the business industry in a competitive disadvantage. Environmental alliances complain that the existing regulatory structure is incremental, short-sighted, and piecemeal, too weak to protect current and future generations. States complain about centralized and inflexible federal rules that take a "one-size-fits-all" approach to environmental issues. Local communities are increasingly upset by environmental decisions they believe are unfair and in which they do not participate. Academics denounce environmental regulations they find to be ineffective, inefficient, overly prescriptive, and lacking accountability (Sexton and Murdock, 1996).

A continuing challenge for each of the stakeholders is to be apprised of the related regulations, disparate plans, and goals in order to better align resources and alleviate redundancies. Opposing views related to individual missions and agendas are often the cause of the impasse toward a successful and holistic watershed plan. Adequate resources are also a limiting factor in watershed planning. When reviewing the charters of private alliances and research studies it ,was found that the various alliances are often competing for the same limited resources to conduct a study.

Public opinion polls consistently find that even though people tend to be dissatisfied with government in general, they express strong agreement with the need for environmental regulations - provided the regulations furnish adequate protection for everyone, and at a reasonable cost (Sexton K. et al, 1999). A watershed management approach is not required by regulation, however if a watershed plan framework were in place that would include the participation of all stakeholders, a comprehensive plan could be developed to mitigate these barriers.

Introducing GIS to the watershed plan framework will be an invaluable tool which will allow existing and disparate data sets to be incorporated, integrated, and analyzed. This information derived from GIS will assist all stakeholders in better understanding the holistic approach to watershed management.

Table 7 Dardenne Watershed Federal Governmental Agencies

Agency/Organization	Type of Assistance
Federal Governmental Agencies	
U.S. Army Corps of Engineers	Planning, designing, building and operating water resources and other civil works projects (Navigation, Flood Control, Environmental Protection, Disaster Response, etc.)
U.S. Department of Agriculture	Provide leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management.
U.S. Environmental Protection Agency	Environmental Regulatory Agency
U. S. Fish and Wildlife Service	Provides permits as a means to balance use and conservation of protected species. to promote long-term conservation of animals, plants, and their habitats, and encourage joint stewardship with others.
U.S Geological Survey	Unbiased, multi-disciplinary science organization that focuses on biology, geography, geology, geospatial information, and water, for timely, relevant, and impartial study of the landscape, our natural resources, and the natural hazards

Table 8 Dardenne Watershed Regional and State Governmental Agencies

Agency/Organization	Type of Assistance
Regional & State Governmental Agencies	
U. S. Environmental Protection Agency Region VII	Scientific information, permit review, compliance assistance
Fish & Wildlife Service	Cost sharing, permit review
Missouri Department of Agriculture	International and domestic marketing, financial assistance programs, regulatory programs and inspection services, disease eradication and testing, and policy
Missouri Department of Natural Resources	Cost share, loans, technical, education regulations, permits, monitoring
U. S. Environmental Protection Agency: Surf Your Watershed Program	Watershed Information
U.S Department of Agriculture Natural Resources Conservation Service	Conservation, technical, financial and educational assistance programs

Table 9 Dardenne Watershed Local Governmental Agencies

Agency/Organization	Type of Assistance
Local Governmental Agencies	
Corps of Engineers For Dardenne Creek Watershed Study	Hydrologic, biologic, geologic and mapping information
Corps of Engineers St. Louis District	Permits, river stages, emergency flood management
Health Department	Consultation, technical assistance for sewage and water supply systems
Missouri Cattlemen's Association	Legislative issues affecting the cattle industry
Missouri Department of Conservation	Information and technical assistance on stream and pond management, forest improvement and wildlife management
Missouri Farm Association (MFA) Inc	Pesticide container recycling program, Environmental Studies Internship
Missouri Pork Producers Assoc.	Environmental Assurance Program, On-Farm Odor/Environmental Assistance Program
U.S. Department of Agriculture Rural Development	Loans/Grants for home ownership and repairs; loans/grants for community facilities, water and sewers systems; direct and guaranteed business loans
Soil and Water Conservation District	Financial incentives, technical assistance, information/ education materials
University of Missouri Extension	Research-based information, demos, educational programming

Table 10 Dardenne Watershed Private and Advocacy Organizations

Agency/Organization	Type of Assistance
Universities, Private & Advocacy Organizations	
Brookside Environmental Services Community Clean Water Initiative	Water Quality Assessments for Dardeene Watershed
Confluence Greenway	Regional effort to become a sustainable, natioanlly significant park and trail system.
Dardenne Creek Water Guage Data: O'Fallon, MO	Provided real-time Rain Gauge Data
Dardenne Creek Water Guage Data: Old Town St. Peters, MO	Provided real-time Rain Gauge Data
Farm Bureau	Public Policy Issues
League of Conservation Voters	Independent political voice for the environment.
Missouri Stream Team	Promoting health for Missouri's 110,000 miles of streams with citizen participation.
River Flows For Missouri From US Geological Survey	Provide River Flows for Missouri Rivers
Sierra Club, Ozark Chapter	Natural resouces advocacy
Southwestern Illinois RC&D, Inc.	Develops and support partnerships, create programs and implement projects that are responsive to the needs of the people within the region, that strengthen local economies, and that encourage the conservation of our environmental resources.
St. Charles County Greenway Network	a grassroots, volunteer-based organization whose mission is to conserve natural resources, encourage sound management of the area's watersheds and protect the quality of life for all citizens.
St. Charles County Government Community Development	Land Development, Permits
St. Charles County Government Division of Environmental Services	Watershed Outreach Programs
St. Charles County Government Information Systems Data Sets	Information Systems works with various departments to provide information to the public through this website. Some of the datasets available are listed below
St. Louis District - Planning, Programs and Project Management Division	Manages U.S. Army Corps of Engineers projects from the study phase through construction completion--including an inspection and assistance role throughout the operation and maintenance of the project.
Trailnet, Inc.	Providing community bicycle/pedestrian planning services to help cities design streets where people can safely walk and bike;
Trust for Pulic Land	A national, nonprofit, land conservation organization that conserves land for people to enjoy as parks, community gardens, historic sites, rural lands, and other natural places, ensuring livable communities for generations to come.
U.S. Department of Agriculture Farm Service Agency	Conservation cost-share programs, commodity loans, commodity programs and farm loans

CHAPTER 6

6. RELATED & HISTORICAL DARDENNE WATERSHED WORK

The following section summarizes two watershed studies for St. Charles County, the Peruque Creek Watershed Study and the Dardenne Creek Watershed Study. The purpose of this section is to show the relevant work completed to date and how these studies can serve as a baseline to integrate into a Dardenne Creek watershed management plan. This section is a precursor to the original geographic information systems (GIS) analysis research conducted in Chapter Seven.

6.1. The Dardenne Creek Watershed Study

In an effort to gain more information about the frequency and magnitude of flooding on the creek, in late 1999 the Dardenne Watershed Alliance paid for the installation of two river gages by the United States Geological Survey (USGS). The gages, one at Highway K in O'Fallon, and one in Old Town St. Peters, measured the hourly stream flow discharge and stage level of Dardenne Creek. The information from the gages is stored in a database and used for calibration of hydrologic and hydraulic models to be produced in the future.

In late 2001, the Dardenne Watershed Alliance produced the Dardenne Creek Greenway Conceptual Plan. The goal of the plan was to conserve the Dardenne Creek corridor through improvements to water quality, stormwater management, park management, and a system of trails near the creek. This was an important step in the history of Dardenne Creek, as it represented a highly focused approach, involving all of the local city and county governments.

The group continued gathering information about the watershed, in the hopes of finding a funding source for a more substantial study of the entire watershed area. This study was to be followed by the execution of the Greenway plan.

In the following years, the Watershed Alliance began discussions with the U.S. Army Corps of Engineers in an attempt to develop a watershed study project that would utilize the experience that the Corps has in Hydraulic Analysis. The original incarnation of the study was to take place from the Corps' 2003 to 2004 Fiscal Years. The Army Corps of Engineers was to perform an extensive hydrological, soils and topology data gathering effort, as well as perform detailed hydrological study for an estimated cost of $600,000.

The Dardenne Creek Watershed Study was a three year comprehensive hydraulic study from, 2004 – 2007, of the Dardenne Creek and its tributaries. The study was performed by the U.S. Army Corps of Engineers, St. Louis District, Hydraulics Branch. Prior to this study, the St. Charles County Flood Insurance Study (FIS). The study represented a detailed hydraulic analysis of the streams in the Dardenne Creek watershed. However, at the time of the FIS report, the majority of the hydraulic models from the FIS were between 10 and 30 years old. Although Dardenne Creek and many of its tributary streams have been studied individually with detailed hydrologic methods, no comprehensive hydrological watershed study had been undertaken for a major St. Charles

County stream. The Dardenne Creek Watershed study was initiated to update the flood plain profile and involved a regional approach, including incorporating all major tributaries.

Changing watershed conditions and rapid development throughout St. Charles County increased the potential for worse flooding conditions elsewhere in the watershed. Local authorities were in need of an updated version of the hydraulic models with the most technically advanced methods. Since the individual studies were completed at different times, and by different engineering companies and agencies, the methods of analysis used were widely varied.

The Dardenne Creek Watershed study was funded by the Planning Assistance to States (PAS) Program. The PAS program is a type of project authorization used by the Federal Government to enter into cost-sharing agreements for water resource projects that benefit a large state or county community. The Planning Assistance to States (PAS) program was the most appropriate funding source because of the comprehensive nature of the study, and its resulting usefulness to the quickly growing St. Charles County.

The U.S. Environmental Protection Agency entered into a 50/50 Cost Sharing Agreement with local sponsors. The Dardenne Watershed Alliance brought the Great Rivers Greenway District (formerly the Metropolitan Parks and Recreation District) in as the primary project sponsor, and the Corps agreed to cover the remaining half of the non-federal project cost. The Great Rivers Greenway District entered into agreement with local communities to share their portion of the non-federal study cost with local sponsors, including the following: St. Charles County, and the Cities of St. Peters, O'Fallon, St.

Charles, Cottleville, and Dardenne Prairie. The Great Rivers Greenway (GRG) provided the local portion of funding up front, which was $100,000 each Fiscal Year. In another cost sharing agreement with the local authorities, the cities of Cottleville, Dardenne Prairie, O'Fallon, St. Charles, and St. Peters, and St. Charles County, provided a total of $50,000 each year.

The Federal funding for the Dardenne Creek Watershed Study project was put into place in May 2004. Surveys and mapping contracts were the first priority, and other data collection efforts and a helicopter survey of the creek got the study underway.

The goal of this program was to prepare comprehensive plans for water resources and related land resources. The final report was issued on January 10, 2007.

6.1.1. Dardenne Creek Hydrological Study Objectives

This US Army Corps of Engineers report covered a three year hydrological study which included the evaluation of land cover topography and soil data collected by the U.S. Geological Survey (USGS). The purpose of this project was to analyze the likelihood of flooding for Dardenne Creek, as well as all of its tributaries greater than one square mile in drainage area.

The following flood frequencies were analyzed for the base condition in the watershed: 2, 5, 10, 15, 25, 50, 100, and 500-year storms, with a 48-hour duration. The forecasted conditions were analyzed to anticipate the frequency and magnitude of flooding based on the planned development of the watershed. Due to the various forecasting methods for each city and county office, a single date in the future that represents the forecasted condition could not be chosen.

The analysis of the entire system of tributaries was intended to represent a major improvement over previous hydraulic models of the streams. Instead of simply studying the individual creeks, this comprehensive, basin-wide approach provided a better understanding of the streamflow in the Dardenne Creek watershed as an interconnected system.

Another key improvement for this study over the original Flood Insurance Study was the use of up-to-date GIS data to develop the watershed models. Using recent aerial photography, a terrain model was produced which could be a much better representation of the drainage in the Dardenne Creek watershed than USGS topographic maps. Soil and land use maps in GIS format were also used to estimate hydrologic parameters.

The finished product from this modeling effort could be used as a tool to analyze any number of potential projects affecting the watershed. Stream stabilization, flood damage reduction, ecosystem restoration, and recreation are all possible applications that could make use of the hydraulic models. As the primary project sponsor, Great Rivers Greenway will be able to use the watershed models to analyze the effects of their planned trail system on the stream dynamics. Ultimately, the watershed models will be in the public domain, and used for any suitable application, at the discretion of local authorities and the GRG. In an interview with the lead Army Corps Engineer in April 2008, it was found that since the time of the hydrological watershed study publication, there has been no further action taken to integrate the findings into a Dardenne Creek watershed plan. The Army Corps of Engineers project management team in the St. Louis district had talked about addressing flooding concerns or erosion problems, but to date, there are no current plans for a follow-up study. Project managers are reviewing budget contributions, but have not been approached by any local St. Charles County organization or governmental office to initiate a follow-up study or to finalize a plan. (Boeckmann, 2008).

6.2. The Peruque Creek Watershed Study

The Peruque Creek Watershed is located north and adjacent to the Dardenne Creek Watershed. The Peruque Watershed Alliance, formed in August 2001, is composed of residents and stakeholders, staff and members of Peruque Creek Watershed communities and interested people from St. Charles and Warren counties. The local community has been actively involved in pursuing the health of Peruque Creek. The Alliance began developing a watershed plan for Peruque Creek. The plan laid out objectives and strategies to minimize and prevent future impacts to natural resources, residents and communities in St. Charles and Warren counties.

In the spring of 2002, the city of Lake St. Louis received a grant from the U.S. Environmental Protection Agency for a special study on Peruque Creek. The consulting firm of Camp, Dresser and McKee (CDM) Inc. was hired to conduct the study to define the challenges to the creek regarding water quality and to suggest solutions to protect the creek as a healthy waterbody. In the course of the study, CDM attempted to gather and review all available data pertaining to Peruque Creek. The report identified gaps in the data and conducted sampling to fill those gaps. Water quality monitoring volunteers and Missouri Lakes Volunteer Program participants contributed in collecting data. The results of this study, with CDM's recommendations, were compiled in a final report published May 2005.

The Peruque Creek Watershed Alliance was intended to be responsible for implementing the CDM recommendations. An important component of their strategy was to provide public education to increase awareness of the environment in general and the Peruque Creek watershed in particular. The report findings concluded that the Peruque Creek Watershed needed a unified and comprehensive Watershed Management Action Plan that would addresses all of the stakeholders' objectives throughout the basin, based upon a sound, scientific assessment of the relationships related to the water and land use resources within the watershed.

An interview with the Peruque Creek Watershed Alliance chairperson in April 2008 revealed that the plan, while comprehensive in scope, did not define the specific actions necessary to implement the findings. However, due to Watershed Alliance fiscal constraints, the plan has not been implemented. As of the final report in 2005, there have been no further actions taken to implement this study (Grossman, 2008), The Alliance stated that an overview of the scope of this dissertation presented to the Peruque Creek Watershed Alliance would be useful. An invitation to speak on the subject Holistic Watershed Management Plan from the basis of this dissertation was extended and accepted.

CHAPTER 7

7. DATA ANALYSIS

This section discusses the biological and chemical input data sets used to conduct geographic information systems analysis for this research. The input data sets are large and have many parameters which, to date, have not been plotted into a geographic information system (GIS). Therefore, no geospatial historical trend analyses have been performed by the MoDNR or St. Charles County. The scope of this analysis is to integrate over 17 years of disparate existing data sets into a GIS. The geostatistical analysis in this dissertation does not correlate all of the variables in the array. Rather, the preliminary findings from the geostatistical analysis denote areas of research that could be performed for future holistic watershed analysis.

The emphasis of this chapter is to illustrate how existing and disparate data sets can be incorporated into a GIS to provide the analysis, historical comparisons, and understanding of data interrelations. With the use of GIS technology, the results can lead to more integral and rational land use management for the watershed.

The water quality data provided for this research have been quality assured by the Missouri Department of Natural Resources, Water Pollution Control Program, Office of Water Quality Monitoring and Assessment Unit Missouri Department of Natural Resources. (MoDNR, 2008).

7.1. GIS Overview

The definition of a geographic information system (GIS), also known as a geographical information system or geospatial information system, is any system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to Earth. In the strictest sense, it is any information system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations.

Geographic information system technology can be used for scientific investigations, resource management, asset management, environmental impact assessment, and urban planning.

The data sets assembled for this dissertation were acquired from the Missouri Department of Natural Resources and the St. Charles County government. Some data were also attained from the Army Corps of Engineers, St. Louis Hydrological Unit: *Dardenne Creek* [hydrological] *Watershed Study*.

7.1.1. MoDNR Water Quality Program

The Department of Natural Resources Water Quality Monitoring Section's mission is to ensure that Missourians will have clean water for drinking, recreation, tourism and continued economic growth. MoDNR staff travel to all areas of the state, conducting a variety of investigations. These investigations routinely include wastewater discharge monitoring, groundwater monitoring, electrofishing and stream surveys. The section often assists with special projects such as enforcement actions, environmental risk assessments or damage assessments resulting from chemical spills. Scientists collect and evaluate a wide variety of water, sediment and benthic macroinvertebrate samples. The results of these studies are intended to be used to ensure the ecological health of the rivers, streams and lakes of Missouri. (MoDNR, 2008).

Currently the MoDNR Water Quality Office does not post information on their website related to the raw chemical or biological data sets that they collect. The MoDNR made the water quality data sets available for this research study, upon request, therefore allowing the data to be assembled into a GIS. The data sets provided were in Microsoft EXCEL™ format. There were three major sources of raw data input provided upon request.

1) The MoDNR chemical data sets were provided by the Water Quality Monitoring and Assessment Division (Ford, 2008). The raw data sets were collected by both MoDNR and USGS Long Term Research Monitoring program from 1983-2007.

2) The MoDNR biological data sets were provided by the Water Protection Program (Sarver & Hemple, 2008). The raw data sets provided were collected in 2001, 2002, 2005, 2006.

3) The MoDNR Volunteer data sets were comprised of both biological and chemical data collections. The raw data sets were collected from 1994-2007 (Stotts, 2008).

4) The MoDNR Volunteer water quality data are intended to be used to inform and educate Missouri citizens; establish baseline data on rarely sampled streams; locate emerging water quality problems and identify long term trends in stream conditions. Highly trained volunteers collect data that can be used to supplement agency-collected data (Missouri Department of Natural Resouces, Volunteer Water Quality and Monitoring Program, 2008).

7.1.2. St. Charles County Government

The St. Charles County Information Systems Division provided the initial 2003 GIS urban features of their jurisdiction in shapefile format, upon request in 2003. However, currently the infrastructure and land use data files are only provided for a fee. Therefore, files, since the required fee went into effect, are not included.

7.2. Data Assembly

This research entailed a compilation of Dardenne Creek watershed water quality in three designated site areas (or zones) taken from three independent parcels of the watershed:

Zone A: headwaters (primarily rural);

Zone B: middle reaches (heavily developed residential area); and

Zone C: Mississippi floodplain (agricultural with proposals to develop commercially).

7.2.1. Physical and Chemical Data Sets

When human activities alter the concentration of naturally occurring chemicals or introduce foreign substances into a stream, the results may be toxic to life in the stream.

Figure 15 is the set of twenty two chemical parameter samples that are collected by the MoDNR Water Quality Monitoring and Assessment Division.

Temp (C)	DO mg/L	pH	KJN mg/L	NH_3N mg/L	NO_3N mg/L
PO_4 mg/L	TP mg/L	Alk mg/L	Hard mg/L	TSS mg/L	TRB (ntu)
FC/100ml	Ecoli/100ml	Ca mg/L	Mg mg/L	Na mg/L	K mg/L
HCO_3 mg/l	SO_4 mg/L	Cl mg/L	SC (Specific Conductivity)(µS/cm)		

Figure 15 MoDNR Water Quality Parameters, 2006 (Serrano O. , 2008).

The significance of testing these chemistry parameters follows:

pH

pH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or too basic, the hydrogen ion (H^+) or hydroxyl ion (OH^-) activity may disrupt critical biochemical reactions, resulting in harm or death to stream organisms.

Changes in pH of a stream may affect aquatic organisms indirectly by changing other aspects of water chemistry. For example, as pH increases, smaller amounts of ammonia are needed to reach a level that is toxic to fish. As pH decreases, the concentration of metals may increase because higher acidity increases their ability to be dissolved from sediments into the water. Metals such as copper and aluminum can disrupt the function of fish gills or cause developmental deformities (Murdoch, 2001).

Dissolved Oxygen

Most plants and animals need oxygen for their growth and survival. If the dissolved oxygen concentration falls too low due to any of the following factors, a stream may not be able to support aquatic life.

The concentration of dissolved oxygen in a stream is affected by various factors, including:

- Temperature, with oxygen being more easily dissolved in cold water;
- Flow, with oxygen concentrations varying with volume and velocity of water flow in a stream;
- Aquatic Plants, the presence of which affects the dissolved oxygen concentration by the process of photosynthesis. This may vary between daylight and dark hours;
- Altitude, with oxygen being more easily dissolved into water at lower altitudes.
- Dissolved or suspended solids, with oxygen being more easily dissolved into water with low levels of dissolved or suspended solids; and,
- Salt, water tending to have lower concentrations of dissolved oxygen than fresh water (Murdoch, 2001).

Anthropogenic Influence on Changes in Dissolved Oxygen

- Excessive organic waste from sewage treatment plants, malfunctioning septic systems or runoff of manure from animal operations;

- Urban runoff from impervious surfaces carrying salt, sediment and other pollutants raise the total solids in the water and reduce the amount of DO it can hold;
- Removal of vegetation in the riparian corridor which causes increased water temperature, erosion resulting in an increase of suspended solids which causes a decrease of DO levels (MoDNR, 2005).

Water Temperature

Water temperature is important because most of the physical, chemical, and biological characteristics of a river or stream are directly affected by temperature.

Temperature affects

- The amount of gas, including oxygen, that can be dissolved in water;
- The rate of photosynthesis by algae and other aquatic plants; and,
- The metabolic rates of aquatic organisms

Riparian cover removal of trees impacts water temperature by eliminating shade along the river or stream (MoDNR, 2005).

Nitrates and Ammonia

Nitrogen is required by all living plants and animals for building protein. In aquatic ecosystems, nitrogen is present in the usable forms of ammonia and nitrate. However, excess amounts of nitrogen compounds, from various sources, including fertilizers, can result in unusually large populations of aquatic plants and /or organisms that feed on the plants. Algal blooms can be the result of this excess nitrogen. As aquatic plants and animals die, bacteria break down the organic matter and increase the biological oxygen demand (BOD), therefore, decreasing DO (MoDNR, 2005).

Phosphorus

Phosphorus is a plant nutrient found in fertilizers, wastewater from sewage treatment plants, runoff from feed-lots and animal waste. Small increases in phosphorus can result in a large impact on the growth of aquatic plants. This may be a factor in the eutrophication of the water with increasing BOD and decreasing DO (MoDNR, 2005).

Turbidity

Low turbidity water is clear, high turbidity water is cloudy or murky. Cloudy water is most often caused by suspended matter (e.g. soil particles) and plankton (e.g. as algae). Measuring the turbidity of water evaluates whether excess soil erosion or algal growth is occurring (MoDNR, 2005).

Conductivity

Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids, such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron, and aluminum. The presence of these substances increases the conductivity of a body of water. Conductivity parameters can be affected by failing sewage systems and agricultural runoff, especially with the increase of the presence of phosphates and nitrates (Murdoch, 2001).

Escherichia coli

Escherichia coli (E. coli) are coliform bacteria and are the commonly-used bacterial indicator for water quality chemical analysis. High concentrations of *E. coli* suggest the presence of disease-causing organisms. Sources contributing to the occurrence of pathogenic bacteria in streams are septic tank failure, poor pasture management and animal keeping practices, pet waste, urban runoff, and sewage from stormwater overflows (MoDNR, 2005).

7.2.2. Physical and Chemical Data Sources

The sources of the historical data sets are provided by the Missouri Department of Natural Resources and the U.S. Geological Survey (USGS), Long Term Research Monitoring Program (LTRMP) (Ford, 2008). The LTRMP is being implemented by the U.S. Geological Survey (USGS) in cooperation with the five Upper Mississippi River System states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), with guidance and overall Program responsibility provided by the U.S. Army Corps of Engineers.

The raw chemical data were provided in an EXCEL database for the years 1983-2007. There were twenty two site locations that were measured along the Dardenne Creek. The database contained a comprehensive list of these in situ water quality data measurements collected at all stations annotated by date and location. It should be noted that no measurements were taken between 1983 and 1993. The data were converted from EXCEL to a GIS shapefile and loaded into this project. Table 10 is a summary of MoDNR water chemistry samples taken per year and per site. Figure 16 is a map of water chemistry sample sites along Dardenne Creek.

Table 11 MoDNR and USGS Water Chemistry Samples and Site Summary

DNR_USGS_Chemistr			Zone A										Zone B						Zone C							
			Sites																							
Year	Sites Plotted	# of Records	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
1983	9	79															10	4	10	10	10	10	10	10	5	79
																										0
1993	1	12																							12	12
1994	1	24																							24	24
1995	1	21																							21	21
1996	1	22																							22	22
1997	1	27																							27	27
1998	5	46	5						5						5						5				26	46
1999	6	75	11						11						11		5				11				26	75
2000	6	19	1						2						2		1				1				12	19
2001	1	11																							11	11
2002	8	78		1	21			9	13	1	2	21													10	78
2003	6	30			4				4			4					4				4				10	30
2004	1	12																							12	12
2005	5	18				1	1	1		1															14	18
2006	10	30				1	1	1		1			2	2		2				2	2				16	30
2007	6	12											2	2		2				2	2				2	12
		516																								516

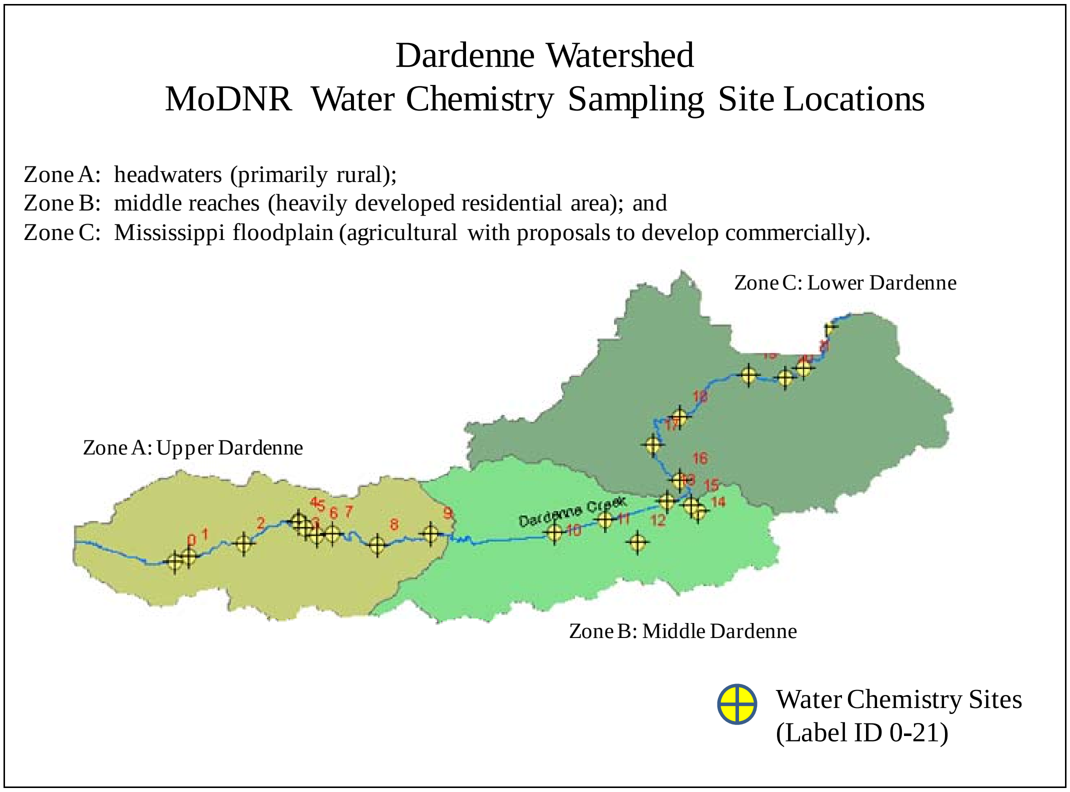


Figure 16 MoDNR Water Chemistry Site Locations (Serrano O. , 2008)

7.2.3. Biological Data Sets

Benthic Macroinvertebrates (BMIs)

Macroinvertebrates are good indicators of water quality as they are permanent residents of the stream. They can only move short distances. This makes them susceptible to pollutants that may be in the water. Some pollutants "pulse" through the water due to discharges of pollutant from a source at intermittent times or due to variation in flow with rain events. Chemical sampling will not always reveal this type of impact, but the macroinvertebrate community will reflect this impairment (MoDNR, 2005).

BMIs play a key role as a biological indicator of stream health and water quality because they:

- Are an important link in the food chain as recyclers of nutrients and also as food for fish;
- Are relatively sedentary and are exposed to pollutants, as opposed to fish which can swim away from the problems. They are often affected by subtle level of degradation, making their good indicators of stream health;
- Are easy to collect with simple and inexpensive equipment; and,
- Are easily identified and have sub-groupings of tolerant and intolerant organisms (MoDNR, 2005).

7.2.4. Biological Data Sources

The MoDNR biological data sets were provided by the Water Protection Program (Sarver & Hemple, 2008). The raw data sets provided were collected in 2002, 2005, and 2006. The Water Protection program assembled two final biological assessment reports in 2002 and 2006.

Table 11 is a comparison of the biological macroinvertbrate samples that were collected in 2002 and 2005 by the MoDNR Water Quality Monitoring and Assessment Division (MoDNR , 2002) and (MoDNR , 2006).

Table 12 Dardenne Creek Benthic Macroinvertebrate Community Sample Comparison 2002-2005 (MoDNR , 2006)

Biological Assessment Report
Dardenne Creek – St. Charles County, Missouri
September 2005 – March 2006
Page 14

Table 13
Comparison of Dardenne Creek Macroinvertebrate Community: 2002 Biological Assessment with the Present Study

	Dardenne Creek Station 3				Dardenne Creek Station 4				
Sample Year	s 2002	s 2006	f 2002	f 2005	s 2002	s 2006	f 2002a	f 2002b	f 2005
Taxa Richness	56	81	90	66	57	63	49	53	49
Number EPT Taxa	12	16	14	10	11	12	5	6	5
% Ephemeroptera	0.7	17.6	18.1	24.2	1.0	9.5	1.8	4.5	29.8
% Plecoptera	0.8	1.1	0.0	0.0	1.4	2.1	0.0	0.0	0.0
% Trichoptera	0.1	1.1	3.2	3.3	<0.1	0.3	2.1	2.5	0.0
MSCI Score	8	14	16	14	8	12	10	12	10
% Dominant Families									
Chironomidae	94.0	67.0	42.9	32.2	91	77.2	50.6	46.2	46.1
Enchytraeidae	0.5	--	--	--	1.5	--	--	--	--
Scirtidae	0.5	--	--	--	--	--	4.5	5.2	--
Baetidae	0.4	--	--	--	--	--	--	--	--
Perlodidae	0.4	--	--	--	0.7	--	--	--	--
Caenidae	--	16.6	16.2	22.0	--	8.6	--	--	28.7
Ceratopogonidae	--	2.8	13.3	5.9	--	--	--	5.2	--
Arachnoidea	--	1.7	--	--	--	--	--	--	--
Tubificidae	--	1.2	--	--	1.1	2.4	10.1	--	--
Tipulidae	--	--	--	--	1.2	--	--	--	--
Hyalellidae	--	--	4.1	9.7	--	1.5	13.9	12.0	2.9
Elmidae	--	--	--	6.6	--	1.5	--	--	6.5
Empididae	--	--	--	--	--	1.2	--	--	--
Hydrophilidae	--	--	3.4	--	--	--	--	--	--
Coenagrionidae	--	--	--	--	--	--	4.7	--	--
Planorbidae	--	--	--	--	--	--	--	4.9	--
Ancylidae	--	--	--	--	--	--	--	--	3.2

The 2005 Biological Stream Assessment report summarized that each of the biological assessment studies conducted on Dardenne Creek have coincided with extended periods of dry weather and low flow. As a result, the report stated it was unlikely that either assessment (2002 or 2005) was an accurate reflection of what the Dardenne Creek benthic macroinvertebrate community is during a season of average precipitation. It was recommend by the MoDNR Water Protection Program that an assessment be conducted within this study reach after the watershed has had at least two years of near-average precipitation to determine how the biological metric values and Benthic Macroinvertebrate Stream Condition Index (MSCI) scores respond to adequate flows.

The biological data sets provided for this GIS research were uploaded as input, however, they were not evaluated for geospatial trends. It is recommended that this work be performed in future studies, when the biological data samples collected could be integrated with the chemical data samples collected on same or near similar dates and seasons to allow for correlation analysis. This matrix had a total 1275 recorded entries, each containing multiple marcroinvertebrate samples, taken at each of the seven site locations. Table 12 is a summary of MoDNR water biological samples taken per year and per site. Figure 17 is a map of water biological sample sites along Dardenne Creek.

Table 13 MoDNR Water Biological Samples and Site Summary Table 2002, 2005, 2006

[redacted]

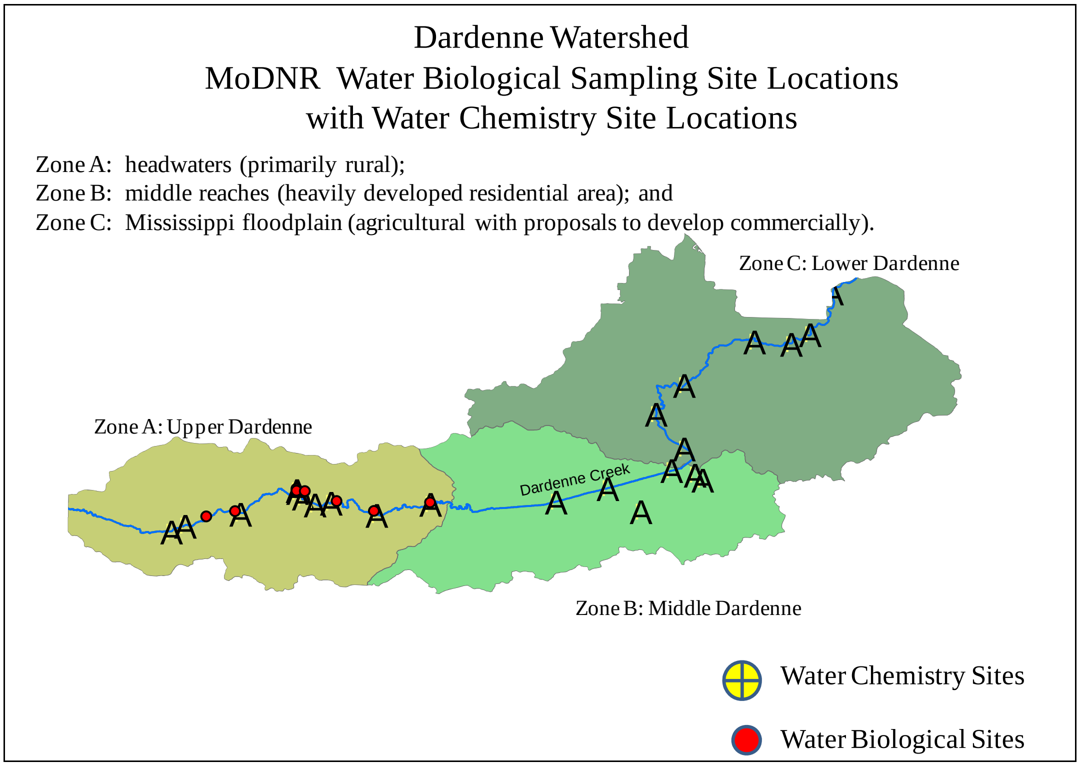


Figure 17 Water Biological Site Locations (Serrano O. , 2008)

7.2.5. MoDNR Volunteer Water Quality and Monitoring Program

The Volunteer Water Quality and Monitoring Program provided both chemistry and biological data that supplement the two previous data sets discussed. The data were organized and converted from an EXCEL database to an ArcMap™ shapefile and added as a layer in this dissertation project.

The Volunteer Water Chemistry matrix had a total 546 recorded entries, each containing a measurement of the twenty two chemical parameters, taken at twenty one site locations from 1993-2007. The Volunteer Water Biological matrix had a total of 118 recorded entries, each containing measurements at eight site locations. Table 13 is a summary of water chemistry samples taken by the volunteers, taken per year and per site. Figure 18 is a map of volunteer water chemistry sample sites along Dardenne Creek.

Table 14 is a summary of water biological samples taken by the volunteers, taken per year and per site. Figure 19 is a map of the volunteer water biological sample sites along Dardenne Creek.

Table 14 MoDNR Volunteer Water Chemistry Samples and Site Summary, 1993-2007

[redacted]

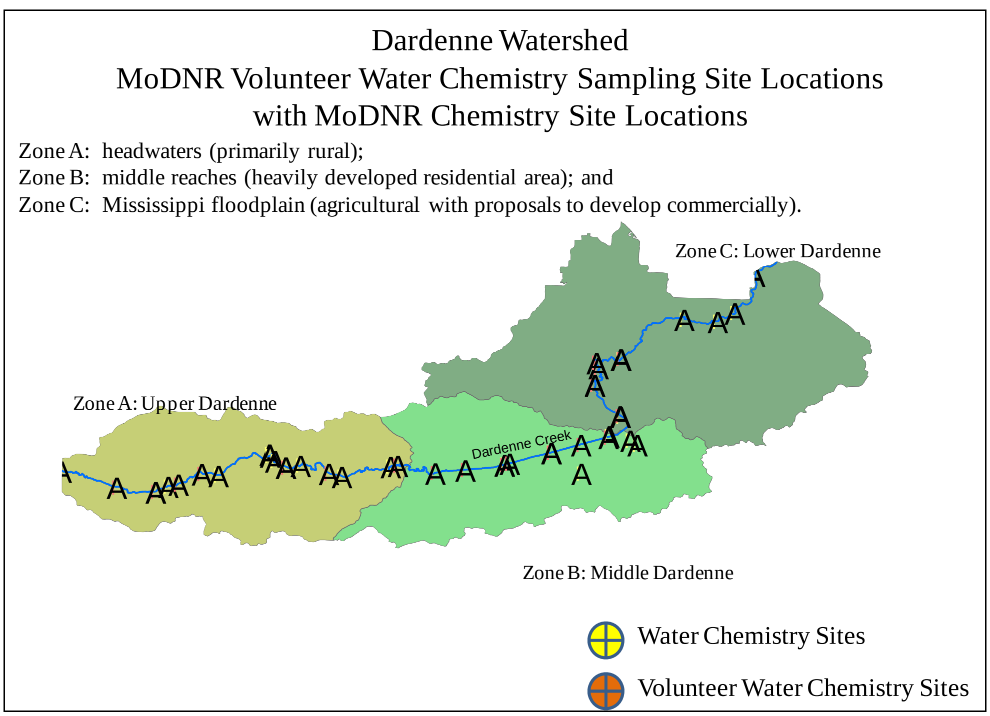


Figure 18 MoDNR Volunteer Water Chemistry Sampling Sites v MoDNR Chemistry Sampling Sites (Serrano, 2008)

Table 15 MoDNR Volunteer Biological Samples Site Summary 1995-2007

Volenteer_Biological			Zone A									Zone B													C	
			Sites																							
Volenteer_Chemical _Sites			0	1		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Volenteer_Biological Sites									0		1	2	3	4	5		6	7	8							
Year	Sites Plotted	# of Readngs																								
1983																										
1993	7	7																								
1994	7	14																								
1995	7	26									3							3								6
1996	5	21																								0
1997	7	34																								0
1998	8	25																3	3							6
1999	8	41																3								3
2000	8	17									3	3	3					3								12
2001	8	114							3		6							3	3							15
2002	9	56							3		6				3			9	9							30
2003	17	46							3		6		4		3				3							19
2004	17	45																								0
2005	15	53							3		3	3		3												12
2006	14	38							3		3		3				3		3							15
2007	8	9																								0
																										118

Dardenne Watershed
MoDNR Volunteer Water Biological Sampling Site Locations
with MoDNR Biological Site Locations

Zone A: headwaters (primarily rural);
Zone B: middle reaches (heavily developed residential area); and
Zone C: Mississippi floodplain (agricultural with proposals to develop commercially).

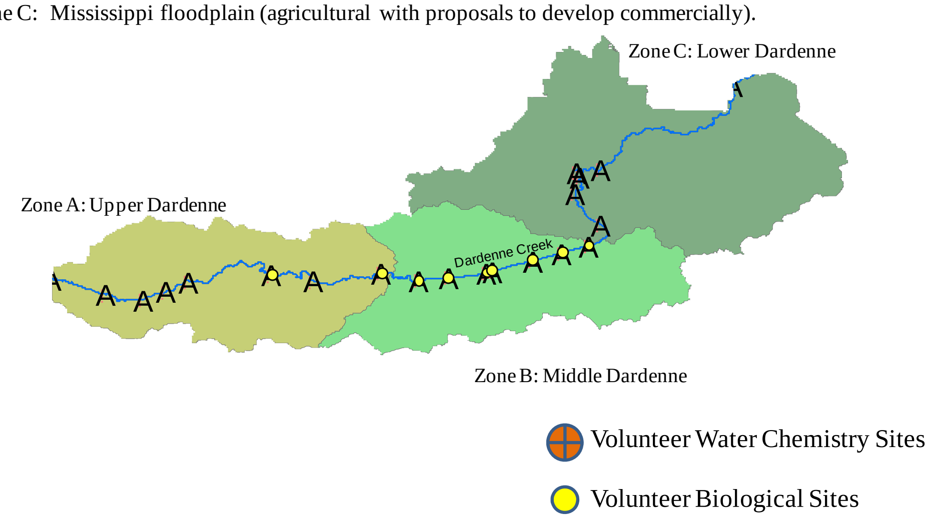


Figure 19 MoDNR Volunteer Biological Sampling Sites v. MoDNR Biological Sampling Sites (Serrano, 2008)

7.3. GIS Data Compilation

ArcGIS™ is developed and regulated by ESRI© to allow multiple datasets to be viewed and stored in a relational database based on geographic coordinates. Shapefiles are spatially described geometries that are points, lines, and polygons. The shapefiles relate specifically to files with geographic coordinates, specified for a map project. For example, shapefiles would represent water quality sites (points), streams and roads (lines), and parcels of land (polygons). The shapefile (e.g., Dardenne Creek Watershed.shp) relates specifically to the polygon "shape" of the watershed as a file with geographic coordinates, specified for a map project. Each file may also have attributes that describe the items, such as the name or temperature.

The project infrastructure contained the urban feature baseline shapefiles that were obtained from St. Charles County. The baseline shapefiles included information such as roads, stream, and land information (Fig. 20, 21).

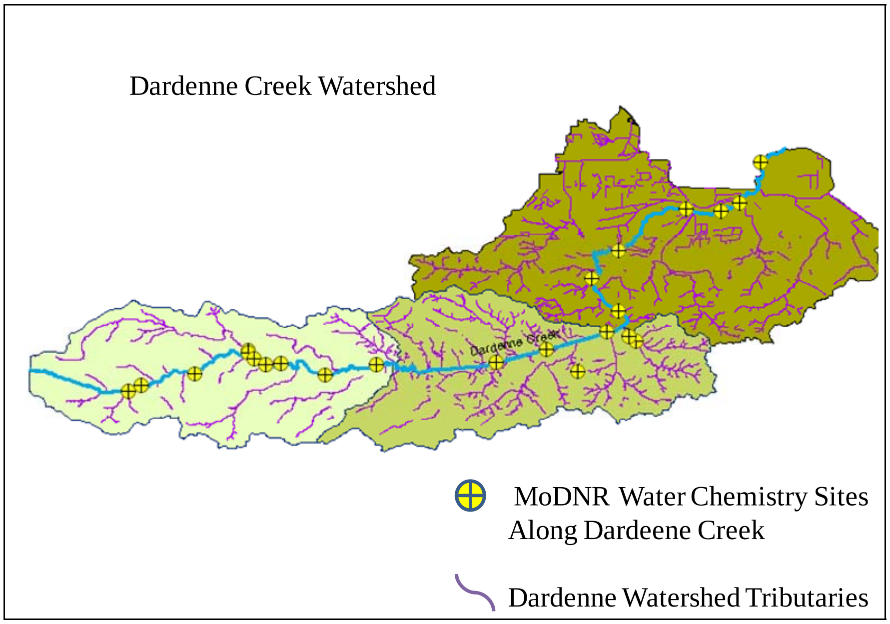


Figure 20 Layering Data Sets: First Layer Dardenne Creek Minor Course Water Lines (Tributaries) (Serrano, 2008)

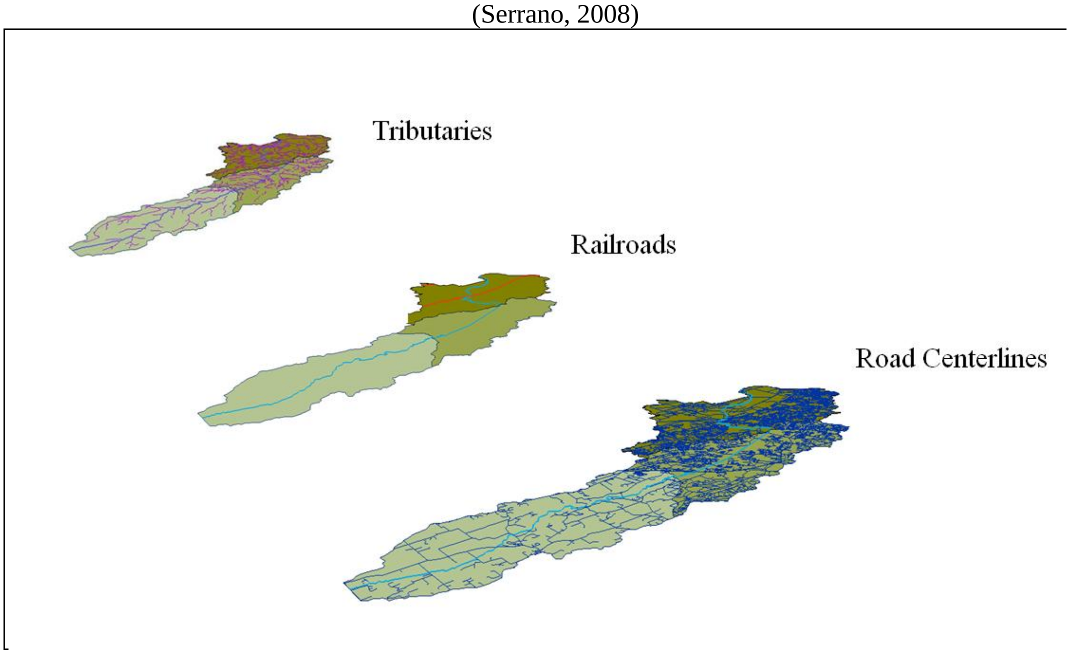


Figure 21 Layering Data Sets: First Layer_ Tributaries, Railroads and Road Centerlines (Serrano, 2008)

This analysis began with the assembly of four raw chemistry and biological data sets provided by MoDNR that were described in Chapter 7.1 and 7.2. The specific site locations for each data set were transformed into points with specific latitudinal and longitudinal coordinates. The raw chemistry and biological sample values were transformed from an EXCEL database into four shapefiles, and converted to a table layer that would be manipulated in ArcGIS™ (Fig. 22).

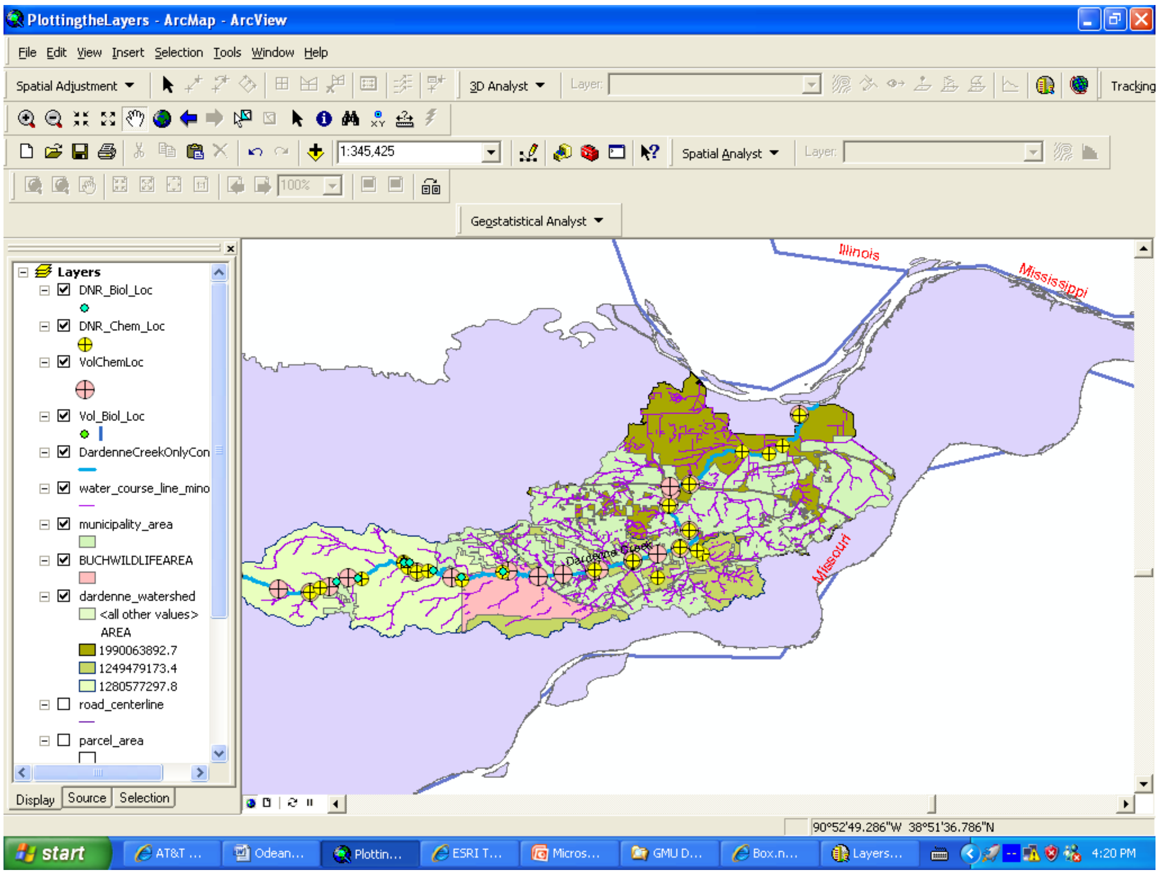


Figure 22 View of multiple Layers Created for the Dardenne Creek Watershed GIS Analysis (Serrano, 2008)

The layers shown in Figure 22 can be displayed or not displayed to show relationships. The layers that were created from the MoDNR raw data samples contain attribute tables that are comprised of the chemical concentration values provided. The attribute tables can be viewed and sorted into subsets of attributes to be manipulated for geospatial analysis (Fig. 23).

Figure 23 View of DNR Chemistry Layer's Attribute Table_ Complete Set of 516 Records (Serrano, 2008)

7.4. Geostatistical Analysis

This section defines the geostatistical analysis initially performed for the MoDNR pH data set values for the years 1983 to 2007. The first step of this pH analysis plotted all MoDNR pH values for all years (Fig. 24).

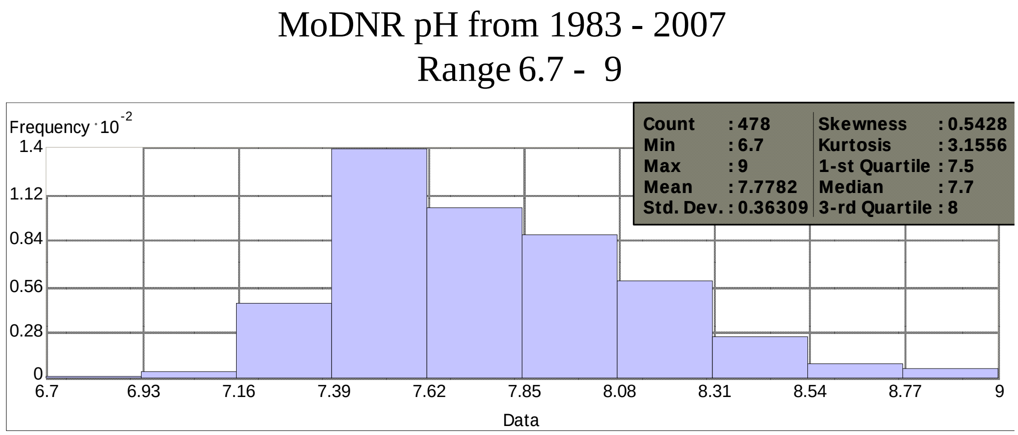


Figure 24 Histogram for All MoDNR pH Mean Values, sample set (1983-2007).

7.4.1. Inverse Distance Weighting

The ESRI© ArcMap™ has a Geostatistical Analyst extension that provides a dynamic environment to help solve spatial problems. Geostatistical Analyst creates statistically interpolated continuous surfaces from measured samples (ESRI, 2001). Given the set for all pH values for the entire database from years 1983 to 2007, the inverse distance weighting (IDW) method was used as a process for assigning values to unknown geospatial points by using values from the scattered set of known geospatial points, for multivariate interpolation. The IDW method begins with setting the distance weighting parameters against known point values. The points highlighted in Figure 25 shows an indicator of the weights (absolute value in percent) associated with each point.

The weights are used to estimate the value at the unknown location, which is at the center of the crosshair.

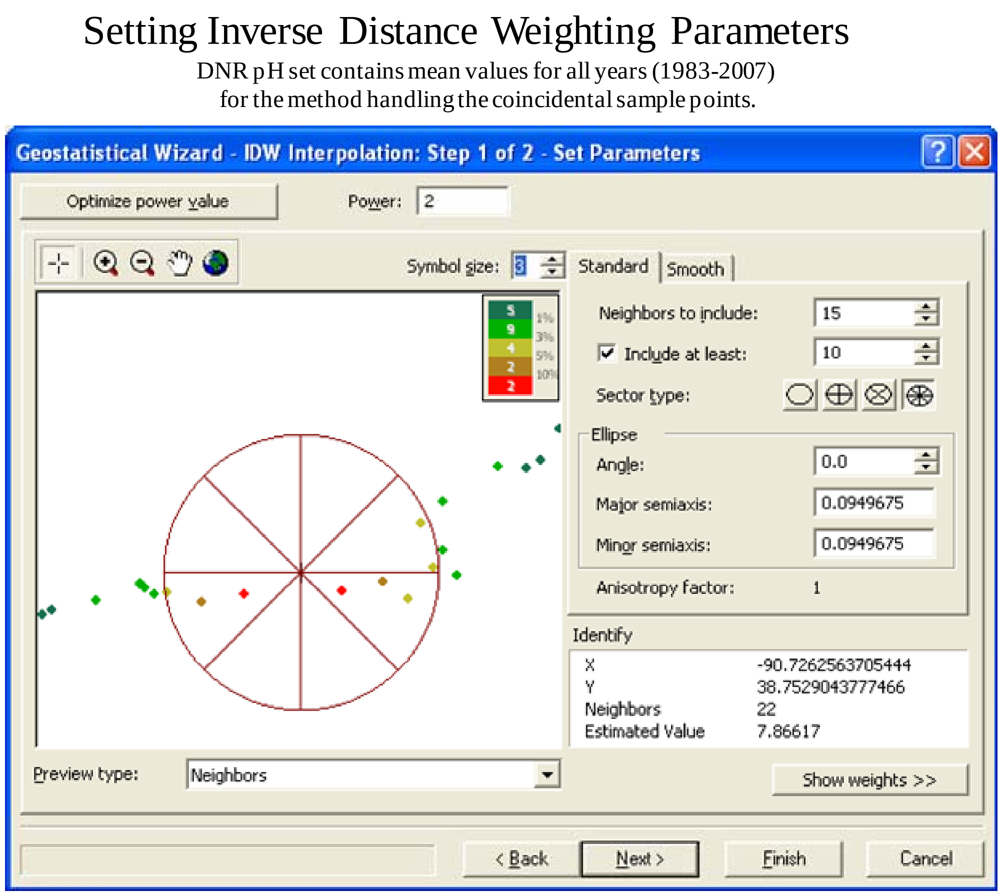


Figure 25 Inverse Distance Weighting Parameters Set, for All MoDNR pH Mean Values (1983-2007).

The associated predicted plot has a best fitted line through the scatter point with the linear regression function assigned (Fig. 26).

Setting Inverse Distance Weighting (IDW) Parameters

Regression Function and Prediction Errors for all values of DNR pH .

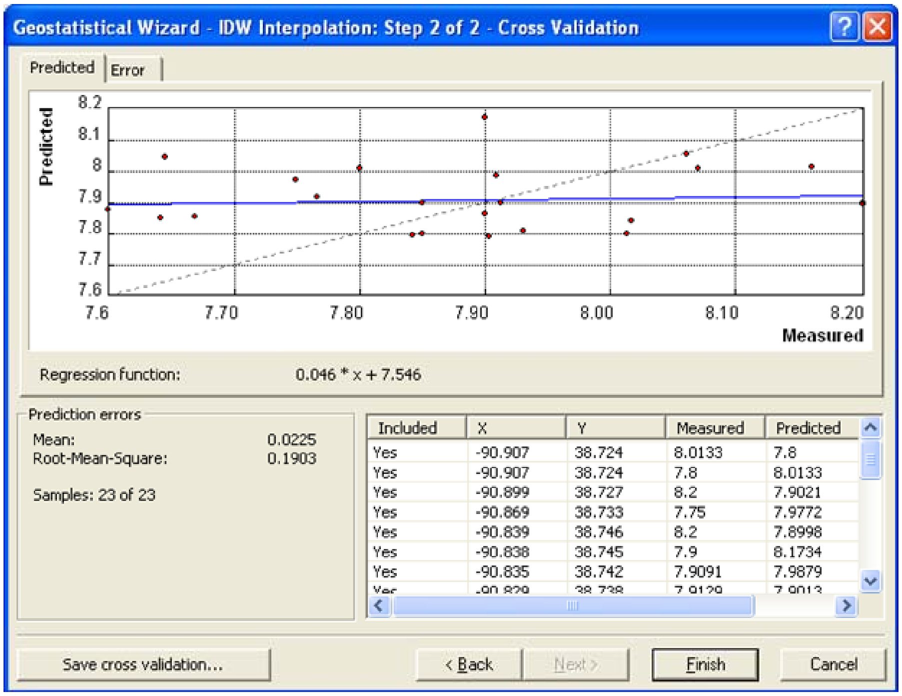


Figure 26 Regression Function and Prediction Errors for All MoDNR pH Mean Values (1983 – 2007).

A deterministic interpolation technique was used to create a prediction layer shapefile or the output surface layer, an area that is derived from unknown values based on the area of surrounding points with known values, using the IDW parameters (Fig. 27). This output surface area is produced from the interpolated values to display predicted variables at locations where data have not been collected.

Inverse Distance Weighting Prediction Ranges Layer

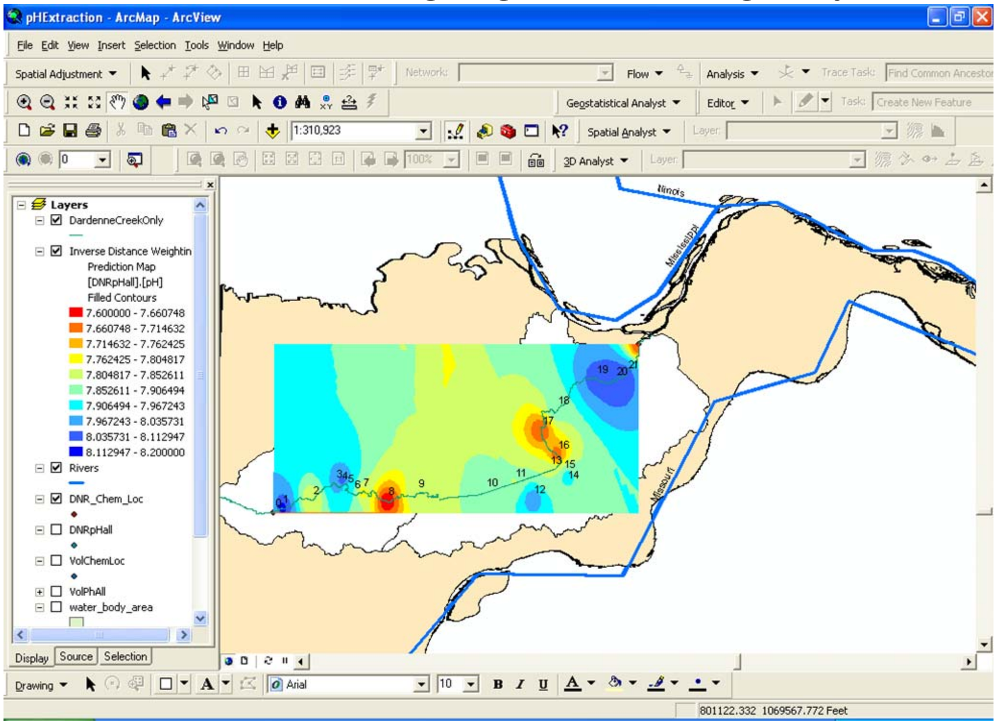


Figure 27 Inverse Distance Weighting Prediction Range for All MoDNR pH Values (1983-2007), as a Layer on the Dardenne Creek Watershed Map.

The surface layer created is defined from the geospatial coordinates within the Dardenne Creek watershed, from the specific MoDNR site locations, taken for the years 1983 to 2007. To have meaningful visual representation, the next step extracted the new surface layer property, to be defined along Dardenne Creek alone. The attributes of the Dardenne Creek were defined by the St. Charles County set of parameters for the respective Dardenne Creek watershed stream and tributary features (Fig. 28, 29).

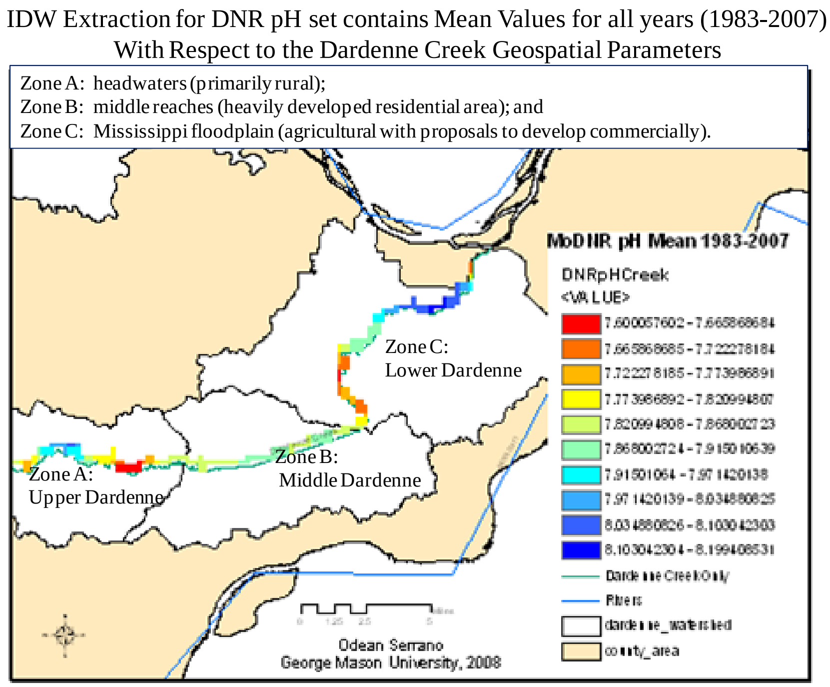


Figure 28 IDW Extraction along Dardenne Creek for All MoDNR pH Mean Values (1983-2007)

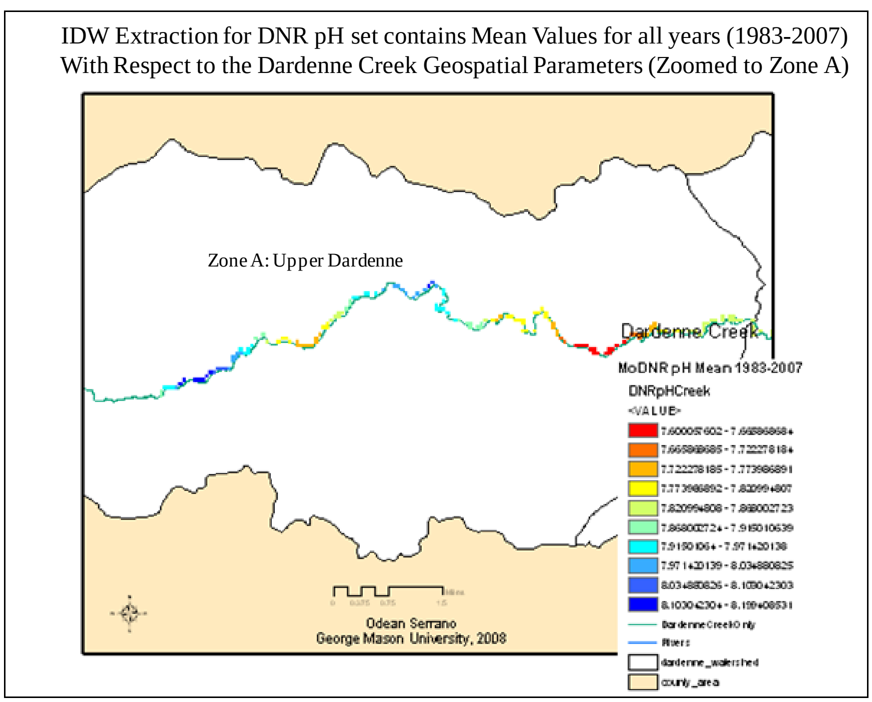


Figure 29 IDW Extraction for All pH Mean Values, Zone A (1983-2007)

7.4.2. Three Dimensional Representation

Using the ArcMap™ 3-D Analyst Extension for the MoDNR pH data set containing all sample values for the years 1983-2007, the data are first clustered and categorized into range classes and a color ramp can be assigned to depict the range values (Fig. 30).

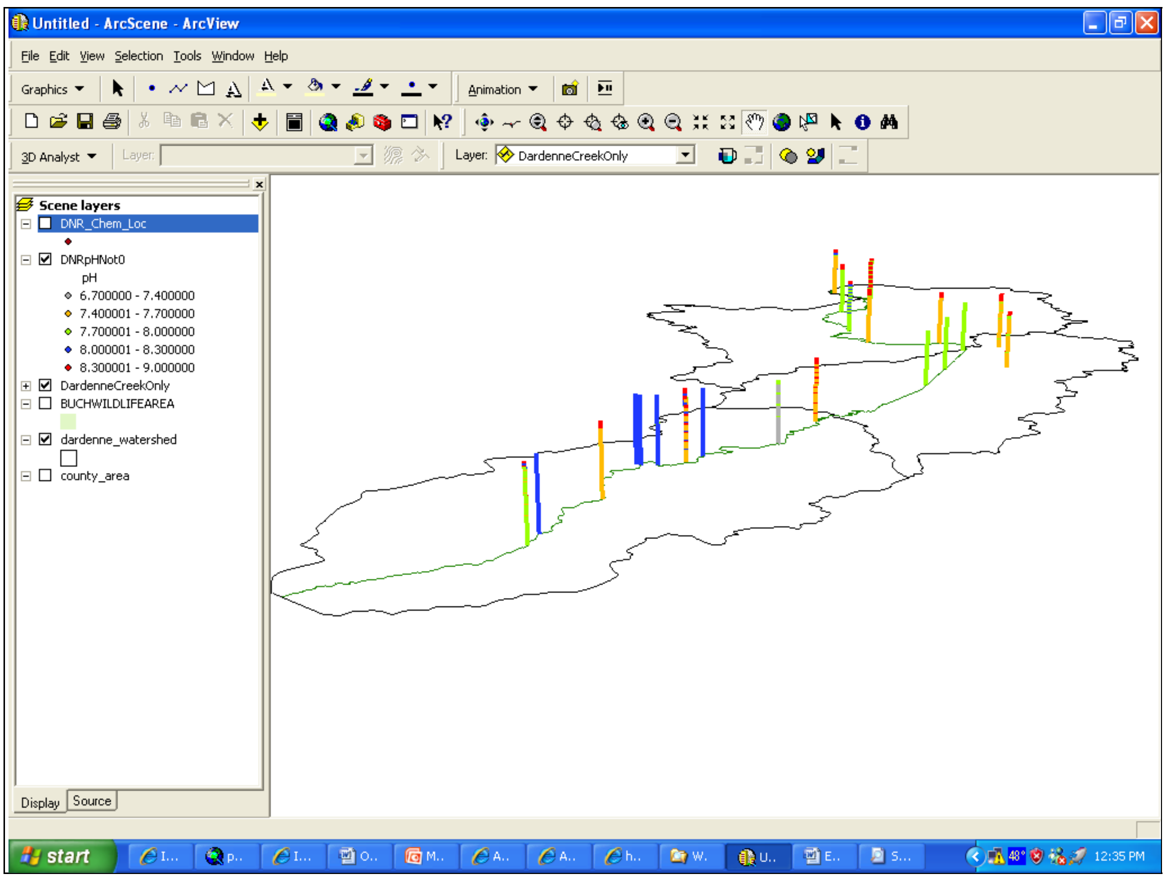


Figure 30 3-D Rendering for All MoDNR pH Mean Values (1983-2007).

The IDW and 3-D analysis methods are shown for the pH mean sample values, for all sample sites along the Dardenne Creek, for all years 1987-2007. These methods can and should be applied for all chemistry and biological parameters collected by MoDNR. These geostatistical models are beyond the scope of this dissertation, however, once prepared, they should enable recognition of both positive correlations among the parameters and to show temporal changes against a changing urban growth landscape.

7.5. MoDNR Biological Reporting Summaries

The MoDNR does not produce regular summary text reporting, nor does it conduct water chemistry trend analysis reporting due to lack of resources (MoDNR, 2008). The MoDNR primarily samples water to fulfill TMDL requirements.

The MoDNR has produced two biological stream assessment reports: 1) *The Biological Stream Assessment Report*, *Dardenne Creek Study from March 2002 through September 2002* and 2) *The Biological Stream Assessment Report, Dardenne Creek Study from September 2005 through March 2006*.

The 2002 *Biological Stream Assessment Report* was developed by the MoDNR's Environmental Services Program's (ESP) Water Quality Monitoring Section (WQMS) at the request of the Water Pollution Control Program (WPCP), to be used to conduct a biological assessment of Dardenne Creek in St. Charles County. This request was made due to concern by the WPCP that increased development in the Dardenne Creek watershed was causing poor water quality and poor habitat conditions in the creek therefore, having a negative impact on the aquatic community. Data collected by Missouri Water Quality Monitoring Volunteers on Dardenne Creek from 1998-2001 suggested that the in-stream concentrations of dissolved oxygen and suspended solids, and turbidity and pH were being altered by changes in the watershed (MoDNR , 2002).

In the 2002 study, the macroinvertebrate community exhibited a notable decline since the 1998 values taken at the station located just downstream of the Little Dardenne

Creek confluence. A recommendation was made in the 2002 assessment that additional surveys be conducted surrounding Little Dardenne Creek and Dardenne Creek confluence (Fig. 31) to determine whether these lower scores were due to natural variability or to some factor within the Little Dardenne Creek watershed.

The *2005-2006 Biological Stream Assessment Report* was produced again at the request of the MoDNR Water Protection Program (WPP), for the Environmental Services Program to conduct a follow-up of the 2002 biological assessment. The follow-up request was based on a previous biological assessment in 2002, where the Dardenne Creek segment had demonstrated lower than expected metric and biological supportability scores.

Sampling at Dardenne Creek and Little Dardenne Creek was conducted on September 13, 2005 to March 13, 2006 to provide data to the WPP for use in evaluating the biological integrity of these two streams.

The objectives of this study were to:

1) Determine whether the pattern of macroinvertebrate community decline in the vicinity of the Little Dardenne Creek confluence observed in 2002 would be evident in a subsequent study;

2) Establish a macroinvertebrate sample station on Little Dardenne Creek to observe whether differences in community composition and metric scores exist between the two streams; and,

3) Include a collection of water chemistry samples from Dardenne Creek upstream and downstream of Little Dardenne Creek as well as from Little Dardenne Creek

(MoDNR Biological Stram Assessment 2006, 2006_For September 2005-March 2006) (Fig. 31).

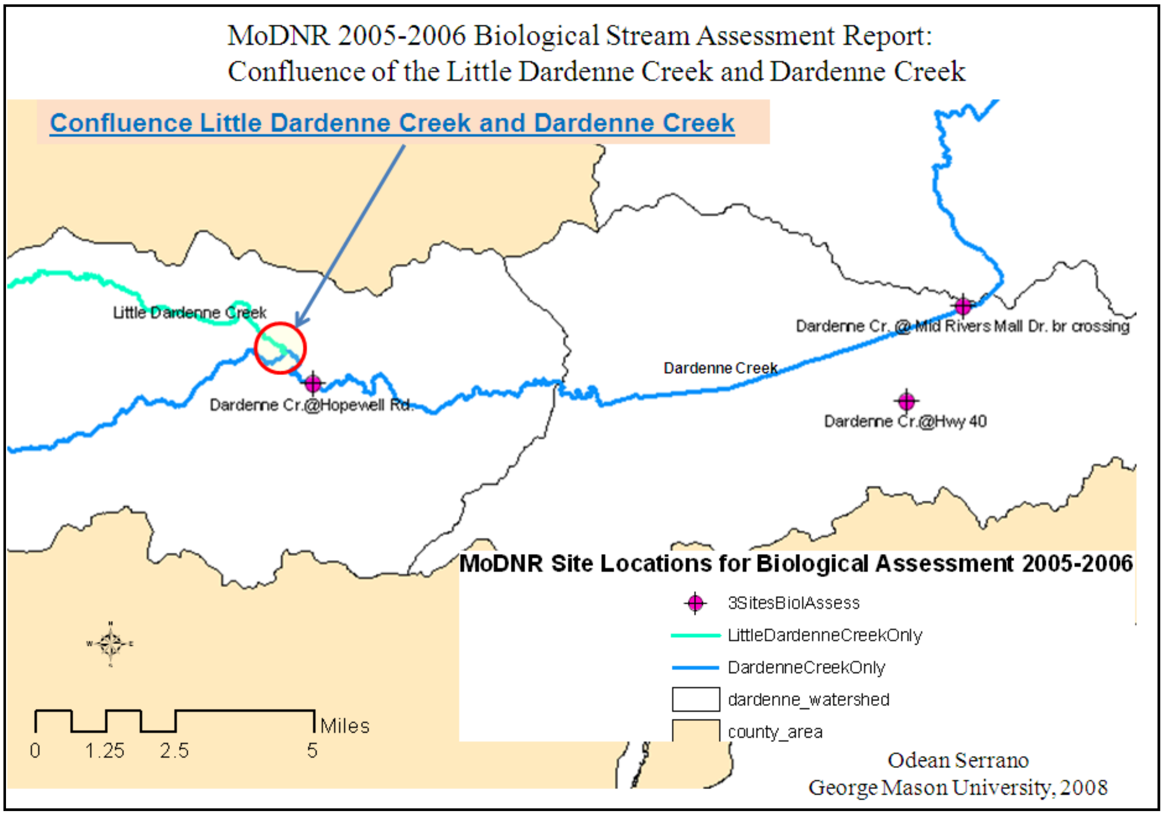


Figure 31 Confluence of Little Dardenne Creek and Dardenne Creek

The fall 2005 sample season was hindered by an absence of coarse substrate habitat at each station that was attributed to the lack of measurable flow during this season. Because there was no surface flow and each station was essentially isolated from one another, it is doubtful that any tributary had contributed water to Dardenne Creek in the weeks prior to the fall sampling. The report summary reported that the low biological metric and MSCI scores throughout the study reach, including Little Dardenne Creek, were attributable to a lack of adequate water to maintain sufficient dissolved oxygen and riffle habitat. The final recommendation was that an assessment be conducted within this study reach after the watershed has had at least two years of near-average precipitation to determine how the biological metric values and MSCI scores respond to adequate flows.

A 2001 Volunteer Water Quality Invertebrate report summarized sampling conducted in 1998 and 2001. Water Quality Invertebrate-ratings were given at three sites along Dardenne Creek, and showed a declining trend in a downstream direction. The Water Quality Rating at Hopewell Road in 2001 (Zone A) was 26, a score that indicates excellent water quality. The Water Quality Rating at Highway 40 (Zone B) in 2001 was 21, indicating relatively good water quality. Water Quality Ratings were given upstream of Mid-Rivers Mall (Edge of ZoneC) in 1998 and 2001 (Fig. 32). In 1998, the score was 16, indicating fair water quality, but the Water Quality Rating at the same site in 2001 was 21, indicating relatively good water quality. The MoDNR Volunteer program data provide for supplemental review of the Biological Assessment Reports however, in most cases dare are not been used for watershed management principles.

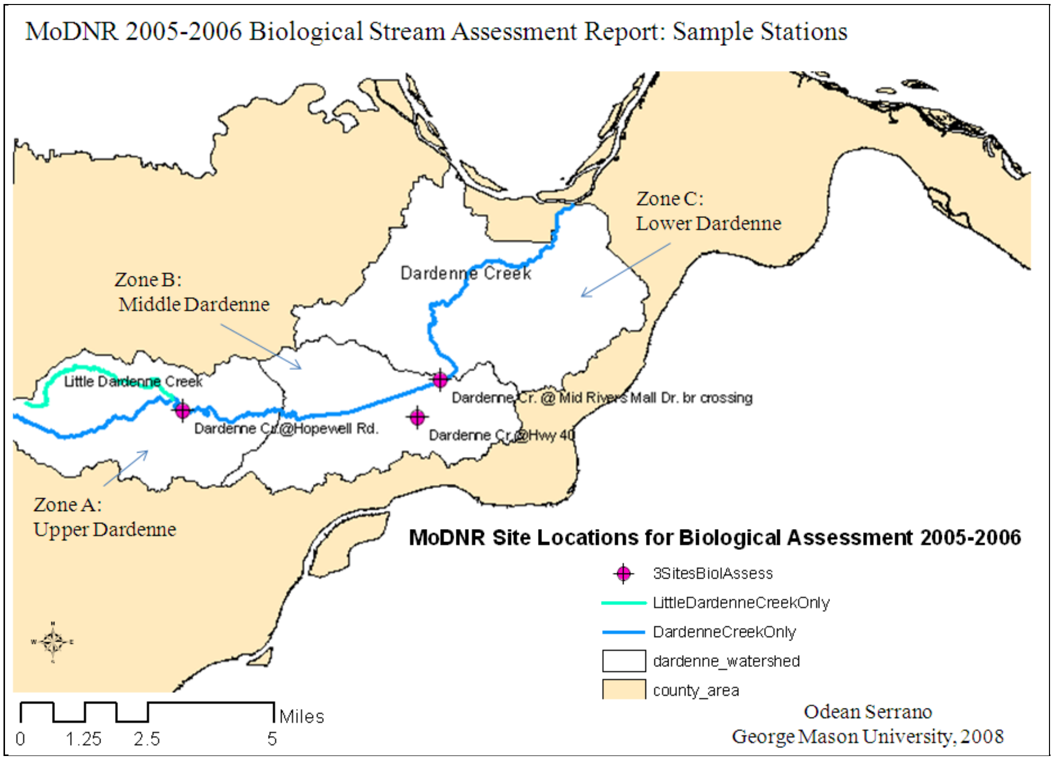


Figure 32 2005-2006 Biological Stream Assessment Report: Sample Stations

According to the MoDNR volunteer water quality coordinator, the water quality rating system used by the Volunteers was rather forgiving. However, the limited amount of ratings made it difficult to pinpoint a particular problem (Stotts, 2008). In addition, there was no relative correlation between the scales used by the volunteer water quality ratings and the Missouri water quality standards. Although this information provided some insight, it could not be used to place Dardenne Creek on the Missouri 303(d) List.

7.6. Trend Analysis

It is important to understand data trends in order to analyze changes in the landscape for watershed management. The following section discusses the geospatial display of trend analysis based on historical data sets collected by the MoDNR. Two parameters were selected as examples to demonstrate the temporal variance display, total suspended solids (TSS) and specific conductivity (SC) from the years 1998 to 2007. The two parameters may be considered as surrogates in understanding sediment loads carried in runoff from urban development in this area.

MoDNR did not collect samples for these two parameters in the years 2001 and 2004. Figure 33 reviews the high density built up areas (BUAs). Site 18, highlighted in blue, is of particular interest for this analysis.

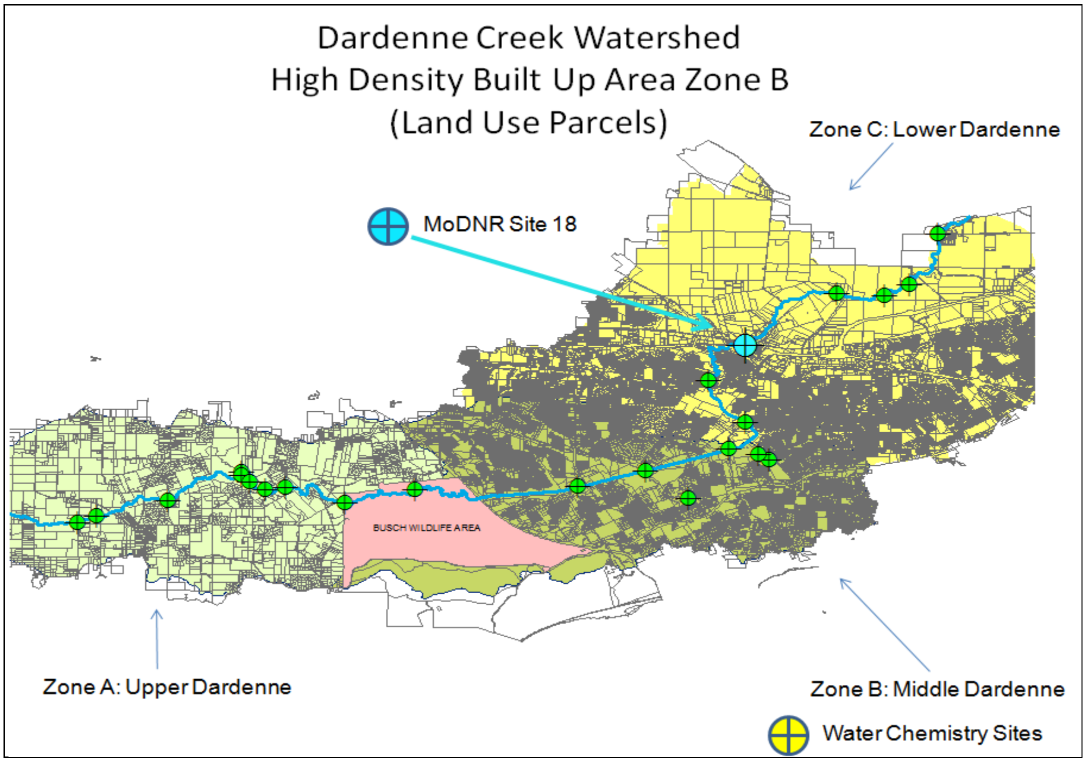


Figure 33 Dardenne Creek Parcel Layer (Built Up Areas)

This section emphasizes the trend analysis and how this analysis can assist with watershed management decision-making. The following graphics are the sequential order of range values for TSS from 1998 - 2007 (Figs. 34 – 41).

From the visual display of the data, in the Figures that follow, it can be seen that the levels of TSS frequently co-varied with SpC in the similar locations along the Dardenne Creek mainstem. The concentric circles in these figures represent more than one value taken at a site.

Figure 34 1998 Total Suspended Solids (mg/L)

Figure 35 1999 Total Suspended Solids (mg/L)

Figure 36 2000 Total Suspended Solids (mg/L)

Figure 37 2002 Total Suspended Solids (mg/L)

Figure 38 2003 Total Suspended Solids (mg/L)

Figure 39 2005 Total Suspended Solids (mg/L)

Figure 40 2006 Total Suspended Solids (mg/L)

Figure 41 2007 Total Suspended Solids (mg/L)

The changes from year to year indicate that there are dramatic differences between Zone A and the upper fringes of Zone B and C. This geospatial information is valuable when illustrating relationships between urban development and BUA's with higher TSS loads. In some instances, the values at Site 18 were low. For example, at Site 18 in 2002, it is not clear what contributed to a zero value for that site. However, what is clear is that standard methods and procedures need to be adopted that would require the scientists to annotate descriptive descriptions, such as low flow, that would help explain the skewed values. GIS is designed to accommodate any data (text, media, point of contact information), that would help a watershed community audience to understand why a reading may be outside the normal range.

This information also provides for a quick and obvious determination that data sets are not being collected in areas concerning urban growth. The issue of urban development is an ongoing challenge of balancing the high urban grown rate and rapid land use change with ecological watershed health. These temporal representations of variables will enhance collaboration in the areas where information needs to be supplemented and will assist in identifying watershed management objectives and priorities.

7.7. Integrating Disparate Data Sets to Display Interrelations

GIS data gathering has been ongoing for some attributes of the watershed however, there has been no work done to date on integrating various watershed science disciplines for a comprehensive view of the watershed as a whole system. The following section is the GIS depiction of layering data for land use management for the Dardenne Creek watershed.

The St. Charles County shapefiles acquired for this research provided many attributes that could be explored synchronous to the water quality shapefiles derived in for this dissertation (Fig. 33). The attribute table for the St. Charles County Municipal area shows the websites and contact information for these areas.

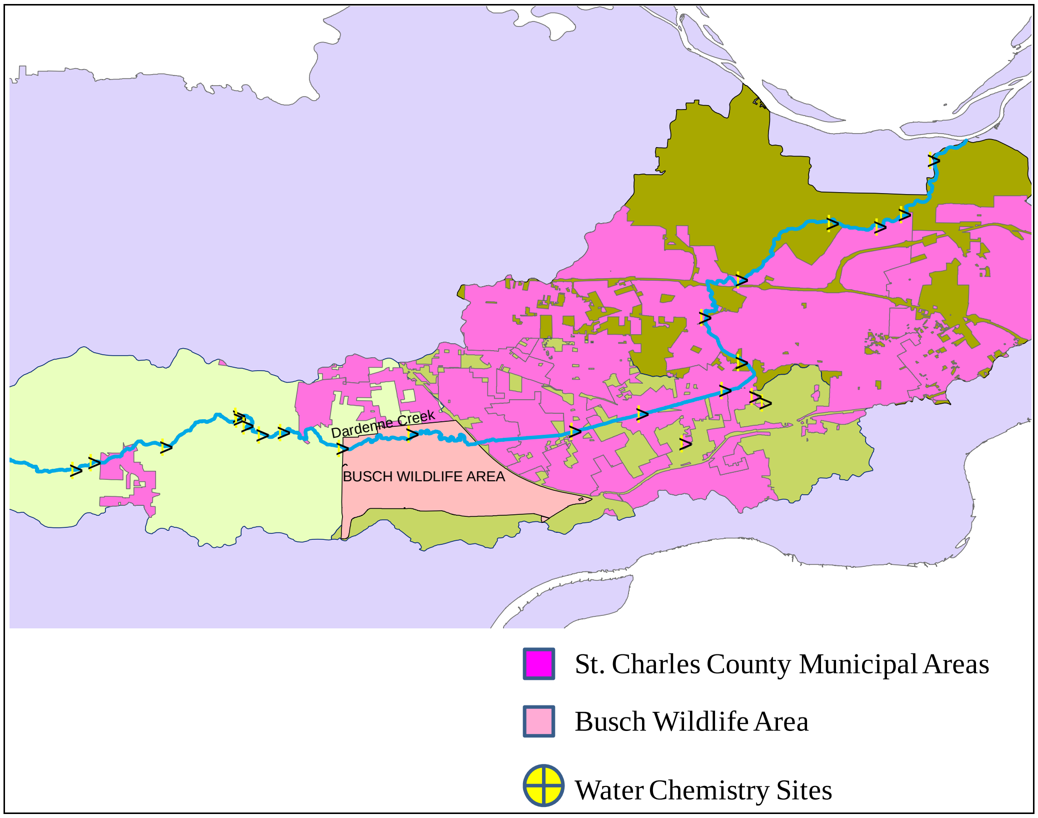


Figure 42 Laying Watershed Physical Features

As a result of the Dardenne Creek [Stormwater] Study, the Army Corps of Engineers published GIS shape files that could also be integrated and layered within a Holistic GIS Dardenne Creek Watershed project. Stream gages placed along the stream provide realtime flow information that is valuable for hydrological studies and for stormwater management. The gages can be plotted on the map project (Fig. 34) and the attribute for the gages linked to the live feeds that shows a display of Figures 35, 36 (U.S. Army Corps of Engineers, 2008).

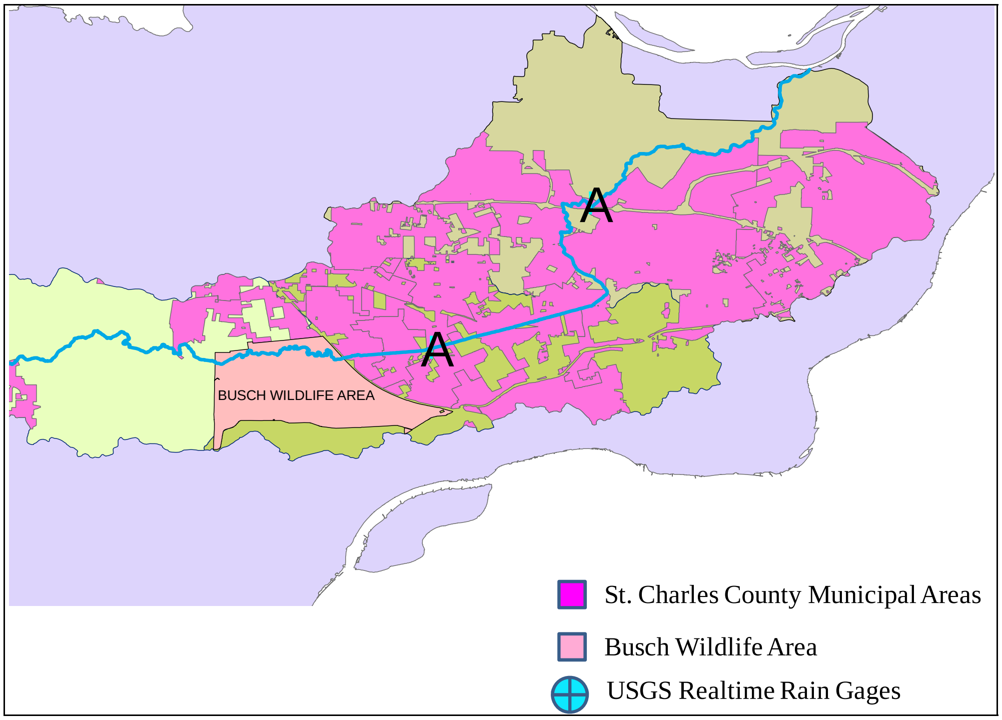


Figure 43 USGS Realtime Rain Gage Locations

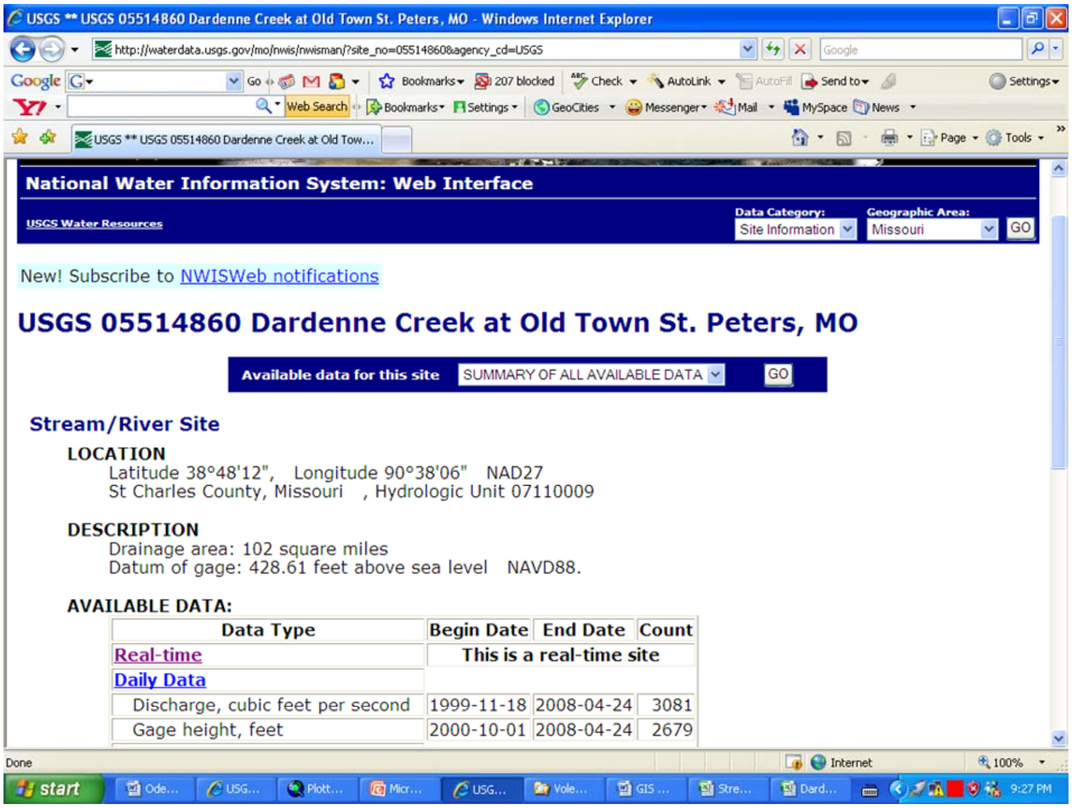


Figure 44 USGS Realtime Stream Gage Website

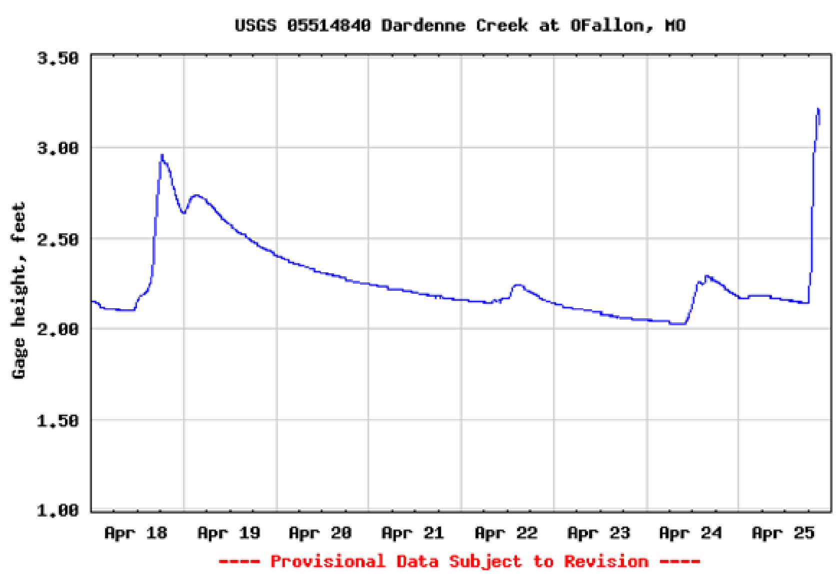


Figure 45 Rain Gage Dardenne Creek at O'Fallon Road Reading

There are enough historical water chemical and biological collection data sets from the MoDNR that could be displayed temporally to help visualize trends in data quality. The data were extracted from the original attribute table and created for each year. The geospatial analyst or manager would then display the single parameter for each year. Using the ArcGIS™ extension, Tracking Analyst, the data can be displayed sequentially, to visually portray temporal changes for that parameter. This would be useful when this temporal change is compared to the land use change detection provided in the St. Charles County parcel maps. The layers build relationships among disparate data sets and show comparisons to further the understanding of the relationships between the many uses of the watershed.

The emphasis of this chapter illustrated how existing and disparate data sets can be worked into a GIS to provide for the multiple-variable and multi-disciplinary analysis, and to assist in the depiction of historical comparisons. This GIS method will provide for a comprehensive display of the dynamic data interrelations that will lead to more rational land use management for the watershed.

CHAPTER 8

8. HOLISTIC WATERSHED MANAGEMENT

Holistic watershed management is a collaborative approach to unite diverse stakeholders' priorities, which would allow for the development of an overarching watershed land-use plan. This approach would lead to the progression toward achieving cohesive land use goals and the identification of best management practices.

The concept of a holistic watershed management plan has been developed or promoted (Brewer & Clements, 2008) and in some cases implemented, in varying degrees. Because watersheds are defined by natural hydrology, they represent the most logical unit for managing water resources. The water resources become the focal point of ecological health which enables watershed managers to better understand the overall environmental conditions and stressors to the natural habitat.

Traditionally, water quality improvements have focused on limitations and control of specific point sources of pollution and on affected water or land resources. While this approach may be successful in addressing specific problems, it often fails to address the more subtle and chronic problems that contribute to a watershed's decline. For example, pollution from a sewage treatment plant might be significantly reduced after a new technology is installed. Yet, the local river may still suffer if other factors in the watershed, such as habitat destruction or altered surface runoff go unaddressed.

Holistic watershed management can offer a stronger foundation by assessing all stressors in the environment, combined with each stakeholder's perspectives on the management and land use of the watershed. This approach acts to promote the watershed as a whole resource that is managed by the community. The stakeholders in the community, including the local county government, become watershed stewards, better equipped to determine what actions are needed to protect or restore the resource.

Each watershed presents unique issues to consider in the development of a plan for the watershed. A holistic watershed plan should first establish the priorities which are collectively determined by all stakeholders within the watershed. The structure and elements of a watershed plan would address the needs of those who use and reside within the watershed (i.e. the stakeholders) including: residential, agricultural, industrial, recreational, and businesses.

The objectives of the watershed plan would carry out the priorities by delineating the procedures for determining the land use, land management, and water quality standards. The governing objective of the plan would address procedures to carry out the laws that pertain to watershed management to ensure regulatory reporting consistency. The objectives would also determine the water quality monitoring program, as a major watershed health indicator, which could supplement the evaluation of whether the objectives are being achieved. Watershed objectives that are locally driven help define the type of water quality monitoring protocols that define monitoring priorities and the level and intensity of monitoring (Nader et al, 1993). Once water quality monitoring protocols are established, data can be used to determine if the objectives are being achieved.

There must also be a designated community “keeper” of the watershed plan from the local county government, with the authority to ensure that the stakeholders’ objectives are carried out. Once a consensus of overarching watershed management objectives and priorities are collectively derived, the plan can be systematically implemented.

Successful implementation of a holistic watershed plan does not always have to begin with grassroots environmental advocates. In 1992, three major chemical companies in South Carolina: Amoco, Dupont, and Bayer took the lead in forming the Cooper River Corridor Project (Brewer & Clements, 2008). The businesses came together and formed a coalition with the US Fish and Wildlife Service, the Wildlife Council, South Carolina's Department of Environmental Protection, citizens, and local corporations to identify and solve ecological problems in the region. The group first decided to identify weaknesses in a five square mile area of the watershed, looking particularly at the habitat of two endangered animal species, two bird species, the longleaf pine, and sweetgrass, a native grass important to an historical basket weaving cottage industry in the area. The Project began a longleaf pine reforestation program, and Amoco planted sweetgrass on many acres of its own land, regenerating sweetgrass growth, which also benefited the local basket making industry. With these successes in working together, the Project, led by Amoco, continues to develop the community strategic planning process for the entire Cooper River Watershed in order to protect and to restore ecosystems and to strengthen local economic opportunities (Brewer & Clements, 2008).

The best practices noted in the Cooper River Watershed reinforced an integrated and coordinated resource management approach with simultaneous consideration of physical and socioeconomic interrelationships and impacts. Typically, relationships between stakeholder organizations with competing views in watershed land use and management lead to conflict and stalemate or litigation.

The structure of a holistic watershed management plan addresses jointly integrated stakeholders' priorities which are cultivated by the overarching regulations and law. The objectives are derived to carry out the priorities. Water quality monitoring is a primary measurement of how well the overall watershed objectives are being implemented. However, the objectives must also integrate multiple land uses and other scientific disciplines such as, hydrology, ecology, and geology, to accomplish holistic watershed management. Ongoing assessment of how well the objectives are being achieved and sharing of best management practices will ensure continual improvement of the integrity of the watershed.

CHAPTER 9

9. GIS FOR HOLISTIC WATERSHED MANAGMENT

The holistic watershed management includes the assimilation of watershed science, land use and water quality law and regulation, and the cultivation of stakeholders views and priorities. The geospatial view of the watershed will help to show the relationships between the disciplines and stakeholders - that there are few diffuse and porous ecological boundaries, such as between field and forest, upland and bottomland, small land fragment and large land fragment, within the watershed. Rather, the watershed exists as a whole, integrating all watershed elements (Fig. 37).

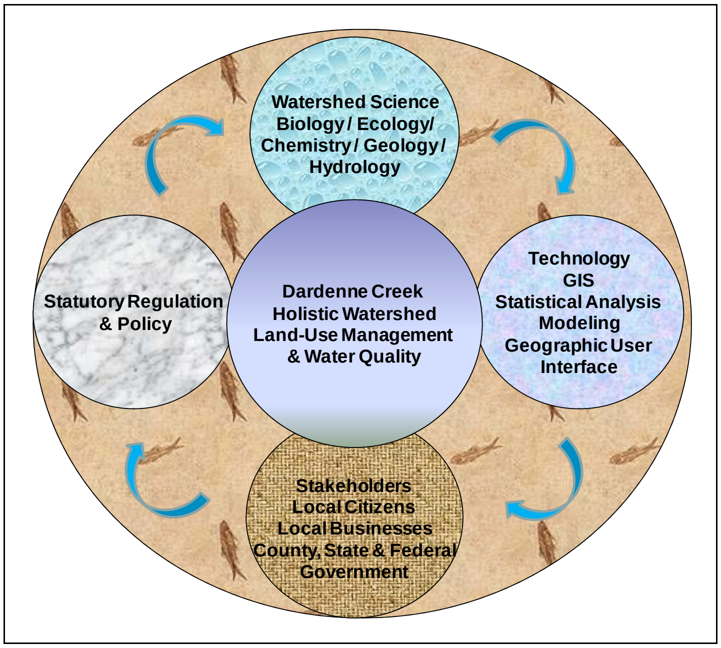


Figure 46 Holistic Watershed Elements

A Geospatial Information System (GIS) will integrate all data and will facilitate addressing stakeholders by visually displaying land use and land management priorities. The geospatial presentations will reduce the vast quantity of data to fewer, more understandable results of spatial information.

A Geographic Information System is a tool that provides the necessary display of interrelated data that can be geostatistically analyzed and which can reveal temporal trend analysis that would assist in integrating complex systems and relationships among multi-disciplinary studies. The results produce a single watershed map project which provides views of multiple layers of disciplinary science combined with current and forecasted land use designations.

Once the data are displayed in a single GIS project, the next phase of a GIS holistic watershed data display incorporates the GIS view of data in a user-friendly, interactive watershed management decision support system, using a graphical user interface (GUI) or a webpage (Fig. 47).

The GUI should identify all stakeholders that are participants in the watershed. Often it is the businesses contributions that will enhance the success of new programs. Since the (Anheuser) Busch Wildlife Reserve lies in the watershed, formalizing a partnership with this entity would be beneficial to all stakeholders for a common goal of ecological watershed health.

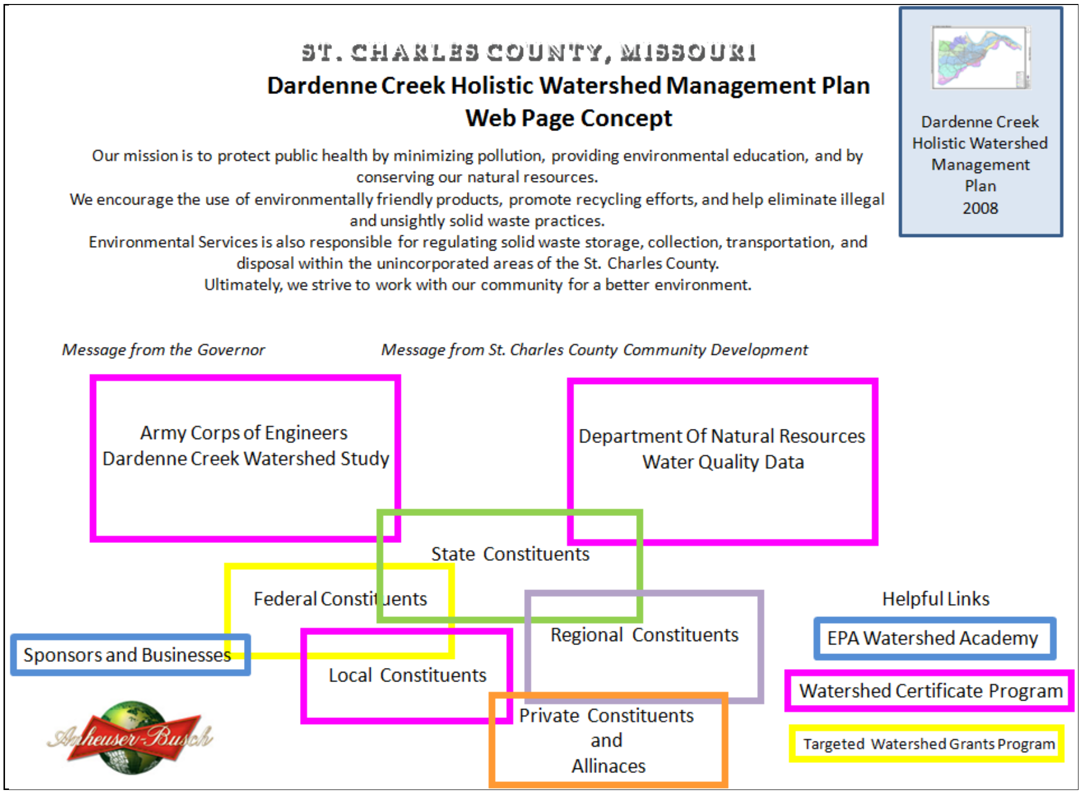


Figure 47 Holistic Watershed Management GUI Prototype

A decision support system model identifies the relative contributions of sub-watershed areas such as: hydrological data sets; urban development; soil erosion and water quality parameters for evaluation of alternative land-use and land management activities and practices. The decision support system model provides the holistic watershed perspective which includes all disciplines rather than focusing on isolated components.

This combination of GIS, a decision support system logic model, and GUI significantly improves the user's ability to manipulate the spatial and non- spatial data necessary to develop a holistic watershed management plan. A web-based approach provides an integrated system of data sets and decision-tree methodologies that allows the user to readily access the watershed management plan and evaluate the results of the objectives defined by the watershed stakeholders.

The GIS dynamic platform provides for continual enhancement of the interoperable watershed management plan by keeping data current and cultivating user utility. The GIS watershed approach maximizes the opportunity for the ecological preservation of the watershed in a holistic manner.

This display of information can provide a better understanding of all of the stakeholders' disciplines including scientific, governance, and community consensus, thus providing maximum utility to the community. Adopting the use of geospatial information as a holistic depiction of the watershed will assist the stakeholders in resolving differences from a perspective of a community rather than from individual perspectives and will assist in successful implementation of a holistic watershed management plan that is dynamic and of utility.

The value of the use of geospatial information integrates the collected multi-disciplinary data and displays the watershed as an interconnected system. This enables the development of a holistic watershed management plan that addresses the differing viewpoints, resulting in consensus views, and having a better chance of being realized. Figure 48 provides an overview of the interconnected aspect of GIS for holistic watershed management. This figure described a continual process intended to continually enhance watershed management practices. The flow begins with the stakholders's watershed priorities, collectively defined. The watershed priorities determine the data collection priorities from disparate scientific disciplines. The input from the scientists and volunteers who collect watershed data are entered in a shapefile format that is the input to the GIS watershed model platform. The output dataset are layers of information that can be geostatistically analyzed for relationships and trends. The analysis is used in a watershed stakeholder forum to assess how well the priorities and objectives are being met. The outcome of this watershed plan review will assist in establishing current priorities to reflect the dynamics of the ever-changing watershed land uses and landscapes.

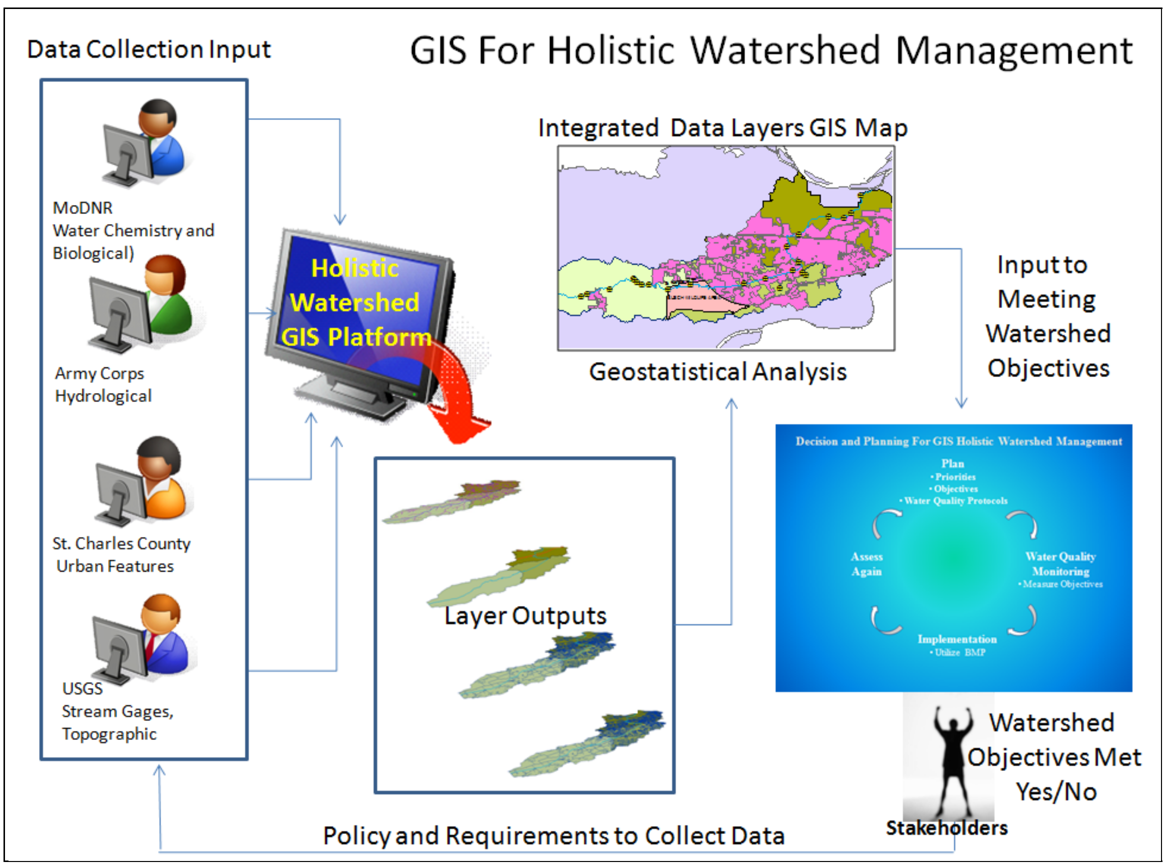


Figure 48 GIS for Holistic Watershed Management

CHAPTER 10

10. CONCLUSIONS & FUTURE DIRECTION

This dissertation discussed three fundamental aspects that contribute to the development of a holistic watershed plan: water quality science, relevant regulations and policy, and community watershed management planning using a Geographic Information System (GIS) for the Dardenne Creek watershed. The watershed is located in St. Charles County Missouri which has undergone rapid change over the past 50 years and rapid ecological degradation. Some attribute this degradation to excessive suburban and urban development along the riparian corridors and adjoining tributaries. This dissertation also investigated the various levels of stakeholder participants who manage and live within this watershed.

Watershed Science

The data collection work that has been done to date to evaluate and monitor the health of the water quality of the Dardenne Creek has been, at times, comprehensive in scope and often quite costly. The objectives and requirements to conduct the disparate studies are not consistent in scope. The respective intra- and inter - governing agencies and citizen organizations rarely worked together to integrate the disparate data sets for the evaluation of the interrelationships between the physical, chemical, and biological water quality parameters.

Water Quality stream monitoring is difficult, in part due to the necessity of adequate hydrological flows required to support trend analysis, and in part due to the lack of fiscal resources to carry out the studies. Because direct measurements of water quality can be expensive for the community, the responsibility for ongoing monitoring programs is typically assumed by state government agencies. However, there are local volunteer programs and resources available for some general hydrological, biological, and chemical assessments. Yet the integration of the agencys' sample collections and the volunteers' sample collections is not often fully achieved.

Relevant Regulation and Policy

Water Quality statutes at both the Federal and State levels are complicated, and on more than one occasion there have been noticeable gaps in the methodologies used to carry out these laws. There are inconsistencies in determining the status and causes of stream impairment ratings, which have lead to lawsuits from citizen organizations against the Federal government for either failure to carry out the laws or for exceeding their authority in applying sediment standards.

Since 1998, the EPA and MoDNR have experienced several law suits concerning the CWA § 303 (d) Lists, brought forth by stakeholders of this watershed region.

As a result, the U.S. EPA has given direct attention to the MoDNR 303 (d) Listings. Both EPA and the State of Missouri are working diligently on resolving the disparities with the reports.

Further, local governments are struggling with increasing regulatory and community pressures as the federal and state governments shift more funding responsibilities for social service and economic assistance to local governments. In Missouri, the state government has shifted more responsibility to local and non-government entities for services over the last five years because of resource reductions (Leuci, 2005).

Stakeholders as participants in managing & living within the watershed

Each watershed has multiple stakeholders, many with a different mission and perspective. This dissertation disclosed the lack of collaboration among various Dardenne Creek stakeholders who often hold narrow and opposing views of land-use and water quality protective measures which often aggravates existing land-use management problems.

A fundamental challenge is that there is not one single defined authority with a watershed management perspective in place to date. The governance roles are defined by regulation while the private businesses and alliances are driven by a particular interest.

Some businesses argue that environmental regulations entail excessively high compliance costs, restrict businesses and personal decisions that some businesses believe put the business industry in a competitive disadvantage. Environmental alliances complain that the existing regulatory structure is incremental, short-sighted, and too weak to protect current and future generations. States complain about centralized federal rules that take a "one-size-fits-all" approach to environmental issues. Local communities are increasingly upset by environmental decisions they believe are unfair and in which they do not participate. Academics criticize environmental regulations they find to be ineffective and overly prescriptive (Sexton and Murdock, 1996).

Opposing views that focus on individual missions and agendas are often the cause of the impasse of a watershed plan. Further, a very important limiting factor is availability of monitoring resources. Often various alliances are competing for the same resources.

Several comprehensive and costly watershed studies have been completed on or near the Dardenne Creek watershed. One study suggested the need for additional water monitoring and assessments to be conducted and the other study lacked the specific actions necessary to implement the findings from the studies.

The result is that while these different Dardenne Creek comprehensive studies have been conducted, they have not evolved into a watershed management plan, due to the lack of collaborative efforts to leverage the findings and resources and the failure to combine the results of the studies into a comprehensive and comprehensible picture.

Implementing a Holistic Watershed Plan with GIS

A holistic watershed approach is concerned with the overall health of the watershed system elements, including the land uses depicting changes in the landscape due to urban development. Holistic watershed management is a collaborative approach to unite diverse stakeholders' priorities, which would allow for the development of an overarching watershed land-use plan. This approach would lead to the progression toward achieving cohesive land use goals and the identification of best management practices. Holistic watershed management can offer a stronger foundation by assessing all stressors in the environment, combined with each stakeholder's perspectives on the management and land use of the watershed. This approach acts to promote the watershed as a whole resource that is managed by the community.

The structure of a holistic watershed management plan addresses jointly integrated stakeholders' priorities which are cultivated by the overarching regulations and law. The objectives are derived to carry out the priorities. The objectives integrate multiple land uses and all watershed scientific disciplines aspect to accomplish holistic watershed management. Ongoing assessment of how well the objectives are being achieved and sharing of best management practices will ensure continual improvement of the integrity of the watershed.

Introducing Geographic Information System into the watershed plan framework is an invaluable tool which will allow existing and disparate data sets to be incorporated, integrated, and analyzed. The GIS model displays relationships in a single watershed map project, performs geostatistical analysis, reveals temporal changes of landscape, and forecasts land use designations priorities. The display of interrelated data sets will alleviate redundant or unnecessary studies and promote cooperative studies that leverage limited resources.

A GIS display of geospatial data will make the holistic watershed plan becoming a dynamic document that is both of utility for displaying the data sets. When the data sets are updated, it provides a centralized repository to store and archive the data sets. This is necessary to conduct historical trend analysis with respect to multiple variables within the data GIS database.

The GIS dynamic platform provides for continual enhancement of the interoperable watershed management plan by keeping data current. The presentation of all these varied data can lead to the Dardenne Creek stakeholders' better understanding of what is in the system and what occurs between the system elements, maximizing the opportunity for the ecological preservation of the watershed. This information derived from GIS will assist all stakeholders in better understanding the holistic approach to watershed management and will lead to more effective land use planning.

Suggested Future Research

This dissertation modeled only a portion of the many physical, chemical and biological water quality parameters. The GIS water quality plotting and geostatistical analysis should be performed for each all available water quality parameters. The correlation among the parameters to determine or prove inter-dependencies among them must also be performed. There is historical data available to determine geospatial trend analysis that could be viewed in the ArcGIS™ Tracking Analyst extension mode to readily view the temporal changes.

The Missouri Clean Water Commission, the MoDNR, and the Dardenne Creek watershed stakeholders would benefit from the comprehensive model that includes all parameters in a geospatial overlay with updated St. Charles County, GIS shapefiles. This integrated set of water quality parameters and land parcel and road information should be introduced as a baseline for the future Urban Development Master Planning, St. Charles 2020.

The issue of fiscal resources to implement a GIS should be addressed. There will be a need for dedicated resources for both software and human resources to implement the GIS watershed platform. Future work would promote a cooperative EPA and the MoDNR policy to require the use of GIS for all watershed management uses. This policy would endorse a holistic watershed management perspective that is current and which continually enhances the multi-disciplinary data sets. This would result in addressing the needs of the all stakeholders, stimulating common goals, and becoming the foundation for holistic watershed management.

Humankind has not woven the web of life.
We are but one thread within it.
Whatever we do to the web, we do to ourselves. All things are bound together.
All things connect. – Chief Seattle

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Appendix A. USGS Region [07] Watershed Levels[1]

Watershed Description

A watershed is an area of land where the runoff from rain and snow will ultimately drain into a common point such as a particular stream, river, wetland or other body of water, ranging in size from a few acres to thousands of square miles. A watershed is defined by natural hydrological properties and is delineated by the U.S. Geological Survey (USGS) using a nationwide system based on surface hydrologic features. The United States is divided and sub-divided into successively smaller hydrologic units which are classified into four levels: regions, sub-regions, accounting units, and cataloging units, and are systematically arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system.

The first level of the USGS classification system divides the Nation into 21 major geographic regions.

A Map of the 21 U.S. Water Resources Regions[2]
Source: USGS Hydrological Unit Map[3]

[1] Source: USGS Water/Science in Your Watershed: http://water.usgs.gov/wsc/map_index.html
[2] [01] New England; [02] Mid Atlantic; [03] South Atlantic Gulf; [04] Great Lakes; [05] Ohio; [06] Tennessee; [07] Upper Mississippi; [08] Lower Mississippi; [09] Souris Red Rainy; [10] Missouri; [11] Arkansas-White-Red; [12] Texas-Gulf; [13] Rio Grand; [14] Upper Colorado; [15] Lower Colorado; [16] Great Basis; [17] Pacific Northwest; [18] California; [19] Alaska; [20] Hawaiian Islands; [21] Puerto Rico & Caribbean.

These 21 geographic areas contain either the drainage area of a major river, such as the Missouri region, or the combined drainage areas of a series of rivers, such as the Texas-Gulf region where a number of rivers drain into the Gulf of Mexico. Eighteen of the regions occupy the land area of the conterminous United States. Alaska is region 19, the Hawaii Islands constitute region 20, and Puerto Rico and other outlying Caribbean areas define region 21.

The second level of the USGS classification system divides the 21 regions into 222 subregions. A subregion includes the area drained by a river system, a reach of a river and its tributaries in that reach, a closed basin(s), or a group of streams forming a coastal drainage area.

The third level of the USGS classification system subdivides many of the subregions into accounting units, otherwise known as a Major Watersheds. These 352 hydrologic accounting units nest within, or are equivalent to, the subregions.

The fourth level of the USGS classification system divides the accounting units into cataloging units, also referred to as a Watersheds. A cataloging unit is defined as a geographic area representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature. The cataloging units subdivide the accounting units (Major Watersheds) into smaller areas (Watersheds). Currently there are 2150 Cataloging Units in the Nation, however USGS efforts are underway to add further levels of subdivisions.[4]

[3] USGS Hydrologic Unit Maps (21 US Regions) http://water.usgs.gov/GIS/huc.html

[4] USGS Hydrologic Unit Map Description: http://water.usgs.gov/GIS/huc.html

Appendix B. Department of Natural Resources: Total Maximum Daily Load Information Sheet 2004

Missouri Department of Natural Resources

Total Maximum Daily Load Information Sheet

Dardenne Creek

Waterbody Segment at a Glance:

State map showing location of watershed

Counties:	Warren St. Charles
Nearby Cities:	New Melle, Cottleville, St. Peters and St. Charles
Length of Impairment:	10 miles
Pollutants:	Unknown
Pollutant Sources:	Urban and Rural Nonpoint Sources

TMDL Priority Ranking: Medium

Description of the Problem

Beneficial uses of Dardenne Creek

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health associated with Fish Consumption
- Boating and Canoeing

Use that is impaired

- Protection of Warm Water Aquatic Life

Standards that apply

- All waterbodies in Missouri are protected by the *general* criteria (standards) contained in Missouri's Water Quality Standards (WQS), 10 CSR20-7.031(3). These criteria (also called *narrative* criteria) list substances that all waters "shall be free from". For example, points (3)(A), (C) and (G)state:
  - Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
  - Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.
  - Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

Background Information and Water Quality Data

The U. S. Environmental Protection Agency (EPA) placed Dardenne Creek on the 2002 303(d) list for unknown pollutants. EPA believes that the results and conclusions from the studies conducted by the

Department of Natural Resources between 1998 and 2000 (see Tables 1 and 2 below) adequately demonstrate that Dardenne Creek is impaired.

Aquatic Invertebrate sampling by the department in the spring of 2000 and the spring and fall of 2002 indicates poor water quality and/or poor aquatic habitat conditions in much of Dardenne Creek. This data is summarized in Table 1. The invertebrate scores used in this table compare the invertebrate community of the stream to the invertebrate community in a reference (high quality) stream in the same area of the state. Scores of 20-16 indicate a healthy invertebrate community.

Table 1. Invertebrate Scores and Percent Fine Sediment Deposition in Dardenne Creek

	Dardenne Cr. upstream of Busch CA	Dardenne Cr. in Vicinity of Busch CA	Dardenne Cr. downstream of Hwy 40
Inv. Score Spring 2000	10-14	16-20	0-8
Inv. Score Spring 2002	8-12	14	
Inv. Score Fall 2002	10-16	16	
% Fine Sediment Deposition	23-71	70-100	

Source: Missouri Department of Natural Resources

The poorer invertebrate scores below Highway 40 probably reflect the problems related to urbanization of that portion of the watershed.

Results of cooperative water quality monitoring program of Dardenne Creek by the Departments of Natural Resources and Conservation are summarized below.

Table 2. Mean Water Quality Data for Dardenne Creek 1998-2003

	Holt Rd.	Hwy Z	Hopewell Rd.	Hwy DD	At Busch CA	Hwy N	Hwy C
Water Temp. (C)	16	20	17	14	21	20	17.5
Dissolved Oxygen (mg/L)	11.9	7.1	10.3	8.6	7.0	8.2	9.4
Conductivity (umhos/cm)	440	414	290	339	334	389	445
Organic+NH3N (mg/L)		0.48	0.69	0.36	0.62	0.98	1.08
NH3N (mg/L)	<0.05	0.06	0.13	<0.05	<0.05	<0.05	<0.05
NO2+NO3N	0.35	0.17	0.47	0.23	0.22	0.25	0.42
Total Phosphorus (mg/L)	0.03	0.08	0.13	0.08	0.11	0.18	0.17
Volatile Susp. Solids (mg/L)		3.7	5.8		7.6		
Turbidity (NTU)		19.5	30		39.6		
Fecal Coliform Bacteria (col/100 ml)			59		104	145	394

Source: Missouri Department of Natural Resources, Missouri Department of Conservation

Over the last several years, Missouri Volunteer Quality Monitoring monitors have been collecting data at nine sites along Dardenne Creek (see map below). In an effort to better understand the stream, the last three years of available volunteer data have been compiled and summarized (see table below). Volunteers sampled the creek for temperature (C°), dissolved oxygen (DO), biological oxygen demand (BOD), nitrates (NO_3), ammonia (NH_3), phosphate (PO_4), specific conductance (SC), total solids (TS), total dissolved solids (TDS), turbidity (TURB), pH, and fecal coliform (FC). Missouri Water Quality Monitoring Volunteer Macroinvertebrate Water Quality Ratings (WQRate) were also included and are an indication of the diversity of macroinvertebrates present. The results of this sampling are discussed below.

Dardenne Creek with Sampling Sites, Warren and St. Charles Counties, Missouri

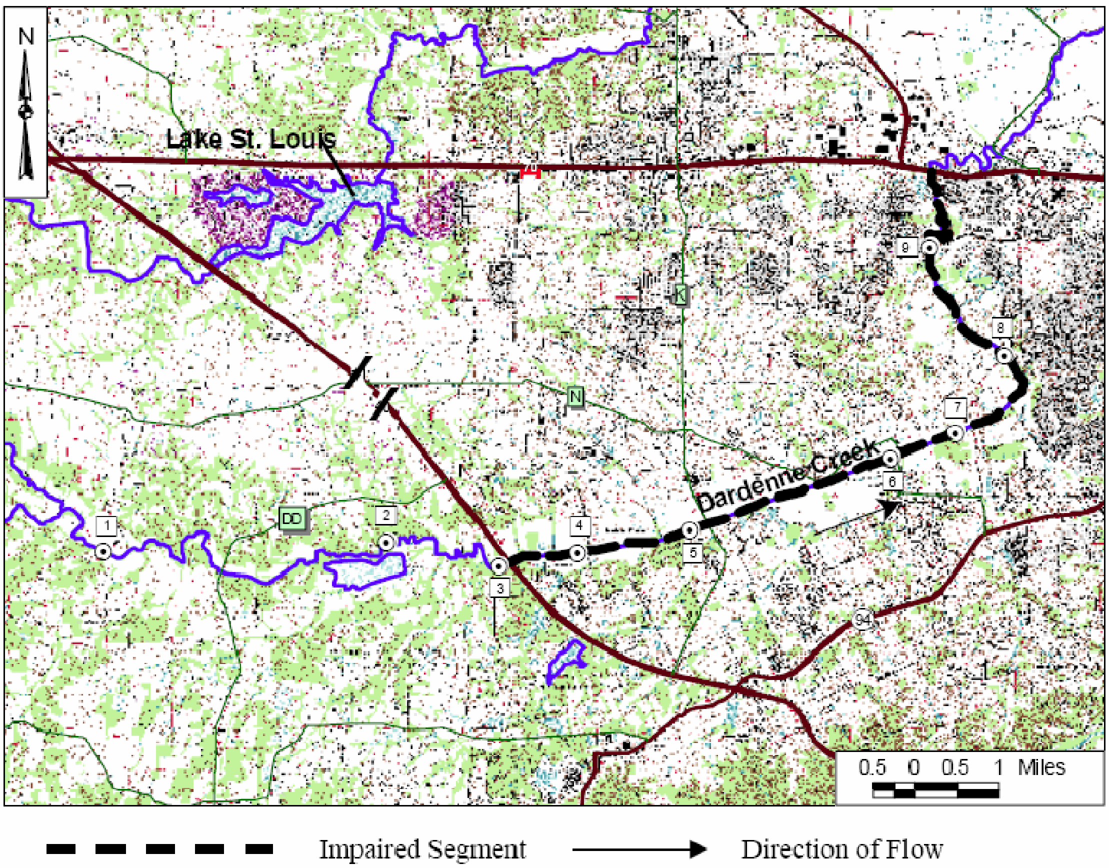

Table 3. Results of Volunteer Water Quality Monitoring: Mean Water Quality Data for Dardenne Creek

Location	WQRate	Temp	DO	BOD	NO_3	NH_3	PO_4	SC	TS	TDS	TURB	pH*	FC**
		C	mg/l	mg/l	mg/l	mg/l	Mg/l	us	mg/l	mg/l	NTU	su	cfu
1. Hopewell Road	26							469	802.9	176	8.8		
2. Busch Conservation Area		8.3	8.4	4.5	0.36	0.52	0.49	337			37.2	7.2	99
3. Highway 40	21	9.2	8.7	3.0	0.34	0.65	0.79	406	358.0		8.9	7.7	84
4. Henning Road		12.8	9.8	1.5	0.14	0.57	0.86	390			10.8	7.6	33

5. Highway K		**9.3**	**7.0**	**3.0**	**1.79**	**0.75**	**0.29**	**630**	**270.6**	**242**	**22.5**	**7.7**	**203**
6. Highway N		**11.1**	**7.4**	**6.8**	**0.72**	**0.79**	**1.07**	**448**	**1108.0**		**22.7**	**7.5**	**20**
7. Upstream of Mid-Rivers Mall	**18.5**	**9.4**	**9.8**	**7.0**	**0.30**	**0.38**	**0.50**	**362**	**24.0**		**37.5**	**8.0**	**580**
8. Downstream of Mid-Rivers Mall		**9.3**	**9.2**	**4.2**	**0.24**	**0.22**	**0.50**	**498**	**232.0**		**22.6**	**7.8**	**227**
9. Mexico Road		**10.4**	**9.7**	**4.7**	**0.20**	**0.47**	**0.68**	**447**			**110.5**	**7.2**	**352**
*Median Value													
**Geometric Mean													

Water Quality Rating: Volunteer Water Quality Invertebrate Ratings were given at three sites, and a declining trend can be seen in a downstream direction. The Water Quality Rating at Hopewell Road in 2001 was 26, a score that indicates excellent water quality. The Water Quality Rating at Highway 40 in 2001 was 21, indicating relatively good water quality. Water Quality Ratings were given upstream of Mid-Rivers Mall in 1998 and 2001. In 1998, the score was 16, indicating fair water quality, but the Water Quality Rating at the same site in 2001 was 21, similar to the score at Highway 40. This Water Quality Rating is rather forgiving, and the limited amount of ratings makes it difficult to pinpoint a particular problem. In addition, there is no direct association between Water Quality Ratings and Missouri Water Quality Standards. Although this information does provide some insight, it could not be used to place Dardenne Creek on the Missouri 303(d) list. However, EPA placed Dardenne Creek on the 2002 303(d) list based on department studies.

For more information call or write:
Missouri Department of Natural Resources
Water Protection Program
P.O. Box 176, Jefferson City, MO 65102-0176
1-800-361-4827 or (573) 751-1300 office
(573) 522-9920 fax
Program Home Page: www.dnr.mo.gov/env/wpp/index.html

Appendix C. Clean Water Act, § 303 (d) List, 2002 Dardenne Creek Status & Table

Missouri's water quality standards are reviewed and modified every three years. Termed the triennial review process, coordinators with the Missouri Department of Natural Resources meet with the U.S. Environmental Protection Agency, other state agencies, and concerned citizens to evaluate the effectiveness of our standards.

Water quality standards provide a means by which attainment of water quality objectives can be measured. The objective is protection of designated uses through the application of narrative or numeric criteria. The antidegradation section requires actions to maintain existing uses. Attainment frequency of water quality standards are used in identifying and characterizing waters of the state for purposes of compiling the 303(d) List and 305(b) report. In addition, effluent limits contained in National Pollution Discharge Elimination System (NPDES) permits are frequently derived using water quality standards.

Revised US EPA Consolidated 2002 Missouri 303(d) List
RESPONSIVENESS SUMMARY TO PUBLIC COMMENTS, EPA PUBLIC NOTICE REGARDING CHANGES TO MISSOURI'S 2002 SECTION 303(D) LIST, DECEMBER 2003.

S	Year	C	2002W BID	Waterbody	Size	Units	Pollutant	Source	Downstream	Upstream	Dcounty	Ucounty	Priority for Analysis
	1994		7255	Creve Coeur Lake	300	Acre	Chlordane *5	Urban nonpoint runoff			St. Louis		L
A	2002	1	7135	Crowder SP Lake	18	Ac	Mercury	Atmospheric Deposition	12,61N,25W		Grundy		M
			221	Dardenne Creek	10		Unknown Pollutant *2	Urban/Rural NPS			St. Charles		L
	1994	1	690	Dark Cr.	8	Mi	Sulfate	Crutchfield AML	NE31,54N,15W	34,55N,15W	Randolph		M
C	1994	3 1	912	Davis Cr.	2	Mi	BOD/DO Nutrients	Odessa SE WWTP	SE10,48N,27W	N9,48N,27W	Lafayette		H
A	2002	1	7015	Deer Ridge Comm. Lake	48	Ac	Mercury	Atmospheric Deposition	18,62N,8W		Lewis		M
A	2002	1	3050	Ditch #1	44	Mi	Mercury	Atmospheric Deposition	State Line	27,29, 12E	Dunklin	New Madrid	M
C	1998	1	510	Dog Cr.	0.2	Mi	[NVSS] <Sediment> *3, 6	Traeger Quarry	NW13,58N,28W	NW13,58N,28W	Daviess		L
C	1996	1	3168	Douger Br.	2	Mi	Zinc	Aurora AML	C11,26N,26W	W7,26N,25W	Lawrence		M
	1994		1145	Dry Auglaize Cr.	1.5	Mi	<BOD, NFR>, [Unknown], 6	Lebannon WWTP, [NPS]			Laclede		L
C	1994	1	811	E. Brush Cr.	1	Mi	Nutrients [BOD,NFR] *3	California N. WWTP	SW10,45N,15W	C16,45N,15W	Moniteau		L
D			372	E. Fk. Crooked Cr			<VSS, BOD,NFR> [Sediment] *1,3, 6						L
D			457	E. Fk. Grand River			[Sediment] *1, 3, 6						L
D			608	E. Fk Locust Cr.			DO, unknown *2, 6						L
			619	E. Fk. Medicine Cr			[Sediment] *1,3						L
C	1994	1	1282	E. Fk. Tebo Cr.	1	Mi	pH	Triple Tipple AML	C2,43N,24W	NW35,44N,24W	Henry		H
D			555	E. Honey Cr.			Unknown *2, 6						L
A	2002	1	7026	Edina Res.	51	Ac	Atrazine, Cyanazine	Corn&Sorghum Production	NE12,62N,12W		Knox		H
A	2002	1	2593	Eleven Point R.	21	Mi	Mercury	Atmospheric Deposition	State Line	18,24N,2W	Oregon		M

US EPA Consolidated 2004 Missouri 303(d) List

Appendix D. Home Builders Association of Greater St. Louis, Inc. v. Missouri Clean Water Commission & Missouri Department of Natural Resources; Petition for Declaratory and Injunctive Relief, January 3, 2005.

IN THE CIRCUIT COURT OF ST. LOUIS COUNTY
STATE OF MISSOURI

HOME BUILDERS ASSOCIATION)
OF GREATER ST. LOUIS, INC.)
)
Plaintiff,)
)
v.) Case No. 05CC-000004
)
THOMAS HERRMANN, in his official)
Capacity as CHAIR, MISSOURI)
CLEAN WATER COMMISSION,)
MISSOURI CLEAN WATER)
COMMISSION and MISSOURI)
DEPARTMENT OF NATURAL)
RESOURCES,)
)
Defendants.)

4

05 JAN -3 PM 1:45

RECEIVED CIRCUIT COURT OF ST. LOUIS COUNTY

SERVE: Thomas Herrmann
707 Dutch Mill Drive
Ballwin, Missouri 63011

SERVE: Missouri Clean Water Commission
Jefferson State Office Building
P.O. Box 176
205 Jefferson Street
Jefferson City, Missouri 65102-0176

SERVE: Missouri Department of Natural Resources
Jefferson State Office Building
P.O. Box 176
205 Jefferson Street
Jefferson City, Missouri 65102-0176

PETITION FOR
DECLARATORY AND INJUNCTIVE RELIEF

COMES NOW Plaintiff, Home Builders Association of Greater St. Louis, Inc. ("HBA"), by and through counsel, and for its Petition for Declaratory and Injunctive Relief does state:

2447612

PARTIES

1. Plaintiff HBA is a not-for-profit Missouri corporation headquartered in St. Louis County with over 1,100 members comprised of builders, developers and others associated with the shelter industry in the St. Louis metropolitan area, including St. Louis County, St. Charles County, Jefferson County, Franklin County, Warren County, Lincoln County and Washington County. HBA, as representative of its members, seeks a determination Defendants are exceeding their legal authority by imposing certain regulatory requirements in certain permits issued and enforced by Defendants. HBA has standing to bring this action on behalf of its members. *See Home Builders Assn. of Greater St. Louis, Inc. v. City of Wildwood,* 32 S.W.3d 612, 615 (Mo. App. E.D. 2000).

2. Defendant Thomas Herrmann is a resident of St. Louis County, Missouri and is chairperson of the Missouri Clean Water Commission. Defendant Herrmann is sued in his official capacity only.

3. Defendant Missouri Clean Water Commission ("Commission") is a state agency created by § 644.021, RSMo. The Commission is, *inter alia*, to exercise general supervision over the administration and enforcement of the Missouri Clean Water Law, §§ 644.006 to 644.141, RSMo, and all rules and regulations and orders promulgated thereunder, and to develop comprehensive plans and programs for the prevention, control and abatement of pollution of the waters of the state.

4. Defendant Missouri Department of Natural Resources ("MDNR") is a state agency created by Article IV, § 47 of the Missouri Constitution. MDNR is to administer the programs of the state as provided by law relating to environmental control and the conservation and management of natural resources.

5. Defendants are attempting to place additional or "extra" requirements on certain land disturbance permits being issued to certain HBA members. The Defendants lack the legal authority to place these additional requirements in such permits and should be ordered to stop doing so.

JURISDICTION AND VENUE

6. The Court has jurisdiction over the parties and the matters in the Petition for Declaratory and Injunctive Relief pursuant to chapter 527, RSMo., and § 536.050, RSMo.

7. Venue is appropriate in this Court pursuant to § 508.010, RSMo because Defendant Herrmann is a resident and Defendant MDNR maintains an office in St. Louis County, Missouri.

FEDERAL REGULATORY BACKGROUND

8. In § 303(d) of the Federal Water Pollution Control Act ("Clean Water Act"), 33 U.S.C. § 1313(d) (hereinafter "§ 303(d)"), Congress directed each State to identify each impaired waterbody within its borders and to submit a listing of such impaired waterbodies (hereinafter referred to as the "303(d) List") to the United States Environmental Protection Agency ("EPA").

9. EPA has adopted regulations at 40 CFR 130.7(d)(1) that require each State to identify each impaired waterbody within its borders, to identify the specific pollutant(s) causing such impairment, and to submit such listing to the EPA.

10. In accordance with 33 U.S.C. § 1313(d)(1)(D)(2) and 40 CFR § 130.7(d)(2), EPA is required to review and approve, approve with modifications, or disapprove the listing of impaired waterbodies submitted by each State.

11. Each State is required by 40 CFR §§ 130.7(b)(1) and (c)(1) to develop a proposed Total Maximum Daily Load ("TMDL") for each waterbody placed on that State's 303(d) List.

12. A TMDL is a calculation of the maximum amount of a given pollutant that a body of water can absorb before its quality if affected.

13. If a watershed is determined to be impaired such that it is placed on the 303(d) List, a State is required to develop a watershed management plan that will include the TMDL calculation.

14. After each State develops a TMDL for a particular waterbody, the State is then required by 40 CFR § 130.7(d)(2) to submit the proposed TMDL to EPA. EPA is required to approve or disapprove the proposed TMDL.

MISSOURI REGULATORY BACKGROUND

15. Chapter 536, and particularly §536.021 RSMo., sets forth the procedure an agency must follow to adopt a rule. The Defendants are required to comply with the rulemaking requirements in chapter 536, RSMo. when imposing regulatory requirements that adversely affect a permittee's legal rights and interests.

16. Section 536.021 states that a rule is void if not adopted in accordance with the procedures set forth in this section, unless it is an emergency rule adopted in accordance with the procedures set forth in §536.025.

17. Defendants have promulgated water quality standards for waterbodies in the State of Missouri. The water quality standards rule is codified at 10 CSR 20-7.031. The water quality standards rule was adopted in accordance with the procedures set forth in §536.021 RSMo.

COMMON STATEMENT OF MATERIAL FACTS

18. On or about August 27, 2002, Defendants submitted the proposed Missouri 2002 § 303(d) List to EPA.

19. On December 17, 2003, EPA approved the Missouri 2002 § 303(d) List that included, among others, Dardenne Creek, Peruque Creek, Mill Creek and Flat Creek. A copy of EPA's December 17, 2003 letter and enclosures is attached hereto and incorporated herein as Exhibit 1.

20. For Dardenne Creek, the specific pollutant identified was described as "unknown" and no other specific pollutant was identified. Therefore, Defendants failed to identify a specific pollutant for Dardenne Creek.

21. For Mill Creek, Peruque Creek and Flat Creek, the specific pollutant identified was described as "sediment" and no other specific pollutant was identified.

22. Defendants are authorized to enforce 10 CSR 20-7.031, which imposes certain water quality standards and discharge requirements on waterbodies such as Dardenne Creek, Peruque Creek, Mill Creek and Flat Creek.

23. Defendants are currently imposing additional or extra regulatory requirements, over and above those set forth in and authorized by 10 CSR 20-7.031, in certain permits that involve discharges into the watersheds of Dardenne Creek, Peruque Creek, Flat Creek and Mill Creek.

24. These requirements include, but are not limited to, the additional or extra requirements to conduct water quality reviews and to intercept and treat stormwater. The imposition of these additional requirements also results in additional delays in the time normally required to issue permits.

25. Defendants have stated that the reason these additional or extra requirements are being placed in permits is because such waterbodies are on the 2002 Missouri § 303d List.

26. Defendants have not developed or submitted to EPA any TMDLs for Dardenne Creek, Peruque Creek, Mill Creek or Flat Creek.

27. Defendants have not developed or submitted to EPA any watershed management plans for Dardenne Creek, Peruque Creek, Mill Creek or Flat Creek.

28. HBA has members that own and/or develop real property in the watersheds of these four waterbodies who are adversely affected by Defendants' unlawful actions. HBA's members incur additional financial costs and incur lost project time as a direct result of the imposition of these additional requirements.

29. A justiciable controversy exists between the parties concerning whether Defendants have legal authority to impose these additional or extra regulatory requirements on permits. Plaintiff met with MDNR on December 16, 2004 and raised these specific concerns as set forth in Counts I through III herein. In a letter dated December 22, 2004, MDNR stated its current actions would continue. A copy of MDNR's December 22, 2004 letter is attached hereto and incorporated herein as Exhibit 2.

COUNT I

DEFENDANTS LACK LEGAL AUTHORITY TO IMPOSE ADDITIONAL REQUIREMENTS IN PERMITS FOR WATERBODIES ON THE § 303(D) LIST PRIOR TO THE APPROVAL OF TMDLs AND WATERSHED MANAGEMENT PLANS AS REQUIRED BY § 303(D) AND 40 CFR §130.7

30. Plaintiff restates, realleges and incorporates by reference the allegations in paragraphs 1 through 29 as if fully restated herein.

31. Defendants cannot place these additional or extra requirements in permits without legal authority to do so. The mere inclusion of these four waterbodies on the §303(d) List does not give the Defendants any legal authority for imposing additional or extra permit requirements *until* TMDLs have been developed and submitted to EPA for review and approval and until watershed management plans have been submitted to EPA for review and approval because § 303(d), 40 CFR § 130.7 and § 536.021, RSMo require that a specific procedure be followed by the Defendants before imposing such additional regulatory requirements.

32. Defendants are acting unlawfully and in excess of their authority by:

A. Imposing more stringent requirements on discharges into these waterbodies prior to development of watershed management plans; and

B. Imposing more stringent requirements on discharges into these waterbodies prior to the development and submittal to EPA, and receiving EPA approval, of TMDLs for each such waterbody.

WHEREFORE, HBA prays that the Court:

A. Declare that Defendants' actions are unlawful and in excess of their legal authority;

B. Declare that Defendants' actions are arbitrary and capricious, unreasonable, and without substantial justification;

C. Issue an Order enjoining Defendants from imposing more stringent regulatory requirements on permits involving discharges to these four waterbodies until Defendants have submitted and EPA has approved TMDLs for each such waterbody;

D. Issue an Order enjoining Defendants from imposing more stringent regulatory requirements on permits involving discharges to these four waterbodies until Defendants have developed watershed management plans for such waterbodies;

E. Award HBA its reasonable costs and attorneys fees in this action; and

F. Award such further relief the Court deems just and appropriate.

COUNT II

DEFENDANTS LACK LEGAL AUTHORITY TO
IMPOSE ADDITIONAL OR EXTRA REQUIREMENTS
IN PERMITS ON WATERBODIES THAT ARE
ON THE § 303(D) LIST FOR "UNKNOWN" POLLUTANTS
OR WHERE THE IDENTIFIED POLLUTANT IS SEDIMENT

33. Plaintiff restates, realleges and incorporates the allegations in paragraphs 1 through 32 by reference as if fully restated herein.

34. Under the Missouri Clean Water Law, chapter 644, RSMo., pollution involves the introduction of a pollutant which alters the physical, chemical or biological properties of the waterbodies or creates a nuisance.

35. Because 40 CFR § 130.7(d)(1) requires that a specific pollutant be identified in order that a TMDL and watershed management plan may be developed to address that identified pollutant, the listing of a waterbody for an "unknown" pollutant is unreasonable in that a TMDL or watershed management plan cannot be developed unless a specific pollutant is identified. As such, listing of a waterbody for an "unknown" pollutant cannot serve as a reasonable regulatory basis for imposing additional or extra requirements in permits for such a listed waterbody.

36. Defendants failed to identify a specific pollutant for Dardenne Creek. As such, the presence of Dardenne Creek on the § 303(d) List cannot serve as a regulatory basis for additional or extra requirements in permits regarding Dardenne Creek.

37. "Sediment," a naturally occurring material frequently present in waterbodies in Missouri following a rain event, is not a pollutant under the Missouri Clean Water Law, chapter 644, RSMo., because the presence of sediment in a waterbody does not alter the physical, chemical or biological properties of a waterbody or create a nuisance.

38. "Sediment" cannot therefore provide a reasonable regulatory basis for additional or extra requirements in permits regarding waterbodies where the identified pollutant is sediment.

39. The inclusion of Mill Creek, Peruque Creek and Flat Creek on the § 303(d) List for an alleged impairment due to the presence of "sediment" cannot serve as a reasonable regulatory basis for additional or extra requirements in permits regarding Mill Creek, Peruque Creek and Flat Creek.

40. Defendants are acting unlawfully and in excess of their authority by:

A. Imposing more stringent requirements on discharges into these waterbodies due to the presence of sediment when sediment is not a pollutant under the Missouri Clean Water Law.

B. Imposing more stringent requirements on discharges into these waterbodies due to the presence of "unknown" pollutants when "unknown" pollutants are not redressable pollutants under the Missouri Clean Water Law, as no TMDLs or watershed management plans can be developed to address an "unknown" pollutant.

WHEREFORE, HBA prays that the Court:

A. Declare that Defendants' actions are unlawful and in excess of their legal authority;

B. Declare that Defendants' actions are arbitrary and capricious, unreasonable, and without substantial justification;

C. Issue an Order enjoining Defendants from imposing more stringent regulatory requirements on permits involving discharges to these waterbodies due to the presence of sediment in the waterbodies;

D. Issue an Order enjoining Defendants from imposing more stringent regulatory requirements on permits involving discharges to these waterbodies due to the presence of "unknown" pollutants in the waterbodies;

E. Award HBA its reasonable costs and attorneys fees in this action; and

F. Award such further relief the Court deems just and appropriate.

COUNT III

DEFENDANTS LACK LEGAL AUTHORITY TO IMPOSE THESE ADDITIONAL PERMIT REQUIREMENTS WHEN DEFENDANTS HAVE FAILED TO FIRST CONDUCT NOTICE-AND-COMMENT RULEMAKING UNDER § 536.021, RSMO TO PROVIDE A LEGAL BASIS TO IMPOSE SUCH ADDITIONAL REQUIREMENTS

41. Plaintiff restates, realleges and incorporates the allegations in paragraphs 1 through 40 by reference as if fully restated herein.

42. The additional and extra permit requirements imposed by Defendants are "rules" as defined in Chapter 536.010, RSMo., and must be promulgated using the notice-and-comment rulemaking procedures in § 536.021, RSMo.

43. Defendants have not adopted these more stringent regulatory requirements using notice-and-comment rulemaking procedures in accordance with § 536.021, RSMo.

44. Defendants have no legal authority to impose these additional and extra regulatory requirements as a "policy statement" without first using notice-and-comment

rulemaking procedures in accordance with § 536.021, RSMo. As such, these more stringent requirements are void and without any legal authority.

45. A justiciable controversy exists between the parties concerning whether Defendants have legal authority to impose these additional or extra regulatory requirements on permits where these more stringent requirements were adopted without using notice-and-comment rulemaking procedures under chapter 536, RSMo.

46. Defendants are acting unlawfully and in excess of their authority by imposing more stringent requirements for discharges into these waterbodies without first adopting such requirements using notice-and-comment rulemaking procedures as required by chapter 536, RSMo.

WHEREFORE, HBA prays that the Court:

A. Declare that Defendants' actions are unlawful and in excess of their legal authority;

B. Declare that Defendants' actions are arbitrary and capricious, unreasonable, and without substantial justification;

C. Issue an Order enjoining Defendants from imposing more stringent regulatory requirements on permits involving discharges to these four waterbodies until Defendants have adopted such requirements using notice-and-comment rulemaking procedures in chapter 536, RSMo;

D. Award HBA its reasonable costs and attorneys fees in this action; and

E. Award such further relief the Court deems just and appropriate.

Respectfully submitted,

THOMPSON COBURN LLP

By: ______________________
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Attorneys for Plaintiff Home Builders
Association of Greater St. Louis, Inc.

Bob Holden, Governor • Stephen M. Mahfood, Director
STATE OF MISSOURI
DEPARTMENT OF NATURAL RESOURCES
www.dnr.mo.gov

December 22, 2004

Mr. Stephen G. Jeffery
Thompson Coburn
One US Bank Plaza
St. Louis, MO 63101

Dear Mr. Jeffery:

Thank you for taking the time to meet with Senator Chuck Gross, Sheri Bilderback of the St. Louis Homebuilders Association (HBA), Jim Hull, Director of the Water Protection Program and me. At the meeting, you indicated a concern on behalf of the St. Louis HBA that, in your view, excessive sediment did not constitute a "pollutant" to waterbodies. In addition, you stated that when issuing land disturbance permits within certain impaired watersheds, the department is essentially exceeding its authority by imposing more stringent sediment control requirements without proper 303d listing and prior to the completion of Total Maximum Daily Load (TMDL) studies. Further, you asserted that any more stringent controls than what would be necessary to protect water quality in non-303(d) listed streams should only be required after being placed in regulation properly promulgated by the Clean Water Commission. Finally, you stated that the Dardenne, Peruque and Mill Creeks were improperly included in the 2002 303(d) list.

Prior to addressing these issues, I would like to offer the department's interest in continuing to discuss these concerns. As you know, we have been meeting quarterly with the St. Louis HBA. In my view, those meetings have been instructive for us as well as the St. Louis HBA and have served as a useful forum to solving problems and misunderstanding between the two organizations. I would like to believe the department addresses every issue 100 percent correctly each and every time. I am under no illusions that we reach that goal in all cases and I suspect that there is some misunderstanding on the part of the department and the St. Louis HBA on these issues. Consequently, I believe that subsequent substantive discussions on these issues would be beneficial for both parties.

As you are aware, Dardenne Creek is listed on EPA's 303d Impaired Waterbodies list for unknown pollutants and Peruque and Mill Creeks are listed for the pollutant of sediment. Sediment constitutes a pollutant because it has both direct and indirect lethal effects on aquatic life. Sediment impacts aquatic life by destroying habitat, suffocating macroinvertibrates and interrupting fish breeding and feeding activities.

Other indirect connections have been shown through temperature alterations and decreases in plant growth. Depending on the source of the sediments, toxic chemicals may reside in sediments for years and continue to affect a myriad of uses from aquatic life to drinking water. According to EPA, sediment/siltation is the fourth highest pollutant identified as the cause for water impairment in the United States resulting in over 5,000 waters being placed on impaired lists across the country. EPA's recent enforcement actions in the St. Louis region and elsewhere in the state for stormwater violations by those developing projects further reinforces the concept that sediment should not be discharged to Missouri waters.

Pursuant to an August, 2000 legal agreement between the Department and EPA, the Department will be developing total maximum daily loads (TMDL's) for Peruque, Dardenne and Mill Creeks according to the schedule in that legal agreement. Once they are complete, they will specify waste load allocations that will provide the basis for determining more specific permit limits and conditions to control the identified pollutants of concern. In the meantime, the department must ensure these streams are not further impaired by discharges within the watershed of the listed segments. Discharges of sediment from land disturbance activities that may not be adequately controlled are among the actions that are likely causes for further impairment.

The Department has not attempted to establish the requirements of the TMDL's through permit conditions before the TMDL's are finished. Rather, the Department has developed its permits to comply with existing federal and state law for land disturbance. As you know, state law establishes that the Department shall deny a permit "if the sources will violate any such acts, regulations, limitations or standards or will appreciably affect the water quality standards or the water quality standards are being substantially exceeded, unless the permit is issued with such conditions as to make the source comply with such requirement within an acceptable time schedule" (§ 644.051.4, RSMo). Federal regulations further provide that "no permit may be issued to a new source or a new discharger, if the discharge from its construction or operation will cause or contribute to the violation of water quality standards" (40 CFR 122.4). Missouri regulations also reflect this federal mandate in 10 CSR 6.010(9)(G). To remain in compliance with federal and state law, the Department must ensure that new land disturbance discharges will not further diminish the ability of an impaired water body to regain the appropriate water quality standards.

General stormwater permits issued in the Dardenne, Peruque, and Mill Creek watersheds achieve this goal. These general permits have been in existence for a number of years and are in use statewide. You are also aware that pursuant to 10 CSR 20-6.010(13), any applicant has the option of requesting a site specific permit that would be tailored to the conditions that exist at a particular site. Consequently, it appears to us that the department is not mandating more stringent requirements.

You are also aware challenges have been raised in other states regarding continuing to issue any land disturbance permits within 303d listed watersheds. Instead, we have approached the issue of land disturbance permits within 303d watersheds with the proper balance - protecting the resource while also protecting the ability of developers to continue their operations. We believe that the department has taken the proper course from both a legal and policy perspective, and is in a strong position to defend the issuance of such permits from a third party legal challenge.

However, as I stated before, I and members of my staff are eager to continue these discussions. There may be opportunities to improve our service to members of the St. Louis HBA by continuing to discuss these concerns and we welcome that opportunity.

Sincerely,

WATER PROTECTION AND SOIL CONSERVATION DIVISION

Scott B. Totten
Director

SBT:bp

c: Senator Jon Dolan
Senator Chuck Gross
Jim Hull, Director, Water Protection Program, Department of Natural Resources
Michael Warrick, General Counsel, Department of Natural Resources
Sheri Bilderback, St. Louis Homebuilders Association

Appendix E. HBA v. Missouri Department of Natural Resources, February 6, 2008 Settlement Agreement: Attained from the Missouri Department of Natural Resources on April 7, 2008

SETTLEMENT AGREEMENT

THE PARTIES hereto agree as follows:

I. Parties

1. Doyle Childers is the duly appointed Director of the Department of Natural Resources, which is an agency of the State of Missouri and is created by § 640.010, RSMo ("Department"). The Missouri Clean Water Commission is created by § 644.021, RSMo., and is domiciled in the Department by § 640.010.2, RSMo. Pursuant to § 640.010.1, RSMo., the Director shall recommend policies to the Missouri Clean Water Commission to achieve effective and coordinated environmental control and natural resource conservation policies. Defendant's staff provides support to the Missouri Clean Water Commission.

2. The Home Builders Association of Greater St. Louis, Inc. (nka Home Builders Association of St. Louis and Eastern Missouri), referred to hereinafter as "HBA," is a not-for-profit Missouri corporation headquartered in St. Louis County with over 1,200 members comprised of builders, developers and others associated with the shelter industry in the St. Louis metropolitan area, including St. Louis County, St. Charles County, Jefferson County, Franklin County, Warren County, Lincoln County and Washington County.

3. The terms and provisions in this Settlement Agreement are binding on the parties, their directors, employees, agents, successors and assigns.

II. Dardenne Creek Pilot Biological Assessment Study

4. HBA and the Department agree to participate in a cooperative Biological Assessment of the segment of Dardenne Creek included in the 2006 § 303(d) List. This cooperative Biological Assessment may serve as a pilot for other similar cooperative activities. The Department will prepare the scope of work for the study which may address macroinvertebrate, water chemistry, benthic fine sediment and other parameters. HBA will have the opportunity to review the proposed scope of work and provide any comments. The Department will implement the scope of work, and HBA, at its option, may

participate in the study, obtain split samples, or conduct its own sampling. Each party shall bear their own costs and expenses associated with the study. After completion of all sampling and investigation and taxonomic identification activities provided in the scope of work, the Department will prepare a draft Biological Assessment Report which will be provided to HBA for review and comment. The Department will prepare a final Biological Assessment Report. The Department shall consider the data from the Dardenne Creek Pilot Biological Assessment Study in accordance with the Listing Methodology Document approved by the Clean Water Commission when making a recommendation to the Commission whether or not Dardenne Creek is impaired and should be included on the applicable § 303(d) List.

DC 2-6-08 - 1:15P
TRH 2-6-08 1:10PM

III. Inclusion of Streams on the Missouri § 303(d) List

5. HBA and the Department agree that any recommendation to place a stream on ~~the 2008~~ ANY § 303(d) List will be based on a weight of the evidence analysis using scientifically obtained evidence that is scientifically defensible as set forth in the Commission's approved Listing Methodology Document.

IV. Dismissal of Pending Litigation and Related Attorneys Fees

6. HBA agrees to voluntarily dismiss its petition in case number 05AC-CC00848, pending in the Circuit Court of Cole County, Missouri, and each party to that action shall bear its or his own costs and expenses incurred in this litigation.

V. Signatures and Approval

7. The parties, by their signatures below, hereby certify that they have full and complete legal authority to enter into the Consent Judgment and agree to be bound thereby.

HOME BUILDERS ASSOCIATION OF ST. LOUIS AND EASTERN MISSOURI	**DOYLE CHILDERS, DIRECTOR MISSOURI DEPARTMENT OF NATURAL RESOURCES**
By: T.R. Hughes	Doyle Childers
T. R. Hughes President	Doyle Childers
Date: 2-6-08	Date: 2-6-08 11:50 AM

Appendix F. St. Louis Area Environmental Stakeholders

Auto Free STL
Yahoo group for those who want to be car-free or car-lite in metro St. Louis.

Bike Katy Trail
Katy trail resources.

Butterfly House
See butterflies around you.

Center for Plant Conservation
Devoted to preventing the extinction of America's threatened flora

Confluence Greenway
40 mile recreation and conservation area at confluence of Mississippi and Missouri.

Dardenne Watershed Alliance
Friends of Dardenne Creek, St. Charles

Earth Share of Missouri
Fundraising and awareness building for more than 65 environmental organizations.

Gateway Center for Resource Efficiency
EarthWays Home showcase energy efficiency, recycled products, and waste reduction.

Gateway Greening
Community gardening

Great Rivers Environmental Law Center
Legal Services to protect the environment

Great Rivers Greenway
One of the largest park and recreation districts in the country.

Great Rivers Habitat Alliance
Dedicated to preserving the natural resources of the floodplain

The Green Center
26 acre Ruth Park Woods, 1/2 acre wetland, 1/2 acre prairie, gardens, arboretum.

Green Drinks
Socialize, network, and learn from others interested in sustainability issues.

Greenway Network
Encouraging sound use of natural resources and green space in St. Charles County

The International Center for Tropical Biology
Promotes research and education in tropical biology

Hiking trail reviews and links

LaBarque Creek Watershed. Transmission lines issues

La Vista Community Supported Garden
Share harvest with local farmers - membership commitment

Lewis and Clark Discovery Expedition of St. Charles

Mississippi River Basin Alliance
Working to conserve and restore the 30-state watershed and eliminate barriers of race and economy that divide it.

Missouri Botanical Garden
Come see the flowers

Missouri Coalition for the Environment
Activism for the environment

Missouri Department of Conservation, St. Louis Regional Office
Protects and manages fish, forest, and and wildlife resources of the state.

Missouri Department of Natural Resources
Preserves, protects, and enhances Missouri's natural, cultural, and energy resources

Missouri Master Naturalist Program
Engages Missourians in the stewardship of our state's natural resources

Missouri Prairie Foundation
Works to protect and restore prairie and native grasslands communities

Missouri Scenic Rivers Resource Page

Missouri Wilderness Coalition, Resource page

Monteverde Conservation League
Administers Children's Eternal Rain Forest in Costa Rica

Missouri Mycological Society
Study and enjoyment of mushrooms with forays, meetings, and education focused on fungi

Missouri State Public Interest Research Group
Research and advocacy for environmental and other public interest issues.

Missouri Votes Conservation
Advocates for the environment through legislative channels

Naturally St. Charles
Environmental internet resources for St. Charles

The Nature Conservancy - Missouri Chapter
Committed to the preservation of ecologically significant areas

The North American Butterfly Association - St. Louis
Promotes recreational butterflying

The Open Space Council for the St. Louis Region
Land trusts, clean stream

The Ozark Trail Association
Develop, maintain, preserve, protect, promote the Ozark Trail

Piasa Palisades Group in Illinois, Sierra Club
meets in Alton

The River des Peres Watershed Coalition
Improve and protect the River des Peres

Scenic Missouri
Preserves and enhances the scenic beauty of Missouri

St. Louis Audubon Society
Conserves and restores natural ecosystems, focusing on birds.

St. Louis Children's Aquarium
Aquatic exhibits

St. Louis Rainforest Advocates
Protecting tropical forests worldwide

St. Louis Regional Bicycle Federation
Promotes vision of a bicycle friendly region

St. Louis University Department of Biology (Biodiversity and Conservation)
Research and education in biodiversity and conservation

St. Louis Soil and Water Conservation District of St. Louis County
Provides technical assistance for wise use of soil, water, and other natural resources

St. Louis Zoo
Conservation, exhibits

TrailNet
Dedicated to creating trails, encouraging bicycling, walking.

Tyson Research Center
A 2,000-acre field station providing opportunities for environmental research, preservation, and education

Wild Canid Research Center
Wolf sanctuary and research.

Webster Groves Nature Study Society
Amateur naturalists interested in plants, insects, birds of St. Louis area.

The World Bird Sanctuary
Preserving the future of the world's wild birds

See also Missouri Chapter links

Appendix G. St. Charles County GIS Request Form, 2008

St. Charles County GIS Services Data License Request Form

201 N. Second Street, Suite 310, St. Charles, Missouri 63301
Phone: (636) 949-7417   Fax: (636) 949-7376   E-mail: gisservices@sccmo.org

Digital data is available only by request pursuant to license agreement and fees.
Please return this form with your license agreement.

Name: ______________________________ **Date:** ______________

Department/Organization/Business: ______________________________

Address: ______________________________

Phone: ______________ **E-mail:** ______________ **Fax:** ______________

Comments: ______________________________

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Available GIS Data Layers	Current Pricing.
County Parks	$50.00
Zip Codes	$50.00
Lakes	$50.00
Rivers	$50.00
Streams	$50.00
Railroads	$50.00
School Districts	$50.00
County Council Districts	$50.00
State House Districts	$50.00
State Senate Districts	$50.00
GRS Control Points	$50.00
Major Roads	$50.00
Land Use	$75.00
Voting Districts	$75.00
Building Footprints	$250.00
Municipalities	$250.00
Zoning	$250.00
Road Centerline	$1500.00
Parcels	$2050.00

Total Cost: ______________

Thank you for your interest in St. Charles County GIS Services. For the most up to date map information we recommend our free online interactive map site available at http://map.sccmo.org. Free digital maps you can print are available online at http://www.sccmo.org/DesktopDefault.aspx?tabid=360

Disclaimer

St. Charles County Government makes no representations about the suitability of these data for any purpose. The data are provided "as is" without express or implied warranties, including warranties of merchantability and fitness for a particular purpose or noninfringement. The user relieves St. Charles County Government and its respective officers, agents and employees of any liability for any and all damages resulting from use or mis-use of these data including, but not limited to, incidental, consequential, special or indirect damages of any sort, whether arising in tort, contract or otherwise, even if St. Charles County Government has been informed of the possibility of such damages, or for any claim by any other party. Furthermore, in States that do not allow the exclusion or limitation of incidental or consequential damages, you may not use these data.

CURRICULUM VITAE

Odean Serrano has over 20 years of experience both professionally and academically in science and policy management. Her professional experience includes over 13 years with NASA overseeing and implementing national environmental programs. She served as a legislative liaison to Congress, the White House and with Federal Agencies, writing, reviewing, and implementing national policy in concert with legislation and Presidential Executive Orders. She oversaw numerous regulatory programs at the national, regional, and local levels. Prior to NASA Headquarters, she held positions at Kennedy Space Center as a Space Shuttle and Payload Operations Engineer/Program Manager.

Ms. Serrano also served as senior fellow at the Environmental and Energy Study Institute, in Washington, D.C. She helped to educate Congress with respect to proposed legislation, on how local, state and regional governments can implement initiatives by leveraging resources to achieve comprehensive urban strategies that serve both the economic and cultural values of the communities

Currently Ms. Serrano serves as a program manager for the National-Geospatial Intelligence Agency. She holds a Masters of Science, Environmental Science & Public Policy from Johns Hopkins University, Baltimore, MD, 1999; Concentrations: Conservation Biology, Sustainable Development, and Environmental Law; and a Bachelors of Science, Mathematics University of South Florida, Tampa, FL: Concentrations: Numerical Theory & Real Analysis