USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Identification of Candidate Parcels for Riparian Buffers: Reducing Fecal Contamination of Vermont Surface Waters

Focus categories: NPP, SW, AG

Keywords: water quality, fecal contamination, nonpoint source pollution, GIS, remote sensing, agriculture, surface water

Duration: 3/1/00 - 2/28/01

	Total	Direct	Indirect
Fiscal Year Funds:	$ 20,964	$ 20,964	$ 0
Non-Federal Funds:	$ 39,628	$ 20,693	$ 18,935

Principal Investigator: Leslie A. Morrissey, University of Vermont

Congressional District: 1st District, State of Vermont

Abstract: Fecal contamination of surface waters from both agricultural and urban environments is a major environmental issue in the state of Vermont. A suite of conservation practices is needed that will significantly reduce bacterial contamination of Vermont's surface waters. One effective approach to reduce contamination in runoff from adjacent agricultural fields to streams and rivers involves the construction of buffer zones and filter strips along streams and rivers. Identification and prioritization of land parcels for riparian buffer zone implementation thus constitute a critical need for water quality programs. The research proposed here focuses on the development of a suitability model to identify and prioritize candidate land parcels for riparian buffer implementation utilizing Geographic Information Systems (GIS) and state-of-the-art remote sensing technologies. Suitability modeling will incorporate environmental parameters that are readily available, can be derived from available data, or can be mapped using soon-to-be-available high-resolution (1m) satellite data. The proposed study is focused on the Mad River watershed and if successful, this methodology could be extended to watersheds throughout the state.

Significance of Proposed Research

Fecal contamination of surface waters is a growing concern in agricultural and wildland areas throughout the U.S. (Crane et al., 1983). Runoff from agricultural lands carrying microorganisms from livestock manure can contaminate water supplies and pose a serious risk to human health. Animal feeding operations, fecal waste storage and application, and grazing pastures are all potential sources of bacterial contamination of nearby waters. Manure and sludge applied to cropland soils and grazing by domestic livestock in pastures are important sources of animal waste carried into adjacent streams during or following precipitation events in rural Vermont. Even in pastures where cows have been removed, elevated bacterial levels may persist for months (Jawson et al., 1982, Tiedemann et al., 1988). To decrease fecal contamination of streams from these sources, both state and federal conservation practices, including the construction of riparian buffer zones, have been adopted.

The construction of buffer zones and filter strips along streams and rivers has been shown to be an effective conservation practice that reduces bacterial contamination of surface waters in agricultural environments (Dickey and Vanderholm, 1981; Doyle et al., 1977; Meals, 1996, Young et al., 1980; Coyne and Blevins, 1995). A riparian buffer is typically defined as an area of trees and shrubs immediately adjacent to streams, lakes, ponds, or wetlands that is managed to enhance and protect aquatic resources. Filter strips refer to comparable grass covered areas. Riparian buffers and filter strips reduce *E. coli* counts in waterways by reducing the volume and velocity of runoff and increasing adhesion onto soil particles and vegetation (Palone and Todd, 1997). Riparian buffers (and filter strips) are most effective when bacterial concentrations are high (Moore et al., 1988) and may intercept up to 95% of the pathogens in surface runoff from manured fields if of sufficient width and properly managed (Coyne and Blevins, 1995). At the local level, pilot studies in two Vermont watersheds have also had modest success (Meals, 1996).

In an attempt to improve water quality at state levels, federal cost share programs were implemented to encourage the use of riparian buffers and filter strips by agricultural landowners. These programs, however, have not been widely adopted by landowners in the state of Vermont. As a consequence, the NRCS, in collaboration with the Vermont Agency of Natural Resources, Non-Game and Natural Heritage Program, and USDA Farm Service Agency, has initiated a program in 1999 to provide economic incentives to landowners to develop riparian buffers within the Mad River watershed. With limited resources, *the identification and prioritization of land parcels for riparian buffer zone implementation are thus a critical need for this and other water quality programs*. The research proposed here will focus primarily on the identification and prioritization of candidate land parcels that could benefit from the development of riparian buffers and filter strips for the purpose of reducing fecal contamination of surface waters in the Mad River watershed. If successful, the methodology could be extended to watersheds throughout the state.

The effectiveness of riparian buffers and filter strips is affected by a number of environmental factors including soil type, soil moisture, vegetation type, slope and dimensions of the buffer. Organic and clay particles in soil are very effective in trapping *E. coli* bacteria (Mawdsley et al., 1995). Mortality of microorganisms entrapped within the soil is subsequently hastened if soils are well drained (Rosen, in prep.). Soil saturation and its role in overland flow are major factors in transporting microorganisms. *E. coli* were found to move as much as 1.5m/hr through saturated hillside slopes in Oregon (Rahe et al., 1978). The length, width, slope, and type of vegetation in a buffer also impact bacterial transport. Glenne (1984) found that steeper slopes are most effective at moving water, sediment, and *E. coli* downslope and, as a result, typically require wider buffers to reduce input into adjacent streams. Widths up to 100 feet or more may be necessary on steeper slopes and less permeable soils (Schultz et al., 1995). Although trees and woody shrubs are more effective in reducing erosion and thus for stabilizing streambanks, grass filter strips are more effective in reducing fecal (and other pollutants) contamination inputs into nearby streams (Schultz et al., 1995). Ideally, therefore, buffer zones should be defined based on the specific setting to limit both erosion and agricultural runoff. In summary, any practice that reduces runoff and sediment transport will simultaneously reduce pathogen transport to nearby waters (Rosen, in prep.).

Geographic Information Systems (GIS) and digital remote sensing are technologies well suited to aid identification and prioritization of candidate land parcels in need of a riparian buffer. High-resolution digital orthophotography (1:5000; 0.5m pixels) and satellite imagery (1m pixels; available in the summer of 2000) can be used to characterize riparian zones, and to determine the presence or absence of a buffer; the length, width, dominant vegetation type of existing buffers; and adjacent land use/land cover. Remote sensing can also provide information on drainage channels that directly circumvent the beneficial effects of riparian buffers and thus represent a potentially direct source of contaminants into streams. These drainage channels are expected to be visible on both digital orthophotography and satellite imagery but are not otherwise currently mapped. Available digital topographic data can be used to derive slope and length measures of fields adjacent to streams. Using these methods, state and federal conservation programs could prioritize their limited resources to maximize returns in terms of improved water quality. With the recent (September, 1999) availability of high resolution IKONOS satellite data, mapping of areas adjacent to streams can be based on multispectral digital image processing and classification techniques rather than manual interpretation of panchromatic photography. This newest generation of satellite data records information in the visible and near infrared wavelengths, and is thus ideally suited for mapping vegetation. These satellite data are expected to easily surpass digital orthophotography (which is based on black and white aerial photography flown in 1992) in value. By utilizing remotely sensed data to map the environmental characteristics of riparian zones, land parcels can be prioritized for buffer implementation based on a combination of environmental factors analyzed within a GIS framework. For instance, a streambank without a riparian buffer adjacent to a pasture would receive a high rank with regard to the need for riparian buffer or filter strip development.

Escherichia coli (*E. coli)* is the most reliable indicator of bacterial contamination of surface waters in the U.S. according to water quality standards promulgated by the U.S. Environmental Protection Agency. Although *E. coli* bacteria are not pathogenic in and of themselves, EPA standards are based on an epidemiological study by Dufour (1984) which demonstrated that *E. coli* was a better predictor of swimming-associated gastrointestinal illness than fecal coliform concentration (Francy et al., 1993). The standards are defined as an indicator concentration where the health risk from waterborne illness is unacceptably high. Water Quality Standards adopted by the State of Vermont set the *E. coli* limit at 77 organisms/100ml for class B recreational waters suitable for direct contact like swimming holes (Vermont Water Resources Board, 1996).

Scope and Objectives of this Research

The goal of this proposed research is to develop and assess the GIS and remote sensing technologies required to identify and prioritize candidate parcels within the Mad River watershed for riparian buffer or filter strip development. Candidate land parcels will be identified based on their probable fecal contribution to adjacent waters as modeled using environmental parameters that are readily available or directly measured. For example, land parcels with commodity crops and manure spreading as well as pastures for livestock grazing adjacent to streams and rivers, on steeper slope gradients, with saturated clay and organic soils, would be identified as the most critical candidate parcels. State-of-the-art digital processing of high resolution IKONOS satellite data will provide a new method for: 1) identifying and characterizing riparian zones, 2) mapping adjacent land parcels by current land use, and 3) determining the density of drainage channels. If successful, this satellite-based methodology could be used to extrapolate the results generated and tested in the Mad River watershed to the entire Winooski watershed. This proposed research effort will be conducted in collaboration with state and federal agencies and local citizen volunteer groups. On-going and collaborative efforts by Friends of the Mad River, Mad River Water, Natural Resources Conservation Service, and Vermont Farm Bureau will complement this proposed project.

Finally, dissemination of the results of this and other *E. coli* measurement programs is needed to increase public awareness of water quality issues and on-going research efforts. We propose to use the WWW for disseminating our results. We are sensitive to representations of water quality indicators (i.e. *E. coli*) on the Web which may be misconstrued or misinterpreted by the public and we will use extreme care in presenting the data.

The objectives of this proposed research are:

- Identify and prioritize candidate land parcels within the Mad River watershed for riparian buffer development using a spatially explicit (GIS-based) suitability model

- Assess the utility of high resolution satellite data for mapping and monitoring riparian buffers along streams and rivers

    - digital orthophotography vs. high resolution satellite imagery

    - manual photo interpretation vs. digital image processing and classification

    - panchromatic vs. multispectral imagery

· Disseminate information to the public on fecal contamination of streams and lakes using a WWW Page listing *E. coli* measurements for:

- this study
- state and municipal beaches
- River Watch watersheds

Study Area

The Mad River has been named one of Vermont's best swimming resources, having 19 of the 210 best swimming holes in the state (Mad River Valley Planning District, 1995). The scenic Mad River flows 42 km north from the Granville Wilderness area to the Winooski River in central Vermont. With an area of 370 km^2, land cover and land use in the watershed is dominated by forests and agriculture. The watershed encompasses the towns of Granville, Warren, Waitsfield, Fayston, Duxbury, and Moretown. The southern end of the watershed is relatively undeveloped and primarily covered with forests. Development and agricultural farmland increases northward. The Sugarbush Ski Resort is also located within the watershed. Although a major resort area in the state, Mad River has been identified on the 1998 Vermont Impaired Waters list. Moreover, a local volunteer group, Mad River Watch, found that of the 38 sites sampled in 1995, 19 violated the water quality standard for class B recreational waters 50% or more of the time (Mad River Program Annual Report, 1995). Fecal contamination in the Mad River watershed has been attributed to agricultural runoff and inadequate septic treatment of human waste. With seven years of water sampling data by River Watch and an on-going riparian conservation program by the NRCS, the Mad River watershed provides an ideal environment for water quality studies.

Methods, Procedures, and Facilities

<u>GIS Database Development and Modeling</u>: Candidate land parcels for riparian buffer development will be identified through the development of a suitability model. Suitability models are used commonly in GIS to identify the best locations for some particular activity. In a broad sense, suitability models provide a framework to systematically organize and synthesize a number of complex environmental variables (e.g., soils, slope, land use/land cover). The goal of this proposed project is to identify and rank locations for riparian zones in critical need of buffers or filter strips. Interval measures of suitability for each environmental data class will be combined with a weighting factor to create ratio measures of suitability. The modeling effort will be based on the incorporation of existing GIS data layers, derivation of new layers, and through mapping. Major tasks required to meet the objectives of this proposed research include:

· Map areas in riparian zone

Presence or absence of riparian buffers and filter strips along the Mad River

If present, document buffer width, length, and vegetative type (shrub/grass, shrub/forest, forest)

· Map land areas adjacent to riparian zone

- land use/land cover (forest, agriculture, residential)
- commodity crop or livestock pasture
- slope of field adjacent to stream/river
- density of drainage channels (indicator of runoff)
- hydrologic modeling of flow and accumulation, drainage area and outlet

· Develop suitability model for buffer development

- Identify candidate land parcels
- Prioritize candidate parcels

GIS data layers for soils, topography, and digital orthophotography are available through the Vermont GIS archive, the Vermont Center for Geographic Information (VCGI). NRCS, in collaboration with VCGI, is just completing the development of a new statewide soils database. Soil type and drainage class attribute information will be available as part of this data layer. Digital elevation models (1:5000) are available through the Vermont Mapping Program for the Mad River watershed for generation of slope gradients. Digital orthophotography (1:5000) is also available for mapping of riparian zones (presence or absence, width, length, vegetation type). By the summer of 2000, high resolution IKONOS satellite imagery will be acquired and incorporated into the analysis, replacing the orthophotography. The orthophotos and satellite data will also be used to map the density of drainage channels along the river and stream. A higher density of drainage channels would indicate increased runoff, that is, higher likelihood of bacterial contamination as water flows through the channels rather than through riparian buffers. A list of the GIS data layers and derivatives to be incorporated in support of suitability modeling include:

Existing GIS data layers

· Property parcels

· Stream network

· Soil drainage class in fields adjacent to stream/river

· Digital topographic data (DEM)

· Digital orthophotography

· Satellite imagery

GIS Derivatives

· Slope gradient in adjacent field

· Hydrologic flow and accumulation downslope, drainage area delineation and location of outlets

Mapping

· Adjacent land use/land cover to stream/river

Commodity cropland

Grazing pastures

· Density of drainage channels/area

· Riparian buffer width, length, and vegetative type

One might assume that land adjacent to a riparian buffer would be filtered by that buffer. In reality, the slope gradient, aspect, and shape determines which downhill path water will take. Hydrologic modeling can be used to trace the path of water (raindrops) down a slope to a specific outlet. Using ESRI's software, flow direction and accumulation, drainage area, and outlet will be derived from 1:5,000 digital elevation data.

Image Processing: Analysis of the satellite data will include image classification and enhancement. Digital classification of land use and land cover in parcels adjacent to the river will be performed using a contextual classifier. Image enhancement (edge enhancement) will be utilized to map drainage channels. Screen digitizing of digital orthophotography and satellite imagery will locate existing riparian buffers and quantify each by width, length, and vegetative type.

The Spatial Analysis Lab (SAL) at the School of Natural Resources will provide all of the computer resources required to meet the GIS and image processing needs of this project. The SAL consists of 6 SGI Unix workstations, CD writer, color plotter, color printers, Exabyte tape drive, CD reader/writer - a fully equipped facility for image processing and GIS. The SAL has site licenses for ESRI's suite of GIS software (ArcView and extensions, Arc/INFO, GRID, etc.) and ERDAS Imagine Image Processing software. A system manager and two full time staff maintain the facility which is supported solely by research dollars.

Evaluation of the Candidate Parcels

Evaluation of candidate parcels will require both site specific visits and collaboration with on-going efforts by federal and state agencies and citizen Riverwatch groups. For example, as part of a collaborative two-year study begun in August of 1999, NRCS will inventory riparian corridors adjacent to 51 commodity crop fields in the Mad River Valley. One evaluation, therefore, will compare the independent rankings of parcels for riparian buffer development for those reaches of the Mad River where the NRCS and this study overlap. In addition, *E. coli* measurements collected by the Mad River Watch group will be compared to the ranking of the adjacent and immediately upstream stream corridor based on the suitability model. We realize that the locations of the River Watch sites may not be optimally located to fully test the results of the suitability model.

Statement of Results/Benefits

The anticipated outcomes of this proposed research include:

· Identification of the location, length and area of adequate inadequate stream buffers

· Development of spatially explicit (GIS-based) methodology for identifying candidate land parcels for development of riparian buffers and filter strips.

· GIS database and map products will be provided to NRCS, ANR, and local River Watch organizations.

· Development of satellite-derived mapping techniques within a GIS framework that, if successful, can be used to map to the entire Winooski watershed.

· Development of a publicly available Web page documenting on-going *E. coli* measurement programs within the state of Vermont including this proposed study, state and municipal beaches, and River Watch watersheds.

If successful, the use of state-of-the-art IKONOS satellite data and GIS for mapping riparian buffers will provide a reliable and accurate method which could be adopted throughout the state of Vermont, across the Northeast, and will be relevant to similar studies throughout the U.S. The development of computer-based techniques in the Mad River watershed that can be extrapolated to the Winooski watershed could provide cost effective and accurate inventories of water quality parameters such as fecal contamination. Finally, dissemination of the results of this study and other *E. coli* measurement programs in the state on the WWW will heighten public awareness of water quality issues within the state of Vermont.

Investigators Qualifications

Leslie Morrissey, the Principal Investigator, is an associate professor in the School of Natural Resources. With twenty years experience and expertise in remote sensing, GIS, and ecology, she is an investigator in three NASA-funded research projects utilizing recently launched satellite data (POLDER and RADARSAT) for mapping wetlands. She is also an International Investigator for the soon to be launched European satellite ENVISAT. To date, she has published 38 refereed journal articles, conference proceedings, and technical reports. She currently mentors four graduate students whose research address issues regarding water quality, wetlands, and human health. One graduate student, Deborah Sargent, is currently studying the contribution of human and agricultural waste to *E. coli* levels in the Mad River watershed in collaboration with the Friends of the Mad River. My curriculum vitae can be found in the Appendix.

Training Potential

Two graduate students from the University of Vermont will take part in this project. The first, Deborah Sargent, was involved in water sampling in the Mad River last year. She will complete her thesis by the fall of 2000. We will utilize her expertise in lab analyses, GIS database development, and WWW page design for the first three months of the project. A second student, to be determined, will begin in the fall of 2000 and participate fully in the first and hopefully second year of proposed research. Undergraduate students will also be recruited to participate in water sampling, GIS database development, and WWW design as part of the School of Natural Resource's internship or honors programs.

Proposed Schedule

GIS database development

Incorporation of data layers (soils, DEM, DOQ, land use/land cover)

Generation of derivative layers (slope, drainage, soil type, and hydrology)

Satellite data acquisition

Mapping of riparian zones

Presence, absence of riparian buffers

Buffer width, length, and vegetative type

Mapping of drainage channels

GIS suitability modeling of candidate parcels

Preliminary evaluation of model

Dissemination of Results

The results of this proposed research effort will be disseminated in the form of one or more refereed articles in scientific journals or conference proceedings. A Web page will also be created to provide a wider outlet for dissemination to the public sector. The graduate students involved in the research will give a seminar at the University of Vermont detailing their analyses and results. The GIS database developed as part of this project will be made available through the Vermont Center for Geographic Information (GIS archive for the state).

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Budget Justification

The federal funds requested for the PI represent one week of effort in the summer. Fringe benefits are at 34.1%. The non-federal contribution represents a 20% effort by the PI and 10% administrative support over the academic year. The proposed research request funds for support of a new graduate student in Water Resources. No fringe benefits are charged on research assistantships. Deborah Sargent, who is funded through another grant, was involved in a preliminary study that also supports this proposed project. She will complete her research, thereby contributing to this research without direct cost to this proposal.

Satellite Data: Seven hundred dollars is requested for the procurement of satellite imagery (IKONOS, 1m and 4m pan sharpened multispectral data). Equipment: $1250 is requested for the procurement of a stream flow meter to verify hydrologic modeling.

Computer Cost: $1000 to cover the cost of maintenance for the Spatial Analysis Lab/SNR.

Travel: Dissemination of the results of this project to the scientific community requires that faculty and students attend professional meetings/conferences where the student will present his/her results ($200/yr).

Indirect costs for UVM are 51%. This cost will be borne by the University as cost share.

Non-UVM match is provided by Friends of the Mad River. Volunteers for water sampling, lab analyses, and access for lab facilities and equipment will support research activities proposed here.