Imperviousness in planning for water quality: a BASINS study

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Imperviousness in planning for water quality: A BASINS study

by

Karen Louise Johnson

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

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Major: Community and Regional Planning

Program of Study Committee:
Monica Haddad, Major Professor
Tara Lynne Clapp
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Ames, Iowa
2005

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This is to certify that the master's thesis of

Karen Louise Johnson

has met the thesis requirements of Iowa State University

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TABLE OF CONTENTS

LIST OF FIGURES ........................................................................................................ v

ABSTRACT .................................................................................................................. vii

CHAPTER 1. INTRODUCTION ................................................................................. 1

Problem Statement ................................................................................................. 1
Research Objectives .............................................................................................. 3
Conceptual Framework ......................................................................................... 4
Research Questions ............................................................................................... 5

CHAPTER 2. LITERATURE REVIEW ..................................................................... 7

Urbanization and Development ............................................................................ 7
Regulation and Planning ....................................................................................... 9
  Low-Impact Development Planning ................................................................. 13
  Impervious Cover ............................................................................................. 15
Water Quality ...................................................................................................... 20

CHAPTER 3. METHODS ...................................................................................... 24

BASINS Framework of Analysis ........................................................................ 24
Research Data ..................................................................................................... 29
Study Area ........................................................................................................ 30
BASINS Application: The Model Composition ................................................ .34
PLOAD Extension: Use and Organization .......................................................... 39

CHAPTER 4. ANALYSIS AND RESULTS ............................................................. 42

Scenario A Results .............................................................................................. 42
Scenario B Results .............................................................................................. 47
Scenario C Results .............................................................................................. 51
Scenario D Results .............................................................................................. 55

Analysis of Results ............................................................................................. 56
Evaluation of the BASINS Model for Water Quality Planning ....................... 57
LIST OF FIGURES

Figure 1. Conceptual Framework .................................................................................... 5
Figure 2. Effects of Imperviousness on Runoff and Infiltration ..................................... 17
Figure 3. Impervious Coverage by Urban Land Use ...................................................... 18
Figure 4. BASINS Systems Overview ......................................................................... 26
Figure 5. Dallas County, Iowa ..................................................................................... 31
Figure 6. Watersheds of Dallas County ...................................................................... 32
Figure 7. The North Raccoon Watershed .................................................................... 33
Figure 8. North Raccoon Watershed Subbasins ......................................................... 35
Figure 9. Land Use Pattern for 1997 ......................................................................... 36
Figure 10. Land Use Pattern for 2000 ....................................................................... 37
Figure 11. Land Use Pattern with Half-Mile New Development Ring ...................... 38
Figure 12. Land Use Pattern with a One-Mile New Development Ring ................... 38
Figure 13. PLOAD Session Organization ................................................................ 39
Figure 14. Impervious Surface Values used in the PLOAD Sessions ......................... 40
Figure 15. Scenario A: BOD Load Evaluation ............................................................. 43
Figure 16. Scenario A: Phosphorus Load Evaluation ................................................... 43
Figure 17. Scenario A: Phosphorus and Nitrate Load Comparison ............................. 44
Figure 18. Scenario A: BOD Load Evaluation for 2000 ............................................. 45
Figure 19. Scenario A: BOD Load Evaluation for Halfmile Development Layer ........ 46
Figure 20. Scenario A: BOD Load Evaluation for Onemile Development Layer ....... 47
Figure 21. Scenario B: BOD Load Evaluation for Low-Impervious Development .... 48
Figure 22. Scenario B: Phosphorus Load Evaluation for Low-Impervious Development ........................................................ 48
Figure 23. Scenario B: Nitrate Load Evaluation for Low-Impervious Development .... 49
Figure 24. Scenario B: BOD Load Evaluation for Halfmile Low Impervious Sessions .................................................................................................................. 50
Figure 25. Scenario B: BOD Load Evaluation for One mile Low Impervious Sessions .................................................................................................................. 51
Figure 26. Scenario C: Phosphorus Load Evaluation .................................................... 52
Figure 27. Scenario C: Nitrate Load Evaluation ............................................................ 53
Figure 28. Scenario C: BOD Load Evaluation .............................................................. 53
Figure 29. Scenario C: BOD Load Evaluation for 2000 ................................................ 54
Figure 30. Scenario D: BOD Load Evaluation .............................................................. 55
Figure 31. Scenario D: BOD Load Evaluation for 2000 ................................................ 56
ABSTRACT

In an effort to help preserve the future of the natural environment through planning, this research focuses on the evaluation of impervious surfaces in land use development. While still embracing current growth and future development plans, an understanding of land use and the impact it has on the environment, especially water quality is needed. One way for planners to better evaluate the land use-water quality connection is the use of GIS and BASINS as a tool to plan for future land use scenarios. Also, within the research is an evaluation of low impact development as a land use planning technique for water resource management.

BASINS, a software package and extension to GIS distributed by the EPA, allow users to evaluate imperviousness, runoff and nutrient loadings for watershed areas within a framework for planning. To illustrate these evaluation methods, the North Raccoon River Watershed past, current and future land use scenarios are used to understand the role impervious surfaces have on runoff and water quality. The outcome of this research is an evaluation of impervious surfaces in water resource management, and an examination of BASINS as an analytical tool for land use planning to contribute to water resource management for future development.
CHAPTER 1. INTRODUCTION

Problem Statement

There is increased interest among planners in conserving natural resources as urban development areas expand. Within many regions, “expanding urbanization [] dramatically affects water resources in terms of quality (physical, chemical, biological pollution, etc.) and quantity” (Durcot et al. 2004, p. 86). The National Association of Local Government Environmental Professionals (NALGEP) (2003) indicates that growth does not always result from an increase in population, but rather from an increase in consumed lands. For example, the recent census of Cleveland, Ohio, showed both an increase in metropolitan land area and an overall decrease in population (Wang and Choi 2005). Similarly, the urbanization of land has increased to twice the rate of population growth in older cities of the Northeast and Midwest (Rybezynski 2002). What once were agricultural lands and rural communities are developing into an expanding urban range of cities.

The conversion of rural land to a more urban environment does more than affect land use. It often degrades natural resources, such as lakes, river, streams, and forest and habitat areas. As Reimold (1990) outlines,

“the outer fringes of these suburban areas are often undergoing rapid development, converting agricultural or forested land into parking lots and shopping malls. In addition to the effect of urbanization on the surface of the land, cities and suburbs are underlain by a complicated network of sanitary sewers, combined sewers, and storm drains that collect wastewater and runoff for eventual discharge to local water bodies” (p.169).

Old Saybrook, Connecticut is facing water quality problems due to loss of land to urbanization needed to accommodate a growing population of over 10,000 (Newcombe 2001). The major issue within the community is that the “valuable wetlands near the mouth
of the river are threatened by encroaching development and runoff laced with residential fertilizers, herbicides and insecticides” (Newcombe 2001, p. 1).

The impact that land use has on environmental resources needs to be addressed during regulatory procedures. Harbor (1994) asserts that planners currently don’t have the tools to address the impacts of land use on water quality because “existing models are so complex and data-intensive that either they are beyond what a local planner can manage in terms of time and/or expertise or the planning agency cannot afford the cost of hiring a professional consultant to perform the analysis.” (p. 96). Pollard (2001) argues that planners should develop land while maintaining consideration for the environment in order to create better managed and regulated land uses for environmentally sensitive developments. Ducrot (2004) agrees that the management of natural resources has become one of the most challenging issues at the urban fringe. Changes in development patterns have, for example, threatened riverbanks and more,

“the reservoirs and watersheds are vulnerable to urbanization, with increased impermeable surface areas from roads and buildings resulting in higher storm water runoff volumes and velocities, accelerated erosion of existing channels, alterations of stream bed and reservoir bottom composition and heightened levels of toxic substances in runoff” (Reimold and Leavell 1990, p. 30).

To help evaluate land use and calculate the impacts on water resources, land use planners could incorporate into the development review process a system for the analysis of water quality.

This study attempts to explore the relationship of land use and water quality by evaluating the conversion of land use and its impact on water quality. The research focuses on impervious cover within land uses and the effects on nutrient loads in receiving waters. The analysis uses software developed by the Environmental Protection Agency (EPA) titled,
“Better Assessment Science Integrating Point and Non-point Sources” (BASINS) to examine pollutant loading within watersheds. The software allows investigators to examine how changes in impervious cover along with the extent of urban area within a watershed can affect water quality. BASINS is a Geographic Information System (GIS) based within the Arc View environment for exploratory spatial analysis. BASINS was intended to be a tool for regulators to use as a model for testing point and non-point source pollution within watersheds of the United States. In this study, BASINS was used to evaluate the benefits of low impervious development as a potential regulatory approach to mitigate problems with water quality due to new land development.

Chapter 1 presents a conceptual framework that depicts the role planning could have in evaluating land use development for water resource management. The Literature Review in Chapter 2 discusses such issues as urbanization and development, the role of regulation and planning in development, impervious cover, and water quality in an effort to understand current issues and future impacts of land use patterns. Chapter 3 examines the use of Geographic Information Systems (GIS), BASINS and accompanying models as a methodology. Chapter 4 illustrates the process of analysis and explores the BASINS study results. Chapter 5 looks at what this study has contributed and the implications and limitations of its analysis.

Research Objectives

An understanding of land use and its impact on the environment is needed to achieve best-fit strategic plans for communities that include preserving natural resources. Growth
and development can still be embraced with attention given to improving or conserving water quality. This thesis has two objectives.

The first objective is to examine the impacts land use change may have on indicators of water quality. By understanding these impacts, planners can acquire the information needed to provide for the physical needs of a growing community while also giving concern for the natural environment.

The second objective is to examine whether BASINS can be used as an effective tool in land use planning for evaluating the impact land use development has on water quality. By including water resource management in their planning, communities could contribute to environmental conservation, while still allowing development and growth to continue to occur.

**Conceptual Framework**

The conceptual framework for this research examines the relationship of development with water quality. It outlines how water quality is evaluated and the role of BASINS as a planning tool for land use regulation. The runoff from impervious surfaces causes pollutants to be collected and carried to streams where it is deposited. These pollutants, such as Nitrogen (N), Phosphorus (P) and Biochemical Oxygen Demand (BOD), can be monitored within the streams to indicate the level of water quality. By monitoring and collecting water quality data, planners can actively contribute to the conservation of natural resources through their land use development plans.
Figure 1: Conceptual Framework

The BASINS software allows for varying development scenarios to be evaluated for impervious cover and runoff and the resulting pollutant loads. Planners can use the BASINS model as a tool to allow planners to evaluate the level of water quality resulting from various development scenarios. This information, in turn, allows them to create fact-based regulation for imperviousness in land use development.

Research Questions

One objective of this study are to determine if BASINS can be used in land use planning as a model for evaluating the potential impacts of land use development scenarios.
on water quality. Another objective is to examine the impacts land use change may have on the indicators of water quality. The following questions are addressed to achieve these objectives: (1) how does changing the amount of impervious surface within different development patterns affect water quality; (2) can BASINS help planners to evaluate land use change and its impact on water quality? This paper tests two hypotheses to answer these questions: (1) BASINS allows planners to examine predicted changes in water quality due to land use change within a watershed; and (2) if the amount of impervious surface within land use development decreases, then water quality increases.

Land use patterns and water quality are interrelated. Land use planners are required to make a comprehensive assessment of that relationship to determine the needed water resource management practices for specific land use developments. Testing impervious surface values for land use change within BASINS may give planners a proactive tool for assessing water quality.
CHAPTER 2. LITERATURE REVIEW

Urbanization and Development

Recent studies have shown through a variety of models and measures that the degree of urbanization largely determines the impact of land use on water quality (Wang et al., 2001, Reimold and Leavell, 1990, and Ducrot et al., 2004). Development itself has "consumed more than 25 million acres in the U.S. between 1982 and 1997". Further, "an average of more than 2.2 million acres has been developed each year, a rate of over 6,100 acres per day" (Pollard 2001, p. 1). This development leads to changes in land use patterns on the edge of urban areas. Wang and Choi (2005) have suggested that urbanization is not just driven by an increase in population but by other factors, such as economic and social issues, both of which can affect water quality.

Arnold and Gibbons (1996) have argued the decline in stream health is due to an increase in development and the overall amount of impervious cover. Their research indicated that impervious surfaces greater than ten percent of the watershed area degrades the water quality. If today's growth trend continues, many healthy watersheds will become degraded (Arnold and Gibbons 1996).

A large number of studies have linked water quality and land use. A study in the Ohio River Valley by a group seeking to protect the watershed, the Ohio River Valley Sanitation Commission (ORSANCO), found that the land use along the river's edge impacted the quality of water within the entire region. The study has shown how changes of land from open and protected spaces to industrial and transportation uses caused problems that included spills, runoff, and urbanization. ORSANCO recognized "that a
A comprehensive water quality monitoring network would be necessary in order to document existing conditions, define specific problems, and provide a means of demonstrating the effects of remedial actions" (Reimold 1990, p. 226).

Wang et al. (2001) studied the relationship of urbanization on stream habitat and fish within different spatial patterns. The variables tested connected imperviousness and proximity of urban land use to streams. The study included 47 small southeastern Wisconsin watersheds with land uses ranging from agricultural to urban uses. The study analyzed the amount of urbanization to examine how the pattern and proximity of development impacted stream ecosystems. Wang et al. (2001) demonstrated that “urban development that minimizes the amount of connected impervious surface and establishes undeveloped buffer area along streams should have less impact than conventional types of developments” (p.264).

Yin et al. (2003) studied the relationships of urban spatial patterns to water quality in the urban core of Shanghai, China. The study used GIS and regression analysis to study the impact and accuracy of surface area build up to quantify water quality. Within the study, water quality monitoring stations were buffered with a series of different rings to calculate surface areas. Surface areas were calculated using satellite images from Landsat 7 ETM+. After completing the buffered rings, the population density, built-up surface and river rank were specified for each ring area. The results of this research showed that “the percentage of built-up surface or urban impervious surface is a key indicator of the effects of non-point pollution on water quality” (Yin et. al 2003, p. 4). The results also showed that as the urban buffer size increased, the stronger the relationship became between built-up surfaces and population density. This meant that population density also mirrored the built-up surface
images. Built-up surfaces in this study proved to be a better indicator than population density for determining water quality.

Harbor (1994) examined a method for planners to use in estimating the impact of land-use change on surface runoff, groundwater recharge, and wetland hydrology. The model set up a hydrologic abstraction that tells the user how much of a given rainfall becomes storm water and surface runoff due to imperviousness and, therefore, a pollutant to surface and ground water. The study used a “curve number (CN)” from the Soil Conservation Service to calculate a runoff depth from a given rainfall. The results of this study illustrated the level of change in total surface runoff that can be predicted from various land use changes. It also showed the potential impact of land use change on groundwater recharge. The final result indicated that an increase in total surface runoff decreased the quality of water balance in the watershed.

It is not only population growth that has caused development change. Cities themselves have moved outward, converting open lands into other land uses that ultimately affect water quality. This research studied land use development on the outer ring of urban centers to understand the need for change in land use planning so that consideration would be given to such characteristics as imperviousness in determining how to sustain growth while still planning for watershed protection.

Regulation and Planning

Federal regulations are in place to regulate the use and quality of natural resources. Currently, “40 percent of assessed waters do not meet water quality standards” and these impairments are leading to “300,000 miles of river and shorelines, and approximately five
million acres of lakes” degraded from non-point pollution (Bergeson 2001). Non-point source pollution is the greatest threat to conservation efforts called for in the Clean Water Act (Birkeland 2001).

Birkeland (2001) argues, “the most promising and controversial tool the Clean Water Act (CWA) offers to address the growing problems of water quality is contained in the Total Maximum Daily Load (TMDL) provisions of Section 303(d)” (p. 297). A TMDL, according to the EPA, is the “maximum amount of a pollutant that a water body can receive and still meet water quality standards” (Iowa DNR 2003b). The TMDL program is the tool that Congress authorized to help achieve one the objective of the CWA to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” (EPA 2002, 79022).

Aside from being a means to set up and schedule the listing and research of water impairments, the TMDL program is the CWA’s effort to decrease the nation’s non-point source pollution problems. The TMDL program sets strict standards for water quality, establishes a process for researching water hazards, and takes action to get the water body back to the established water quality standards. The EPA makes it the mission of the TMDL program to “protect public health and the health of impaired aquatic ecosystems by ensuring attainment of water quality standards, including beneficial uses” (Watershed Information Network 2003). The TMDL program requires that states add streams and water bodies that do not meet ambient water quality standards to the impaired water list. The impaired waters list identifies the area of the watershed, the type of impairment, and the priority level for remediation based on the classification of the water body and the type of impairment.
The listing process does not single-handedly clean up impaired waters, but section 303(d) of the CWA requires TMDLs to be set up at levels which are achievable, implementable, and in accordance with water quality standards (EPA 2002). In Iowa, the Department of Natural Resources (DNR) must produce every even numbered year a listing entitled the 305(b) list. This contains a water quality assessment of all waters within Iowa’s borders (Iowa DNR 2003b). This listing is then used to create Iowa’s 303(d) list of impaired waters, based on the state’s water quality standards.

With non-point source pollution being one of the greatest threats to the conservation of water resources, the previously discussed regulations offer federal officials guidelines for water quality management. However, these regulations are only as good as their implementation. Compliance with these regulations in conjunction with land use planning can produce better quality natural environments while also accommodating land use development.

At a more local level, land use planners implement regulation that can be used to increase water quality. Harbor (1994) contends that planning could incorporate water quality study in local planning through initial plan reviews, long-term problem analysis and local planning guidelines. There are multiple levels of regulation within land use planning to incorporate water quality assessment. A very regional scale of planning can include the Comprehensive Planning process. The Comprehensive Plan is a policy guide that sets goals for regional scale planning to identify areas of environmental concern and areas of possible development. Typically the Comprehensive Plan incorporates goals and implementation strategies for a 10 to 20 year range. Zoning Ordinances and Subdivision regulations are the devices used to implement the goals of the Comprehensive Plan and are the next level of
regulation that could include environmental management strategies. Zoning Ordinances that regulate land use by district and specify the permitted land uses, offers planners an opportunity to regulate density and intensity of land use (Meck et al. 2000). Zoning Codes address water quality management through planning using bulk and space regulations for either building or lot coverage for specific parcels. The stricter the bulk and space regulations the less impervious cover on city parcel thereby increasing open space within city limits. Subdivision codes regulate both the division of land into two or more parcels or lots and the design and location of community infrastructure (Meck et al. 2000). These planning tools and individual development review give planners the opportunity to incorporate water quality management techniques to address water quality and manage city development needs in all communities.

One example of planning review for water quality analysis is the Cache River Watershed in Southern Illinois. The watershed is the current home to as many as 100 species of plants and animals. It also supports 10 globally rare or endangered species and ecological communities (Kraft and Penberthy 2000, p. 327). The current threats to the Cache River watershed include (1) loss and fragmentations of natural habitats, (2) alterations of the natural hydrologic systems and wetlands, (3) excessive erosion and sedimentation, (4) degradation of surface and ground water quality, and (5) land use and development activities that don’t fit the plan for future resource planning (Kraft and Penberthy 2000). Planning officials conducted surveys community members, both urban and farming, to determine their view of the environmental problems. They also used a series of tabulations with data from the Bureau of Agriculture to determine the supply of and demand for water resources of the area. The goals and outcomes of the study were to integrate development of the surrounding
land with protecting and conserving the endangered and valuable elements of the watershed. The plan identified a group of natural resource concerns and established a set of recommendations for accomplishing the goals of the plan.

While federal regulations set standards for water quality, the compliance with and enforcement of the regulations begins in many planning offices. Land use planning builds the codes needed to enforce the federal standard through general land development patterns. One such example is the land use planning option of low-impact development.

**Low-Impact Development Planning**

If imperviousness is a direct indicator of water quality, reducing the amount of impervious land cover could decrease the amount of runoff. One way to plan for low impervious cover is through the use of low-impact development (LID) techniques. LID techniques include such things as rooftop retention, permeable surfaces, bio-retention, and buffer strips (EPA, 2000c). Low-impact development is a fairly new form of planned development that focuses on natural resource conservation. LID was developed with its introduction in Prince George’s County, Maryland, in the mid-eighties (Low Impact Development Center, 2004). The county needed environmental techniques to solve problems with failing storm water management systems and LID provided them.

Low impact development is a “site design strategy with a goal of maintaining or replicating the predevelopment hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape” (EPA, 2000c). The Low Impact Development Center (LIDC) points out that “LID allows for a greater development potential with less environmental impact through the use of smarter designs and advanced
technologies that achieve a better balance between conservation, growth, ecosystem protection, and public health/quality of life” (LIDC, 2004). The premise is that planning using low impact development techniques allows the development itself to naturally manage the runoff through decreased impervious cover. The design approach makes low-impact development a functioning part of an ecosystem, not a separate entity. It is versatile and can be applied equally well to new development, urban retrofits, and redevelopment/revitalization projects (EPA 2000).

The LID approach uses five basic tools: (1) encouraging use of conservation measures, (2) promoting impact minimization techniques, such as impervious surface reduction, (3) providing for strategic runoff timing by slowing flow rates, (4) using integrated management techniques for the reduction and filtration of runoff, and (5) advocating pollution control measures to improve environmental conditions (Coffinan et al. 1998). LID is “designed to reduce runoff volume by infiltrating rainfall water to groundwater, evaporating rain back to the atmosphere after a storm, and finding beneficial uses for water rather than exporting it as a waste product down storm sewers” (LIDC 2004).

LID is a simple, effective, economical, flexible, and balanced approach to planned environmental design. For example, a study published by the Chesapeake Bay Foundation showed that using LID in a development in rural Virginia “converted 75 percent less land, created 42 percent less impervious space, and produced 41 percent less runoff” than a conventional development pattern (Pollard 2001, 5). Even beyond new planned developments, LID approaches were able to reduce negative impacts on water quality within existing development patterns. Infill and redevelopment areas using LID techniques as part
of the planning process resulted in little or no change in existing land use patterns or the
density of use (Pollard 2001).

Another study on the use of the low-impact approach on parking lot design showed
that with increased areas of pervious surfaces, runoff volumes decreased. Parking lots are
one of the greatest sources of impervious cover in urban developments. They replace
natural vegetation and "increase both the volume and peak rate of runoff, and also provide a
place for traffic-generated residues and airborne pollutants to accumulate and become
available for washoff" (Rushton 2001, p. 172). The preliminary results from a two-year
study have shown that a modified low-impact pattern on parking lot design with more
natural pervious surfaces decreased runoff amounts by 10 to 15% (Rushton 2001).

While LID approaches are not specific to a particular land use and do not contain
standard criteria for development, their use offers planners an opportunity to take control of
environmental concerns within development. Planning with the use of LID techniques
offers a sensible and adaptable approach for development to help, and not hinder, water
quality conditions and naturally sensitive lands.

In this research, imperviousness as an element of low-impact development is tested
to examine the use of low impervious regulation as a form of planning for water resource
management. A variety of land use patterns are tested using both average impervious values
and low impervious values to compare the loading of water quality indicators.

Impervious Cover

To sustain natural resources and still plan for future growth, it is important to
evaluate imperviousness to understand the impact of land use change on natural resources.
One definition of imperviousness is "the fraction of the watershed covered by constructed, non-infiltrating surfaces such as concrete, asphalt, and buildings" (Booth and Leavitt 1999, p. 314). To this should be added areas of "nominally pervious" surfaces that are sufficiently impacted or otherwise so low in permeability that the rate of runoff from them is similar or indistinguishable from that of pavement" (Booth and Leavitt 1999, p. 314).

Although impervious surfaces do not directly produce pollution, they contribute to the transportation of contaminants to streams and drainage ways. Arnold and Gibbons (1996) assert that impervious surfaces (1) contribute to the hydrologic changes that degrade waterways, (2) intensify land uses that do generate pollutants, (3) prevent natural processing in water systems, and (4) are efficient transportation systems for polluting waterways. So with an increase in impervious cover comes an increase in runoff volumes and rates, moving the pollutant-saturated runoff into drainage ways without penetrating the ground for filtration. For example, the amount of runoff from a parking lot and a grass field will vary greatly because the parking lot contains a complete impervious cover and water will directly transport pollutants from that impenetrable surface to waterways. Figure 2 shows general estimates of the amount of runoff generated by different amounts of impervious surfaces.
Figure 2: Effects of Imperviousness on Runoff and Infiltration
(Arnold and Gibbons, 1996, p. 245)

As shown, an area of natural ground cover only allows for approximately 10 percent runoff due to impervious surfaces. However, with surface cover reaching 75 to 100 percent imperviousness, runoff can occur as high as 55 percent (Arnold and Gibbons 1996). Impervious surface coverage can be generally used to characterize standard land uses. For example, 10 to 20 percent and 30 to 50 percent impervious cover are typical of residential and low-density commercial land use categories, respectively. High-density commercial and industrial land use districts frequently have 75 to 100 percent impervious cover. See Figure 3 below for a more detailed breakdown of urban land use impervious values.
Arnold and Gibbons (1996) reported that impervious surface coverage has a negative impact on stream quality. The greater the amounts of impervious cover, the more pollutants reach a stream and affect its health. Slonecker and Tilley (2004) agree with the relationship of imperviousness and stream water quality. They suggest, “the imperviousness issue has even been suggested as a unifying theme for overall study of watershed protection” (Slonecker and Tilley 2004, p. 166).

One common issue in addressing impervious surface percentages in land use is the variability in the percent for each land use. For example, studies have noted that agricultural and rural uses have a very small percent of imperviousness, but as suggested previously, the definition of impervious cover also incorporates surfaces that have been compacted to appoint of having impenetrable characteristics. Very few studies have incorporated agricultural uses into land use and water quality analysis or have looked at the issue of compactness.

Wissmar et al. (2004) studied the impact of changing forest and impervious land covers in urban and rural watersheds in the lower Cedar River Watershed near Seattle, Washington. The study used land cover characteristics to evaluate the impact that changes

<table>
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<tr>
<th>Land Use Type</th>
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<tr>
<td>Commercial</td>
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<tr>
<td>Industrial</td>
<td>72</td>
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<th>Residential Use by Lot Size</th>
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<tr>
<td>1/8 Acre</td>
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<tr>
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<td>12</td>
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in forest covers and impervious surfaces had on annual flood discharges from a “pre-
settlement (full forest) cover” to 1991-1998 conditions. Seven watersheds were examined
with four of the watershed considered urban and three considered rural. The results
indicated that the percent of forest areas decreased and impervious surfaces increased, as
one would assume. The interesting point was when the change occurred. The study showed
a much greater percent change in the period from 1991 to 1998 than from the pre-settlement
stage. The study also showed higher peak discharge rates for the areas of the urban
watersheds with the greatest percent of impervious cover. Wissmar et al. (2004) concluded
that the “ability to identify areas of differing degrees of forest cover and impervious surfaces
allowed us to apply a spatial hydrologic model to predict changes in the discharge
characteristics of watershed that experience a mosaic of land uses in both space and time”.

Many research studies indicate that the percent of impervious cover is a quantifiable
predictor of water quality. Arnold and Gibbons (1996) argue that natural resource planning
addressing impervious surface coverage is an effective way of addressing urban
environmental issues, particularly those related to water resources. Imperviousness is used
because is it the variable that can easily be measured for all scales and forms of
development. It can then be used to influence development decisions when shown in
relation to water quality conditions. For planners, having a quantifiable element of land use
correlated to water quality, such as imperviousness, could offer a source for water resource
evaluation within the development review process.
Water Quality

“Water is the source of life” and land use is one factor in its survival (quality) (Gray et. al. 2001, 39). Land use can affect water quality through a variety of sources, both urban and non-urban. According to Randolph (2004), agricultural land uses have been identified as a major contributor to water quality, impacting up to 60% of all river basins. Urban land uses have also been an area of concern due to issues such as runoff and urban discharges. Both urban and non-urban land uses cause pollution through point and non-point sources.

Point sources of pollution include municipal waste discharges from wastewater treatment plants and many manufacturing and processing plants. Non-point source pollutants have become the main contributor to decreased water quality in the nation’s lakes and streams (Brett et al. 2005).

Three broad categories constitute the most common way to evaluate water quality: chemical, physical and biological parameters (Dzurik 2003). Chemical parameters include the measurements of organic and inorganic chemicals. Among these chemicals are dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand, acidity, and hardness. Physical parameters include total suspended and dissolved solids, turbidity, color, taste and odor, and temperature. Biological parameters encompass living organisms, such as aerobic bacteria (oxygen breathing), anaerobic bacteria (non-oxygen breathing), algae, disease-causing organisms, and various types of coliform bacteria (E. coli and Escherichia).

These three categories produce the eight major identified categories of water pollutants, (1) disease-causing organisms, (2) oxygen-demanding wastes, (3) sediment, (4) nutrients, (5) organic chemicals, (6) inorganic chemicals, (7) heat, and (8) radioactive
substances (Thompson 1999, 277). Each pollutant is measured as a concentration level (mass of pollutant per volume of water collected).

Nutrients (such as nitrogen and phosphorous) occur naturally. Excess, however, can cause harmful affects on water quality. According to many research studies, nitrogen and phosphorus are the two primary limiting nutrients in receiving waters (EPA 2005, Tsihrintzis and Hamid 1997, Brett et al. 2005, Minnesota Pollution Control Agency 2000). Rain, runoff, groundwater, drainage networks, and industrial and residential effluents carry them to receiving waters (EPA 2000b). Urban sources of nutrients include such things as lawn clippings and leaves, fertilizers applied improperly, auto emissions, and sand and salt applied to highways.

In receiving waters, excess amounts of these nutrients can cause algal blooms and excess plant growth, which blocks sunlight and consumes oxygen during decomposition (Tsihrintzis and Hamid 1997). If the level of oxygen-consuming materials reaches a high enough level, then “oxygen otherwise available for aquatic life is depleted, resulting in stress or death for organisms” (MPCA 2000, p. 1.20-3). In urban areas, pollutants such as pet waste, street litter, and organic matter can create high oxygen demand. Biochemical Oxygen Demand (BOD) is a commonly used parameter for determining the oxygen demand in receiving waters. BOD is a measure of the amount of oxygen demand for decomposing wastes in stream water (EPA 2005). A measurable increase in BOD results in a decrease in dissolved oxygen (DO), which is measured to compute the BOD. A BOD test takes five days to complete and is determined by comparing the DO of a water sample taken immediately with a sample placed in a dark location for five days (EPA 2005). The difference between the immediate sample reading of DO and the reading of the sample
tested five days later is the amount of BOD, in milligrams per liter. Additional sources of BOD include feedlots, wastewater treatment plans, failing septic systems, and urban storm water runoff (EPA 2005).

Although there is no Iowa Water Quality standard pertaining directly to BOD, the “Environmental Protection Rule 567, Chapter 61, Water Quality Standards” indicates that the maximum level of BOD should not exceed 7 mg/liter (Iowa DNR 2004a). Maximum levels of nitrogen (depending on the type of nitrogen being measured) range from .1 mg/L for ammonia to 10 mg/L for nitrate. The maximum level for phosphorus is .1 mg/L (Mueller and Helsel 1996).

The United States Geological Survey (USGS) conducted a study of point and non-point sources of nitrogen in major watersheds of the United States. The study found that nitrogen in both point and non-point sources varies from region to region and that “the transport of nitrogen in streams is increased as amounts of precipitation and runoff increase” (Puckett 1994, 1). Puckett argues that there is a continual need for nitrogen and nutrient non-point source evaluation to aid water quality and environmental managers to create policy to reduce nitrogen loading.

Studies have shown that urban areas with the greatest impervious coverage offload the most nutrients to rivers; however, others argue that agricultural areas lead to the greatest nutrient loadings. The USGS suggests that nitrogen compounds are found in highest concentration downstream from both agriculture and urban uses, but increased phosphorus levels are found most often downstream from urban land uses (Mueller and Helsel 1996 and USGS 1999).
Brett et al. (2005) examined nutrient and sediment concentrations in 17 streams in the Seattle area to study urban non-point source pollutant impacts on stream quality. Brett et al. (2005) suggested, “that urbanization markedly increased stream phosphorus concentrations and modestly increased nitrogen concentrations. However, nutrient concentrations in Seattle region urban streams are significantly less than those previously reported for agricultural area streams” (p. 330).

Wang and Choi (2005) used “LEAMwq”, the mix of a land use simulation model with a water quality model, to assess estimated land use changes on potential non-point source pollutants (nitrogen (N), phosphorus (P), and total suspended particles (TSP)) in the St. Louis metropolitan area. The results indicated that total nitrogen (TN) decreased due to the conversion of agricultural land uses into more urban uses; however, in other scenarios “the reduced TN loads due to Ag loss was masked and the TN kept increasing with the increasing runoff” from the urban land uses (p. 201).

In this study, the use of the two major nutrient factors, N and P and one major indicator of water quality, BOD, were studied to examine pollutant loading due to land use change from non-urban to urban land uses.
CHAPTER 3. METHODS

The methods used in this study include a spatial data analysis of secondary data to examine the effects that land use development has on water quality. This research employs a simulation model to analyze results from water quality data. The study focuses on the change in water quality that could occur due to changes in land use patterns and its impervious surface variables.

Geographic Information System (GIS) provides a tool to help with the assessment and integration of water resource management in planning. GIS offers multiple methods of analysis for evaluating land use and water quality. It, thus, provides the needed framework support for planning. GIS can be a reliable evaluation tool for land use planning and can contribute to water quality planning not just within metropolitan areas, but also in growing and sprawling local (rural) areas. The water quality data within BASINS provides the raw material for a case study looking at multiple options of land use patterns for the proposed study area.

BASINS Framework of Analysis

The BASINS framework is set up for the advancement of watershed research in the enhancement of natural resource management. BASINS, an extension running within the Arc View framework, is a “multi purpose environmental analysis system for use by regional, state and local agencies in performing watershed-and water-quality-based studies” (EPA 2001a, p.1). The program allows the user to conduct water quality and watershed-based ecological studies on areas of concern within specific communities. The objectives of the
program, as outlined by the EPA (2001a), include: (1) to facilitate examinations of environmental information; (2) to support analysis of environmental systems; and, (3) to provide a framework for examining management alternatives.

BASINS, originally introduced in 1996, has made it “possible to quickly assess large amounts of point and non-point source data in a format that is easy to use and understand” (EPA 2004). BASINS expands the capabilities of mapping into in-depth analysis (ESRI 2004). This analytical tool uses the GIS environment for natural resource evaluation, while interpreting a real life scenario for decision-making.

The BASINS software gives the planner the ability to evaluate the atmosphere, pollutants, transportation of pollutants within soils and water for specific land uses, thereby creating the real-life environmental scenario required for water quality analysis (ESRI 2004). These capabilities largely rely on the Utilities section of Assessment and the SWAT and PLOAD sections of Models. With these tools, the planner can carry out several forms of analysis, as indicated in the Analysis section of Figure 4 below.
While this study does not use all the system tools that BASINS offers, BASINS is set up to allow any user-supplied data to be run using the assessment tools. These tools within calculate and evaluate the user’s data using overlay techniques, as well as user-specified variables (e.g., land use changes). The results are the specific loading rates for each set of land use changes.

The assessment tools within BASINS were designed “to perform both regional and site-specific analyses” (EPA 2001a, 14). The tools are titled “target”, “assess”, “data mining”, and “watershed reporting”. The target tool performs broad-based water quality evaluations on the entire project area. This allows environmental managers to make initial, broad decisions based on multiple watershed areas for a regional view of water quality. The assess tool performs water quality evaluations on watershed or subbasin areas, as well as analyzing water quality data by station and processing a comparative view of each segment of watershed. The data-mining tool builds a dynamic link between the mapping facility and
included database tables. The reports tool displays graphically and in tables each calculation made within the BASINS environment and produces results for each new data layer created through analysis. For this paper, only the assess tool within the PLOAD model was used for analysis of data stations and water quality information.

While BASINS offers four models for water quality analysis, the models used for this research include only the Soil and Water Assessment Tool (SWAT) and the Pollutant Loading (PLOAD) models. The SWAT model is "a river basin, or watershed, scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields on complex watershed with varying soils, land use and management conditions" (EPA 2001a, 334). The model relies on the user to input the data for the land use and watershed layer that the utilities section of the BASINS software created. Once the planner has entered or imported the data, the software produces an overlay of the study area for a comprehensive analysis of the land. The extension model is designed "to interact with the BASINS utilities and data sets to set up and modify the SWAT model input files as well as facilitate the calibration of the model on site-specific conditions and data sources" (EPA 2001a, 334). The SWAT model can be run on a single watershed study area or on multiple watershed areas for a more regional approach.

The PLOAD model provides further insights useful to planners seeking to control water quality in changing environments. PLOAD "is a GIS tool to calculate non-point sources of pollution in watersheds" (EPA 2001b, 1). PLOAD can apply to wide range of situations, including NPDES storm water permitting, watershed management, and reservoir protection projects. The program "will spatially overlay the watershed and land use
coverages in order to determine the areas of the various land use types for each watershed” (EPA 2001b, 2).

The PLOAD framework enables planners to simulate average pollutant load and water quality response to future land use scenarios. It can be used with standard GIS functions to model all data for spatial analysis (Wake County 2001). PLOAD allows planners to choose which water quality pollutants to model within various simulations of land use change. In this study, the variables within the PLOAD model included the land use pattern and the impervious values associated with the land use categories. The other factors contributing to water quality associated with the PLOAD model (such as soils, river depth, width, and flow) are all stable conditions arrived at through site-specific data imported into the BASINS model. After the chosen pollutant loads have been modeled and reported, PLOAD can generate the layout and tables as needed: (1) total pollutant loads by watershed; (2) pollutant loads per acre by watershed; and, (3) event mean concentration (EMC) by watershed.

GIS, BASINS and PLOAD together build a framework for integrated water resource management analysis. As the EPA (2001a) states, “GIS organizes spatial information so it can be displayed as maps, tables, or graphics. GIS provides techniques for analyzing landscape information and displaying relationships.” For this research, BASINS and PLOAD are used to model the change in land use patterns resulting from future development in an effort to predict water quality.
Research Data

State, federal, and privately owned water-monitoring stations gather the data that
comprise the national water quality databases. The EPA compiles the data in digital format
for use within the BASINS software. The EPA divides the data into eight United States eco-
regions. Data from the seventh region, which includes Iowa, was extracted from the
BASINS software and later clipped within the GIS environment to conclude the data
collection portion of this study. Also within the GIS databases were records for mapping
spatial layers that included land use and development patterns and zoning in Dallas County,
Iowa, the target area of this paper (Dallas County Conservation Department 2003).

The four types of data used within the BASINS software (EPA 2001a) included: (1)
Base cartographic data; (2) Environmental background data; (3) Environmental monitoring
data; and, (4) Point source/loading data. For this paper, only the first 3 data types were used.
This study is focusing only on non-point source pollution in its study of runoff and
imperviousness; therefore, the point source data was not required. The study data supplied
by the EPA has been included in Appendix A for further information on data themes and
database tables.

The base cartographic data contained themes for the study area, including hydrologic
unit boundaries, major roads, populated place locations, urbanized areas, state and county
boundaries, and EPA eco-regions. This data gave the background information for first
analyzing the study area in simple form and then developing a base map for overlay within
the BASINS and PLOAD models.

The environmental background data required for the BASINS model supplied
information for watershed delineation and environmental analysis. The themes include
National Water Quality Assessment (NAWQA) study areas, state soil database (STATSGO data), reach files (river systems), land use and land cover data, national dam inventory, and digital elevation models. The modeling tools analyze and use this information to create the soil overlays. The PLOAD extension takes this overlay and creates average pollutant loads, as discussed earlier.

The environmental monitoring data included many of the databases needed within PLOAD to run the model and create the loading averages for study by subbasin. The database tables included water quality data from monitoring stations by category year, from bacteria monitoring stations also by year, and data from gauge sites, weather sites, and watershed data stations and affiliated data.

The data must be in shapefile format. It must also contain the needed variable tables for analysis within PLOAD. The data required included land use layers depicting all land use categories, watershed data delineated within the BASINS framework, pollutant loading rates, and impervious surface values in percentages by land use category (EPA 2001b). The analyses, through a series of PLOAD sessions, assessed water quality resulting from land use changes and their subsequent shift in impervious surface values.

Study Area

Many American states are rich in prime farmland and natural resources, but with the expansion of urban fringe areas, they are starting to see farmland conversion to other land uses. This change has already begun in Iowa. Over 480,567 acres of farmland have been converted to non-agricultural uses (residential, industrial, commercial, and others) between 1986 and 1997. This acreage accounts for 0.07% of the total land area in Iowa per year.
(Anderson and Huntington 1998). With these conversions comes community awareness, increased attention to conservation, and efforts to save the remaining natural resources.

One area in Iowa that faces population increase and development is West Des Moines. West Des Moines has become the fastest growing city in Iowa. Its population stands at 46,403 people (Department of Community Development 2003), making it the 11th largest city in the state. With the growth of West Des Moines, many city officials and developers look to Dallas County (Figure 5) as a prime area for urban growth.

![Figure 5: Dallas County, Iowa.](image-url)
Dallas County has 40,750 people, and is the 15th largest of Iowa's 99 counties (Lutz-Zimmerman 2001). The county is largely agricultural, but with West Des Moines moving in on the eastern side, the county is starting to see an increased population and obvious changes in land use.

Dallas County has great natural resources, including its river systems and the high quality soils for agricultural production. Dallas County contains parts of four major watersheds, including Middle Des Moines, North Raccoon, South Raccoon, and Lake Red Rock watersheds (Figure 6). These resources face possible degradation as urban growth continues.

Figure 6: Watersheds of Dallas County
(EPA 2004)
The North Raccoon Watershed incorporates portions of nine counties within its boundaries (EPA 2004). It cuts through the central part of Dallas County, and is the study area for this research (Figure 7).

Figure 7: The North Raccoon Watershed

The 303(d) list designates some branches of the Raccoon River water system as impaired. The impaired section of the river in Dallas County stretches from the Polk /Dallas County line upstream to the merge of the North and South Raccoon River branches. According to the Iowa DNR, this section of the river received its designation because of the
indication of bacteria and the presence of nitrates. Because this section of the river is classified as primary contact or Class A waters, it has received a high priority designation.

**BASINS Application: The Model Composition**

The first step in setting up the data for the research analysis was to use the delineation utility in the BASINS software to determine the subbasins of the North Raccoon Watershed. The utility yielded 25 subbasins within the watershed (Figure 8). The subbasins are the unit of study for PLOAD in mapping nutrient loads and in determining the amount of urban development change for the watershed.

The delineated watershed was then used to determine the nutrient loads by subbasins of the Raccoon River Watershed. PLOAD was used in two very specific ways within this research. First, it was used to analyze the effect of changes in impervious surface cover by land use. Second, it was used to evaluate the change in nutrient loadings through a sequence of land use patterns depicting increased urban land uses.
The next step was the development of four land use patterns to create a sequence of predicted future land use patterns of increasing urban development. The first two land use patterns were collected from 1997 and 2000 data. They revealed the initial increase in urban area. The percentage of growth in this period became the assumed rate of urban expansion for the two future time frames in this study. These future patterns placed a ring of new urban development of a specific dimension around existing urban land uses. The two new urban patterns are a half-mile development ring and a one-mile development ring, assuming a continued growth of urban expansion for all urban centers. The land use patterns were reclassified and mapped in BASINS. The study looked at only an urban and non-urban land...
use classification. This effort yielded four land use patterns that were then used to calculate the total urban area per subbasin.

The land use patterns set up a four-step sequence of predicted land use change for the analysis. In 1997, the North Raccoon Watershed contained 2.24 percent urban area (Figure 9). From 1997 to 2000, the urban area within the North Raccoon Watershed increased in urban land by 69 percent. In 2000, the total urban land area was 7.15 percent (Figure 10).

Figure 9: Land Use Pattern for 1997
The urban land use change of 69 percent between 1997 and 2000 was used as the maximum unit of urban change for the predicted land use patterns. This allowed for the assumption that some new development will consist of infill and redevelopment of existing urban spaces and will slow the rate of urban expansion over time. The half-mile land use development pattern depicts an increase in urban land use from 7.15 percent in 2000 to a 16.01 percent urban land use (Figure 11). This is an increase of 55 percent in urban land area from 2000.
Figure 11: Land Use Pattern with Half-Mile New Development Ring

Figure 12: Land Use Pattern with a One-Mile New Development Ring
The final land use pattern, the one-mile development ring, predicts a 27 percent urban watershed (Figure 12). This pattern represents a predicted watershed with a 41 percent increase in urban land area compared to the half-mile land use pattern.

PLOAD Extension: Use and Organization

PLOAD was used to evaluate both the effects on water quality from larger urban areas and their increased impervious surfaces. The four land use layers were used to create PLOAD sessions to perform a series of analyses. The PLOAD sessions were organized according to chart shown in Figure 13. Four scenarios were created to test changing impervious values listed in Figure 14 for the created land use patterns. These land use patterns and impervious values then became the basis for this study.

Figure 13: PLOAD Session Organization
The land use categories were simplified to urban, non-urban, and new-urban uses. The new-urban land use category was chosen for the predicted area of urban development increase to reflect the mixed-use developments typically seen on the developing edge of cities.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Scenario A</th>
<th>Scenario B</th>
<th>Scenario C</th>
<th>Scenario D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Default</td>
<td>Low-Impervious_1</td>
<td>Reclass</td>
<td>Low-Impervious_2</td>
</tr>
<tr>
<td>Urban</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>New Urban</td>
<td>35</td>
<td>20</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Non Urban</td>
<td>2</td>
<td>2</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

*Figure 14: Impervious Surface Values Used in the PLOAD Sessions*

Scenario A, defined as default, included one PLOAD session for each of the four land use patterns. The default impervious values were chosen with help from the BASINS default database table. It is commonly accepted that industrial and commercial areas usually carry an impervious percent higher than 60 percent. Therefore, this study assumed an average of 60 percent for all existing urban areas to represent areas of industrial, commercial, and possible mixed-use urban land use. Also, new urban development rings on the outer edge of existing urban areas were given an impervious value of 35 percent because land development on the outer edge of cities consist of residential uses inter-mixed with small urban centers. Finally, the BASINS default of 2 percent imperviousness was used for non-urban areas.

Scenario B, defined as low-impervious_1, included two PLOAD sessions using the predicted half-mile and one-mile development patterns to test the use of low impervious development within the new urban development areas. The impervious value for "new
urban" areas was reduced from 35 percent in Scenario A to 20 percent for Scenario B. The existing urban and non-urban values for imperviousness were held constant to allow for testing one particular value.

Scenario C, defined as reclass, examined all four land use patterns. The goal was to examine if non-urban land uses have a higher impervious value than the 2 percent represented within the BASINS default tables. In this scenario, the existing urban and new urban values of imperviousness were held constant with Scenario A.

Finally, scenario D, defined as low impervious_2, included two PLOAD sessions testing the half-mile and one-mile land use patterns. The scenario allowed examination of the use of low impervious development in new urban areas with the assumption that the non-urban value of imperviousness as tested in scenario C was accurate at 20 percent impervious.

A PLOAD session was run for each of the land use patterns within each of the four scenarios with the given impervious values. The results were reported in spreadsheet format for N, P, and BOD, as discussed in Chapter 2. The results are shown in Chapter 4 in both graph and map form to examine the usefulness of BASINS as a model for water quality study.
This chapter looks at the question of the usefulness of the BASINS model (described in Chapter 3) as a planning tool to assist in determining appropriate actions for water quality conservation efforts. The following discussion identifies the outcomes of each of the four scenarios and then addresses the usefulness and limitations of the results.

**Scenario A Results**

The PLOAD sessions for Scenario A using the BASINS-generated default database tables of data collected by governmental agencies provided the baseline for analyzing the effects of increased urban land areas projected in the later scenarios. The following graphs compare nutrient loads to the percent of urban land use per subbasin.

All four PLOAD sessions run within Scenario A indicated that with an increase in the percent of urban area, there is a general increase in the level of BOD (Figure 15). While most of the represented pairs of values fell below the maximum allowed value for BOD, the subbasins with greater than 40 percent urban area had BOD values much greater than the allowable standard of 7 mg/L (Iowa DNR 2004a).
The examination of Scenario A also indicated that while BOD increased when urban area increased, phosphorus (P) decreased overall at the same time (Figure 16).
The comparison of N to P, shown in Figure 17, indicated that nitrates increase as urban areas grow, but phosphorus slightly decreases under the same conditions. This result could stem from the reduction in non-urban (agricultural) areas, as suggested by Wang and Choi (2005).

![Nitrate and Phosphorus Load Evaluation](image)

**Figure 17: Scenario A: Phosphorus and Nitrate Load Comparison**

PLOAD results for the 2000 land use session showed the BOD levels and their location within the most urban areas of the watershed (Figure 18). The darkest gray areas indicate BOD levels above the 7mg/L allowable limit. They all occur in the subbasins with the highest percent of urban land area.
Figure 18: Scenario A: BOD Load Evaluation for 2000

The half-mile development pattern, which increased urban land use by 8.86 percent, increased BOD loading in fifteen of the twenty-five subbasins (Figure 19).
The one-mile development pattern yielded a much larger water quality problem with nine of the twenty-five subbasins over the allowable BOD limit (Figure 20). Compared to the half-mile load evaluation map (Figure 22), BOD loading in the one-mile development pattern has increased in sixteen subbasins. Only two subbasin remain in the lowest load rate category.
Overall, the standard values used for the Scenario A analysis indicated that as urban
development expands without any form of water quality management, the subbasins of the
watershed continue to worsen from the nutrient loads. They place a higher oxygen demand
on the waterways and, predictably, exceed the allowable standards in many of the subbasins.

Scenario B Results

A possible approach for water quality management is the use of low impervious
development, as discussed previously. Compared to Scenario A, nutrient load values in
Scenario B decreased with the use of low impervious development (Figure 21, 22, and 23).
The BOD values for Scenario B were only 5 points over the allowable 7 mg/L limit (Figure 24), a substantial difference from Scenario A. While the highest urban values still exceed the allowable limits, those points represent existing urban subbasins with no decrease in imperviousness.

![BOD Low Impervious Evaluation](image)

**Figure 21: Scenario B: BOD Load Evaluation for Low-Impervious Development**

![Phosphorus Low Impervious Evaluation](image)

**Figure 22: Scenario B: Phosphorus Load Evaluation for Low-Impervious Development**
Figure 23: Scenario B: Nitrate Load Evaluation for Low-Impervious Development

With the use of reduced impervious values within the new urban areas, Scenario B predicted a decrease in BOD loading in 15 of the 25 subbasins (Figure 24).
Similarly, the PLOAD session using the one-mile radius of increased urban growth along with low-impervious land use revealed a decrease in the number of subbasins exceeding the allowable BOD limits (Figure 25). The one-mile session substantially decreased the BOD load values for 13 of the 25 subbasins in comparison to scenario A (Figure 20).
In Scenario B, the PLOAD sessions illustrated an overall decrease in the values of BOD, nitrates, and phosphorus with the application of low impervious development techniques to new urban development areas.

Scenario C Results

Scenario C examined the change in nutrient loads from non-urban land uses assuming a greater impervious value (>2%) than the default values in the BASINS software.
The values of N and P were likewise increased from those used in Scenario A because as imperviousness increased in agricultural areas there would be less filtration of these nutrients. Even with these changes, phosphorus still decreased. Nitrates, however, increased when compared to the percent of urban land (Figure 26 and Figure 27).

BOD values for Scenario B were predicted to exceed the allowable limit of 7 mg/L (Figure 28) because the increase in nutrient loading for N and P would result in a higher oxygen demand.

![Phosphorus Reclass Load Evaluation](image_url)

*Figure 26: Scenario C: Phosphorus Load Evaluation*
By using the increased impervious value of 20 percent for non-urban land uses, Scenario C predicted that not one subbasin is under a BOD value of 12.76 percent, as shown.
in the legend, for the existing land use pattern for 2000 (Figure 29). Taken in association with the predictions of Scenario A, Scenario C predicted that all subbasins exceeding the allowable limit of BOD would remain over that limit with the introduction of new urban land uses. As a result, the PLOAD sessions for the half-mile and onemile land use patterns are irrelevant and are not displayed.

Figure 29: Scenario C: BOD Load Evaluation for 2000
Scenario D Results

Scenario D examined the use of low impervious development with the assumption that the non-urban value of imperviousness tested in Scenario C was accurate. Even though the load values for Scenario C were predicted to exceed the allowable limit for BOD, Scenario D resulted in a decrease in the load values with low impervious development in new urban areas (Figure 30).

Figure 30: Scenario D: BOD Load Evaluation

The half-mile new development pattern (Figure 31) also resulted in lower BOD values than that of the 2000 land use pattern in Scenario C (Figure 29). There was an overall decrease in 7 of the 25 subbasins.
Analysis of Results

This study showed that, with the conversion of agricultural/non-urban uses to the new-urban status, the load values for $N$ increased as $P$ decreased. Wang and Choi (2005) also found similar results. There was, however, one catch. $N$ would not decrease as much because of increased runoff from urban land uses owing to its impervious cover.

While the low impervious values used in the four scenarios may not be exact, the resulting nutrient load rates in the PLOAD scenarios suggest that lowering the
imperviousness of land use within new development improves water quality. This result was true when comparing Scenario A to Scenario B and Scenario C to Scenario D, even though the predicted load values were above the allowable limits.

Even though the values predicted are questionable for the scenarios because they are extremely high, the scenarios indicated a reduction in BOD values with the use of lower impervious development in new-urban land uses. While the Scenarios did not depict nutrient load values for BOD with complete accuracy, they remain useful for examining low imperviousness as a technique for new urban development patterns.

Evaluation of the BASINS Model for Water Quality Planning

The scenarios revealed that with increased urban land use there was also degradation in water quality due to increased nutrient loading. With that said, there are other issues to be addressed, including whether BASINS can be used to assist planners in evaluating land use change for the impact on water quality.

The BASINS study revealed high pollution levels of N and P that are, as the literature indicates, attributable to agricultural uses. The BASINS default model also revealed urban land uses as the major contributor of runoff due to the high values of impervious cover. So when a small percentage of urban land use was introduced into a non-urban dominated watershed, the values for impervious surfaces were disproportionately attributed to urban development. As shown in recent TMDLs from Iowa watersheds (Iowa DNR 2004b, and Iowa DNR 2004c), the impairment of waterways from nutrients and BOD are related to the high quantity of agricultural uses in a watershed with a very small percent attributable to urban contributions.
Another problem to be addressed in assessing the usefulness of BASINS is the element of imperviousness. Within the BASINS model, impervious values are assigned to a land use category. A specific land use category, such as some agricultural uses, can carry a variety of impervious percentages due to the permeability of the soils. The lack of land use categories within the study affected the accuracy of the results in testing the conversion of agricultural uses to urban uses. The restricted number of land uses and impervious values somewhat skewed the weight of urban land area contributions to pollution.

BASINS may not be accurate or subtle enough to test the conversion of agricultural uses to urban developments in a rural watershed. However, BASINS, when used within a dominantly urban watershed, may be capable of showing a useful comparison between traditional urban development and low-impervious development patterns.
CHAPTER 5. CONCLUSIONS

The objectives for this research were to (1) examine the impacts that land use change can have on three indicators of water quality, and (2) to verify if BASINS could provide a useful tool for land use planning in evaluating the impacts land use change with their different levels of imperviousness has on water quality. The case study included the use of BASINS in evaluating the North Raccoon Watershed under several different possible future development strategies.

The BASINS model, while constrained by the accuracy of input data, is a tool feasible for the use as a water quality management tool within land use planning. The model allows planners to incorporate an assessment tool to test new urban developments for water quality impacts. Using BASINS to assess a predominately agricultural watershed is, however, questionable owing to its lack of impervious values that take into consideration soil permeability.

BASINS useful as a tool in the development review process to illustrate the impact of new urban developments on water quality, specifically when using low-impervious development techniques. BASINS, however, does not seem feasible as a comprehensive land use planning tool for the rural watersheds of Iowa because of the limitation and constraints of the software.

As Harbor (1994) notes, the development and use of tools to estimate the potential impacts of land use change on water quality provide a valuable insight for planners. It allows planners to take an active role in protecting water quality through advocating different types of land use development, such as low-impervious development. While the
data set may have flaws, the model is sensitive enough to test for small changes in land use characteristics. Even though the output may be in a generalized form, the results do predict that changes in imperviousness in land use development will affect water quality conditions.

**Contributions**

This study allowed for many of the misunderstood environmental impacts of land use to be quantified in a database. The study of land use and water quality is feasible, but technically difficult to determine based on the high number of water quality variables and the many unknowns in the chemical parameters of water. The goal of this study was not to develop a technical and quantitative model of water resource management, but to begin to understand if the use of BASINS as an analytical tool would better integrate water resource management techniques in traditional land use planning. A secondary goal of this research was to examine the role imperviousness plays in affecting water quality.

**Limitations**

The very general categorizations of land use in this study did not allow a high-resolution analysis of variability in imperviousness associated with different land uses. This limitation must be taken into consideration with respect to results reported here for the overall calculation of the land use impact using PLOAD and its extensions.

**Future Study**

This thesis tested a general application of BASINS as a potential tool for land use planning. The next step would be a more specific site analysis of a development area to
examine the use of low-impervious development within a land development plan to better quantify how imperviousness can impact water quality. While this thesis examined land use changes over a large area assuming new urban development on previously non-urban land, a more specific land use analysis would be feasible within the PLOAD framework. A smaller study area would, however, simplify this type of analysis within BASINS.

There is also a need for more in-depth research on the degree of imperviousness associated with different land use categories, such as non-urban land uses. The present study would have benefited if the imperviousness of each land use category could have been quantified in more detail. In addition, future study in this area could incorporate the use of and need for infill development within the North Raccoon Watershed. It could also incorporate the impact impervious cover would have without expansion of urban areas, but with the change in land use within existing urban areas. This analysis could create a more realistic planning scenario to better understand the use of low impervious techniques in urban development.

Finally, future study of water resources could use BASINS as part of a more detailed analysis of the role land use change plays on water quality. For example, while this study did not use point source pollutants within the study area, BASINS has the capability to include such sources within the analysis. By including a more comprehensive analysis of point and non-point sources, future studies could better examine the Raccoon River Watershed and take advantage of opportunities for land use planning that integrates tools to address water resource management.
REFERENCES CITED


APPENDIX: BASINS META DATA

1:250,000 Scale Quadrangles of Landuse/Landcover GIRAS Spatial Data of CONUS in BASINS

Identification Information:
Citation:

Originator: Environmental Protection Agency, Office of Water/OST
Publication_Date: 1998
Title: 1:250,000 Scale Quadrangles of Landuse/Landcover GIRAS Spatial Data of CONUS in BASINS
Online Linkage:
EPA ESDLS BASINS model and data <http://www.epa.gov/OST/BASINS/>
Description:
Abstract:
This is land use/land cover digital data collected by USGS and converted to ARC/INFO by the EPA. This data which resides in EPA's Spatial Data Library (ESDLS), is useful for environmental assessment of land use patterns with respect to water quality analysis, growth management, and other types of environmental impact assessment. GIRAS LU/LC is being used in EPA's, Office of Water/OST BASINS water quality assessment model.

For more information (metadata) on EPA's GIRAS LULC spatial dataset, please reference the web site at <http://www.epa.gov/nsdi/projects/giras.htm>

Access_Constraints:
None.

Use_Constraints:
None. Acknowledgement of the U.S. Environmental Protection Agency would be appreciated.

Native_Data_Set_Environment: Arcview Shapefile format for Windows 95 PC
Cross_Reference:
Citation Information:
Originator:
Publication_Date: 1976
Title:
A Land Use and Land Cover Classification System for Use with Remote Sensor Data
Publication Information:
Publication Place: Reston, Virginia
Publisher: U.S. Geological Survey Professional Paper 964
Online Linkage: <http://landcover.usgs.gov/pdf/anderson.pdf> (PDF file)
Cross Reference:
Citation Information:
Originator: U.S. Geological Survey
Publication Date: 1990
Title: USGeoData 1:250,000 and 1:100,000 Scale Land Use and Land Cover and Associated Maps Digital Data
Publication Information:
Publication Place: Reston, Virginia
Publisher: U.S. Geological Survey

Cross Reference: Citation Information:
Originator: U.S. Environmental Protection Agency
Publication Date: 1994
Title: Metadata for 1:250,000 Scale Quadrangles of Landuse/Landcover GIRAS Spatial Data in the Conterminous United States
Publication Information:
Publication Place: Washington, DC
Publisher: U.S. Environmental Protection Agency
Online Linkage: <URL:http://www.epa.gov/nsdi/projects/giras.htm>

Spatial Reference Information:
Horizontal Coordinate System Definition:
Geographic:
Latitude Resolution: 0.0001
Longitude Resolution: 0.0001
Geographic Coordinate Units: Decimal Degrees
Geodetic Model:
Horizontal Datum Name: North American Datum of 1983
Ellipsoid Name: Geodetic Reference System 80
Semi-major Axis: 6378137
Denominator of Flattening Ratio: 298.257

U.S. EPA Reach File 1 (RF1) for the Conterminous United States in BASINS

Identification Information:
Citation:
Citation Information:
Originator: U.S. Environmental Protection Agency, Office of Science and Technology
Publication Date: 19980801
Title: U.S. EPA Reach File 1 (RF1) for the Conterminous United States in BASINS
Publication Information:
Publication Place: Washington, D.C.
Publisher: U.S. Environmental Protection Agency
Online Linkage:
For BASINS model and data <http://www.epa.gov/OST/BASINS/>
For further documentation and reference to EPA's River Reach Files <http://www.epa.gov/owowwtrl/monitoring/ri/riindex.html>
Description:

Abstract:
Reach File Version 1.0 (RF1) is a vector database of approximately 700,000 miles of streams and open waters in the conterminous United States. It is used extensively by EPA and States, and has been used by the U.S. Fish and Wildlife Service and the National Weather Service for many years. This configuration of RF1 for the geographic information systems community, extends the use of RF1 to ARC/INFO users in the U.S.Geological Survey, the U.S. Environmental Protection Agency and others.

RF1 was prepared by the U.S. Environmental Protection Agency (EPA) in 1982 from stable base color separates of National Oceanographic and Aeronautical Administration (NOAA) aeronautical charts having a scale of 1:500,000. These charts provided the best nationwide hydrographic coverage available on a single scale at that time. They included all hydrography shown on USGS maps having a scale of 1:250,000 with extensive additions, corrections and improvements in detail made by NOAA from aerial photography and satellite imagery. All hydrographic features on those charts were optically scanned from the color separates using a scanner resolution finer than feature line width. The surface water features selected for inclusion in the RF1 database were converted from raster form to vector form with coordinates expressed as latitude and longitude. Surface water names in RF1 were derived from the source maps and supplemented by names from miscellaneous state maps and maps of the USGS. Many other RF1 attributes are described herein.

In the 1980's, RF1 was used by EPA for performing water quality modeling on whole river basins for all of the hydrologic regions in the conterminous United States. In this role, it was used to provide national assessments and overviews of water quality and to provide the foundation for a nationwide stratified sampling frame for performing statistical summaries of modeled and measured water quality on all the surface waters of the 48 States.

In the 1980's, environmental data integration was strengthened significantly by EPA using the Reach File. Whereas, STORET had, for many years, integrated the water quality monitoring data of EPA, States, the USGS, and other Federal agencies by agency codes, standard water quality parameter codes, date, time, depth, site coordinates, state, basin, and user-definable polygons, the Reach File provided STORET with the capability to search upstream and downstream to relate the environmental data of many agencies to each other along stream paths. This brought about the ability to integrate ambient water quality at sites sampled by the several hundred official monitoring agencies using STORET in a new and powerful manner. Thus, for example, any and all water quality measurements made by the USGS and stored in WATSTORE were easily accessed via STORET prior to the introduction of the Reach File, but with the Reach File, it became possible to integrate the data from USGS WATSTORE records with the much larger holdings of environmental data from EPA, States and other Federal agencies on a station-by-station basis along stream paths. Stream ordered data integration of this type was important in the development of effluent guidelines pursuant to the Clean Water Act during the 1980's, and is but one example of the new dimension in data integration made possible by the standard reach numbering scheme and the hydrologic networking provided in RF1.

Linking multiple databases to RF1 and hence to each other, was accomplished by a process called reach indexing. The process takes advantage of the facts that each reach has been assigned a unique identifier and the stream path for each reach is described in terms of latitude/longitude coordinates. Using simple algebraic processing, each lat/lon point for every point of interest in a database is indexed to the closest point in the nearest RF1 reach. The unique reach number for that reach and its relative position, prorated against the full computed reach length, is placed in the database being reach indexed. From then on, access to all points that have been reach indexed in that indexed database, may be achieved in hydrological order by navigating upstream or downstream through RF1, picking up reach numbers in hydrological order from RF1 and retrieving the points of interest, if present, from the indexed database by reach numbers as the reaches are encountered in the navigation of RF1. For distribution with BASINS v.2.0, the spatial attributes of the database were prepared in Arcview shape file format while selected relational attributes were prepared in Arcview DBF file format.
Purpose:

This data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System.

This ARC/INFO coverage is intended for general water resources applications within the GIS user community. It was created to replace two earlier USGS translations of RF1. This coverage supercedes all previous ARC/INFO coverages.

The RF1 coverage provides Geographic Information System (GIS) applications with a valuable data layer for base mapping of reaches within the conterminous U.S. Reach files are used in numerous types of analysis, e.g., proximity to populations. Currently, EPA's Gateway/GIS subsystem, Ecological Sensitivity Targeting and Assessment Tool (ESTAT), and various EPA public-use web-based GIS applications utilize this data set.

Supplemental Information:

Intended use of data This data set was prepared to support the BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System, Version 2.0.


Procedures: The BASINS RF1 Data for the conterminous U.S. was obtained from the U.S. EPA IBM Mainframe as a separate ARC/INFO Export coverage for each hydrologic region. The export coverages were then imported and merged into one U.S. EPA region/hydrologic region ARC/INFO coverage. Each coverage was then merged with flow data to create an enhanced RF1 coverage. (just changed 1-26-98)

Reviews Applied:

Quality Assurance Data Procedures: The RF1 data were visually checked to make sure that the appropriate hydrologic regional RF1 pieces had been appended together correctly. Also the RF1 coverages were checked to make sure the flow data had been added correctly.

ARC/INFO watch files are created during the extraction of data from the EF Oracle database, the processing of the EF data into ARC/INFO point coverages, and the insertion of the point coverages into ESDLs. These files are created to monitor and verify that the processing occurred without error.

Limitations of Data:

Not all RF1 reaches reported in the conterminous U.S. are included. For example, reaches with no assigned locational coordinates cannot be included. The coordinates and the attribute data of this coverage are machine conversions by EPA of the data in the EPA RF1 files exactly as it exists in the original RF1, archived in 1982. No coordinate data were altered beyond mere conversion to an Albers Equal Area projection. The RF1 streamflow data were obtained without alteration directly from EPA STORET files as data developed for RF1 in June, 1982.

The RF1 streamflow data consist of mean annual flow and 7Q10 low flow estimates made at the downstream ends of more than 60,000 transport reaches coupled to an estimate of the time-of-travel velocity for the full length of those same reaches under each of those two flow regimes. EPA needed to estimate flows for more than 60,000 reaches because it needed flow data on all RF1 reaches and the
USGS had consistent streamflow data on fewer than 2000 of them. Even on these few reaches where consistent data were available, the data were needed at the downstream ends of the reaches rather than where the USGS gages were typically located. Thus, in fact, all of the RF1 flow data are estimates at locations other than USGS gage sites. An additional limitation in the gage network was that vast areas of the country were without USGS data for drainage areas under 500 square miles, except for gages with data gaps, data skew, and anomalous conditions. Approximately 2,000 gages in this category were included in the data set used, such that 4112 gages with flow data were actually used in producing the estimates for all RF1 reaches. Another group of gages was used in the flow estimation process. Drainage area, an attribute essential to the flow estimation process used, is usually available from all USGS flow gages. All of the 4112 gages that included useful flow records, and approximately 4000 additional gages that did not have useful flow data for the project, were used to assign drainage area to reaches in RF1. The drainage area attribute available for gages was thereby used on approximately 8000 gages. By snapping gages to reaches, the project was able to acquire drainage area for approximately one reach in every eight reaches in RF1. Thus some gages were used for streamflow data and their drainage area measurement, and the remaining were used for only their drainage area measurement.

Streamflow data from the USGS Daily Values File for the 4112 gages were used to develop estimates of mean annual flow and 7Q10 flow at the gage sites. Because of data skew and anomalous conditions at many of these gages, interactive graphics techniques were applied to the solution of the mean annual and 7Q10 flow estimates at the gage sites. The interactive graphics provided visual displays of all of the daily values at the 4112 gages to visually detect skew and data anomalies within an automated framework in which the team of hydrologists in the project were able to apply graphical procedures generally used manually by hydrologists all over the world to solve for the mean annual and 7Q10 flows. It was determined in 1982 that these estimates were essentially equal to those produced for the same gages by USGS fully automated methods, except where the data were skewed or anomalous. Hydrological procedures described in "ESTIMATION OF STREAMFLOWS FOR THE REACH FILE," June, 1982 were used in an EPA contract with W.E. Gates and Associates, Inc. to transfer the mean annual flows and 7Q10 low flows at gaged sites to the downstream ends of all reaches including ungaged reaches. The average velocities over the length of each transport reach in the Reach File were developed for those two flows using streamflow, measured time-of-travel data where available, and watershed characteristics under the same contract with W.E. Gates and Associates.

EPA has advised users (1983 EPA memo to Regions, States and other RF1 users), that the overall flow estimation methodology used in producing the RF1 flow estimates was not designed to produce accurate results on start reaches or small ungaged tributaries, nor in estuaries or ungaged coastal streams. Thus the accuracy of the flow estimates in these types of streams is not expected to be adequate for many applications. The principal use of these estimates, it pointed out, was intended to be on reaches where the estimates had been made between upstream and downstream gages. Reviewers commented at that time, that the flow estimates in this latter category were essentially the same as their own which had been made by methods of their choice. EPA added that use of these flow values may benefit from an initial evaluation on a basin-wide or watershed basis, distinguishing between accuracies of the flow estimates among the various reach types, such as start reaches, and reaches in which the flow is regulated by man's activity. Factors such as irregular density of reaches in a particular area of a state or data problems within the period of record for a particular gage, may introduce local variations in the accuracy of these flow estimates. The USGS Water Resources Division cautions users that since the RF1 flow estimates are provided at the downstream ends of gaged and ungaged reaches and not at the actual gage sites, these RF1 flow estimates may differ from USGS records at the gage sites. Furthermore, the USGS Water Resources Division cautions users that these 1982 RF1 flow data are from EPA files and may not accurately represents current records of the USGS.
Summary of Differences: Total vector-object count in the AAT file: 64,955 arc features, some reaches represented by 2 records due to the 500 point limit per record in ARC/INFO Reaches without attributes: 129 CUSEG's in the RF1.AAT file have no match in the RF1.STRUCTx files, i.e., topologic attributes are missing on 129 reaches in RF1 Structure File.

Attributes without traces:

3607 RF1.STRUCTx CUSEG's have no match in the RF1.AAT file. Since ARC/INFO builds its own topology from the RF1 trace file, it will produce topologic anomalies on 3607 reaches except where the missing trace records are isolated reaches. To be of further assistance in this matter, a file which details the presence and absence of Trace File data and Structure File data on a reach-by-reach basis has been incorporated in this coverage under the Entity_Type_Label RF1.CUSEGLIST.

Related Data Sets:

RF1 was built as a database consisting of two groups of record types. The first group contained three record types which provided reach-by-reach information related by Catalog unit and reach segment number (CUSEG); the second contained two record types which provided information on areal objects namely, open waters and watersheds, which were also related by CUSEG. This ARC/INFO coverage was assembled from the three record types of the first group through a reconfiguration process beginning with the use of the following three intermediate files retrieved from EPA STORET system:

RF1struct.all RF1flow.all RF1trace.all

The rf1trace file consists of all records of the RF1 Trace Record Type; the rf1struct consists of all records of the RF1 Hydrologic Structure Record Type; and the RF1flow file consists of a subset of the RF1 Reach Characteristics Record Type. The rf1trace was used to produce the necessary AAT file and the other two files were used as sources of attribute data.

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 1994
Currentness_Reference: publication date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As Needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -127.97564
East_Bounding_Coordinate: -65.25502
North_Bounding_Coordinate: 48.27508
South_Bounding_Coordinate: 22.86745
Keywords:
Theme:
Theme_Keyword_Thesaurus: None
Theme_Keyword: Reach File
Place:
Place_Keyword_Thesaurus: None
Place_Keyword: Conterminous United States
Access_Constraints: None
Use_Constraints:
None. Acknowledgement of the U.S. Environmental Protection Agency would be appreciated.

Data_Quality_Information:
Logical_Consistency_Report:
Point features present.
Completeness_Report: See Supplemental_Information
Lineage:

Process_Step:
Process_Description:
The BASINS v.1.0 data in Arc/Info coverage format and Albers Conic Equal Area projection with datum NAD27 was converted to geographic decimal degrees projection with datum NAD83 using Arc/Info. The coverages were then converted to Arcview shape files using the Arc/Info ARCSHAPE command. Selected fields in the RCHPUB database which contain estimated characteristics of stream segments were joined with the RF1 original primary attribute table to produce the primary attribute table of the RF1 version in BASINS. For distribution with BASINS 2.0, the RF1 data layer were divided by EPA regions (i.e. distribution by CD). Other form of data distribution (e.g. by cataloging unit) is available through the web at <http://www.epa.gov/OST/BASINS/>.
Process_Date: 19980218
Process_Contact:
Contact_Information:
Contact_Organization_Parent:
Contact_Organization: Tetra Tech, Inc.
Contact_Address:
Address_Type: Mailing Address
Address: 10306 Eaton Place, Suite 340
City: Fairfax
State_orProvince: Virginia
Postal_Code: 22030
Country: USA
Contact_Voice_Telephone: 703-385-6000
Contact_Instructions: See Distributor_Information

Populated Place Point Locations for CONUS, Alaska, and Hawaii in BASINS

Identification_Information:
Citation:
Citation_Information:
Originator: U.S. Environmental Protection Agency/Office of Water
Publication_Date: 19980801
Title:
Populated Place Point Locations for CONUS, Alaska, and Hawaii in BASINS
Publication_Information:
Publication_Place: Washington, D.C.
Publisher: U.S. Environmental Protection Agency
Online_Linkage:
For BASINS model and hydrographic data <http://www.epa.gov/OST/BASINS/>
Description:
Abstract:
This data set provides the location of populated places as represented on USGS topographic maps. It includes a collection of populated place names derived from USGS Geographic Names Information System II (GNISII) Topographic Names data.
For distribution with BASINS v.2.0, the data layer was prepared in Arcview shape file format.

**Purpose:**
This data set was created to provide the location of populated places in the United States in order to establish their proximity to surface waters. The relationship between populations potentially affected by water quality problems can then be established. It will also aid in the determination of the sources of water quality problems.

**Supplemental Information:**

**Intended Use Of Data:** This data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System.

**References Cited:**

Metadata of GNIS2 <http://nsdi.usgs.gov/nsdi/wais/maps/gnis.HTML>

**Limitations of Data:** None

**Procedures:** The source data were obtained as State ASCII files on 9-track tape from the USGS. The ASCII files were first converted into ARC/INFO point coverages with an ARC/INFO AML program. The AML program assigned a spatial accuracy code to each point depending upon the degree of its geographical coordinate agreement with USGS 7.5" quadrangle, county and state coverages.

The data were checked for spatial accuracy to 7.5" USGS quad level, except for Alaska, Hawaii (a 7.5" USGS quad boundary coverage for these areas) and Colorado (GNIS II data did not contain quadrangle names).

The majority of the names were compiled from 1:24,000 scale, 7.5-minute topographic maps. When there were no published 7.5 minute maps or advance copies with names available, 15 minute maps were used; when there was no coverage by either series maps, 1:250,000-scale maps were used.

After Phase I data compilation, the geographic names in each State file were edited by comparing computer files with the accumulated records of the U.S. Board on Geographic names (BGN) on a one-to-one basis. When the initial edit of the geographic names in the state file was completed, the corrections were made, and other information such as variant names and BGN data were added.

The quality assurance of the enhanced data consisted of checking accuracy codes equal to 1, 3 and 9. An accuracy code with a value of 1 means that the 7.5" quadrangle boundaries that the point's geographic coordinates fell within matched the points associated 7.5" quadrangle name. An accuracy code value is equal to 9 if the point's coordinates are outside the United State borders. Anything on the border of the U.S. and touching the correct county was reassigned an accuracy of 4. An accuracy code value is equal to 3 if the point is outside the associated state border but still inside the U.S. borders. Anything on the point's associated state boundary and touching the correct county was also given an accuracy of 4. The state coverages were also checked against each other to ensure data format consistency throughout the country.
For distribution with BASINS v2.0, the ARC/INFO coverages in BASINS v1.0 that included the spatial extent of each of the ten U.S. EPA Regions, plus the 8-digit hydrologic units that crossed region boundaries were reprojected from Albers to Geographic projection and converted to ARCVIEW shapefiles.

**Time_Period_of_Content:**
**Time_Period_Information:**
**Range_of_Dates/Times:**
**Beginning_Date:** 1989
**Ending_Date:** 1994
**Currentness_Reference:** 1996
**Status:** Complete
**Maintenance_and_Update_Frequency:** As Needed

**Spatial_Domain:**
**Bounding_Coordinates:**
**West_Bounding_Coordinate:** -170.0000
**East_Bounding_Coordinate:** -65.0000
**North_Bounding_Coordinate:** 70.0000
**South_Bounding_Coordinate:** 19.0000

**Contact_Information:**
**Contact_Organization.Primary:**
**Contact_Organization:** U.S. Geological Survey
**Contact_Address:**
**Address_Type:** mailing address
**Address:** 523 National Center
**City:** Reston
**State_or_Province:** VA
**Postal_Code:** 20192
**Contact_Voice_Telephone:** 703-385-6000

**Native_Data_Set_Environment:** Arcview Shape files

**Data_Quality_Information:**
**Logical.Consistency_Report:**
Point features present.
**Completeness_Report:**
See Supplemental_Information
**Lineage:**
**Process_Step:**
**Process_Description:**
The BASINS v.1.0 data in Arc/Info coverage format and Albers Conic Equal Area projection with datum NAD27 was converted to geographic decimal degrees projection with datum NAD83 using Arc/Info. The coverages were then converted to Arcview shape files using the Arc/Info ARCSHAPE command. For distribution with BASINS 2.0, the DWS data layer were divided by EPA regions (i.e. distribution by CD). Other form of data distribution (e.g. by cataloging unit) is available through the web (<http://www.epa.gov/OST/BASINS>.)

**Process_Date:** 19971201

**Spatial_Reference_Information:**
**Horizontal_Coordinate_System_Definition:**
Geographic:
**Latitude_Resolution:** 0.0001
**Longitude_Resolution:** 0.0001
**State Soil Geographic (STATSGO) Database for CONUS, Alaska, and Hawaii in BASINS**

**Identification Information:**

**Citation:**
- **Originator:** U.S. Environmental Protection Agency
- **Publication_Date:** 19980801

**Title:**
- State Soil Geographic (STATSGO) Database for CONUS, Alaska, and Hawaii in BASINS

**Publication Information:**
- **Publication Place:** Washington, D.C.
- **Publisher:** U.S. Environmental Protection Agency

**Online Linkage:**
- For BASINS model and hydrographic data [http://www.epa.gov/OST/BASINS/]

**Description:**

**Abstract:**

The STATSGO database is a digital general soil association map developed by the National Cooperative Soil Survey. It consists of a broad based inventory of soils and nonsoil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The soil maps for STATSGO are compiled by generalizing more detailed soil survey maps. Where more detailed soil survey maps are not available, data on geology, topography, vegetation, and climate are assembled, together with Land Remote Sensing Satellite (LANDSAT) images. Soils of like areas are studied, and the probable classification and extent of the soils are determined. Map unit composition for a STATSGO map is determined by transecting or sampling areas on the more detailed maps and expanding the data statistically to characterize the whole map unit. The original data set consists of georeferenced digital map data and computerized attribute data. The map data are collected in 1- by 2-degree topographic quadrangle units and merged and distributed as statewide coverages. The soil map units are linked to attributes in the Map Unit Interpretations Record relational data base which gives the proportionate extent of the component soils and their properties.

This data set provides a soil association map in ARCVIEW Shapefile Format for the Conterminous United States. The shapefile is prepared and distributed by EPA regions. Selected attribute related tables which contain soil properties are provided. This data set is a subset of the original STATSGO data set developed by the National Cooperative Soil Survey.

**Purpose:**

STATSGO depicts information about soil features on or near the surface of the Earth. These data are collected as part of the National Cooperative Soil Survey. STASGO is designed primarily for regional, multi-county, riverbasin, state, and multi-state regional planning, management, and monitoring.

**Supplemental Information:**

**Intended use of data:** This data set was prepared to support the U.S. EPA BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) System, Version 2.0.
References Cited:


Metadata <http://www.ftw.nrcs.usda.gov/stat2.html> EXIT DISCLAIMER

Time_Period_of_Content:
Time_Period_Information:
Single_Date/Time:
Calendar_Date: 19940000
Currentness_Reference: Publication Date
Status:
Progress: Complete
Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate: -170.00
East_Bounding_Coordinate: -65.00
North_Bounding_Coordinate: 70.00
South_Bounding_Coordinate: 19.00 EXIT DISCLAIMER

Data_Quality_Information:
Logical Consistency Report:
Certain node/geometry and topology (GT)-polygon/chain relationships are collected or generated to satisfy topological requirements. (The GT-polygon corresponds to the soil delineation). Some of these requirements include; chains must begin and end at nodes, chains must connect to each other at nodes, chains do not extend through nodes, left and right GT-polygons are defined for each chain element and are consistent throughout, and the chains representing the limits of the file (neatline) are free of gaps. The tests of logical consistency are performed using vendor software. The neatline is generated
by connecting the explicitly entered four corners of the digital file. All data outside the enclosed region are ignored and all data crossing these geographically straight lines are clipped at the neatline. Data within a specified tolerance of the neatline are snapped to the neatline. Neatline straightening aligns the digitized edges of the digital data with the generated neatline (i.e., with the longitude/latitude lines in geographic coordinates). All internal polygons are tested for closure with vendor software and are checked on hard copy plots. All data are checked for common soil lines (i.e., adjacent polygons with the same label). Quadrangles are edge matched within the state, merged into a statewide data sets, and then edge matched to adjacent state data sets. Edge locations do not deviate from centerline to centerline by more than 0.01 inches.

Completeness Report:
A map unit is a collection of areas defined and named the same in terms of their soil and/or nonsoil areas. Each map unit differs in some respect from all others in a survey area and is uniquely identified. Each individual area is a delineation. Each map unit consists of one to 21 components. In those few areas where detailed maps did not exist, reconnaissance soil surveys were combined with data on geology, topography, vegetation, climate, and remote sensing images to delineate map units and estimate the percentages of components. The STATSGO map unit components are soil series phases, and their percent composition represents the estimated areal proportion of each within STATSGO map unit. The composition for a map unit is generalized to represent the statewide extent of that map unit and not the extent of any single map unit delineation. These specifications provide a nationally consistent representation of STATSGO attribute data. The actual composition and interpretive purity of the map unit delineations were based on statistical analysis of transect data. The composition was largely determined by measuring transects on detailed soil survey maps. The number of transects used was proportional to the relative size, number, and complexity of the delineations. The combined data on the length of the map units crossed by the transects were used to determine the percentages of the different soil and nonsoil areas in each map unit. Specific limits were established on the classification of soils and the design and name of map units. These limits are outlined in U.S. Department of Agriculture. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. Soil Conserv. Serv., U.S. Dep. Agric. Handb. 436.; U.S. Department of Agriculture. 1992. Keys to Soil Taxonomy. SMSS Technical Monograph No. 19. Soil Surv. Staff, Soil Conserv. Serv.; U.S. Department of Agriculture. 1993. National Soil Survey Handbook, title 430-VI. Soil Surv. Staff, Soil Conserv. Serv.; and U.S. Department of Agriculture. 1993. Soil Survey Manual. Soil Surv. Staff, U.S. Dep. Agric. Handbook 18.

Adherence to National Cooperative Soil Survey standards and procedures is based on peer review, quality control, and quality assurance. Quality control is outlined in documents that reside with the Natural Resources Conservation Service state soil scientist.

Spatial Reference Information:
Horizontal Coordinate System Definition:
Geographic:
Latitude Resolution: 0.0001
Longitude Resolution: 0.0001
Geographic Coordinate Units: Decimal Degrees
Geodetic Model:
Horizontal Datum Name: North American Datum of 1983
Ellipsoid Name: Geodetic Reference System 80
Semi-major Axis: 6378137
Denominator of Flattening Ratio: 298.257

Hydrologic Unit Boundaries of the Conterminous United States in BASINS

Identification Information:
Citation:
The changes made to the data sets from ESDLs are as follows:

1) Reprojected the ARC/INFO coverages to a geographic projection.
2) Derived accounting unit and cataloging unit layers only from original data.
3) Converted ARC/INFO coverages to Arcview Shapefiles with ARC SHAPE command in Environmental Systems Research Institute (ESRI) GIS software.

Purpose:
These data sets are intended to support watershed analysis in BASINS.

References Cited:


Limitations of Data:

These data were originally digitized at a scale of 1:250,000 with some portions of coverage at 1:100,000- and 1:2 million scale. Limitations of the data strictly revolve around this scale input. Use of these boundaries with larger scale data (i.e. 1:24k hydrography) is not recommended as it would be beyond the resolution capabilities of the data set.
Ending Date: Unknown
Currentness Reference: Publication date
Status:
Progress: Complete
Maintenance and Update Frequency: As needed
Spatial Domain:
Bounding Coordinates:
West Bounding Coordinate: -125.00
East Bounding Coordinate: -66.00
North Bounding Coordinate: 50.00
South Bounding Coordinate: 24.00

Spatial Reference Information:
Horizontal Coordinate System Definition:
Geographic:
Latitude Resolution: 0.0001
Longitude Resolution: 0.0001
Geographic Coordinate Units: Decimal Degrees
Geodetic Model:
Horizontal Datum Name: North American Datum of 1983
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