



# Targeting of Watershed Management Practices for Water Quality Protection



## EPA Region VII



- University of Nebraska–Lincoln
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# Introduction

Ensuring a clean and adequate water supply implies using water conservatively and protecting water resources from pollution. Sediment, nutrient, and pesticide losses in runoff are major pollutants of surface waters in the Midwest. This publication addresses targeting best management practices (BMPs) in watersheds or landscapes to maximize the impact of investments in water quality protection. It is intended as a resource for those who advise on or practice land and water management. The authors recognize the ecological and social diversity of watersheds and land managers, and that agricultural pollutants often come from small parts of watersheds as a result of landscape sensitivity coupled with management inappropriate for water quality protection. Targeting BMPs to important source or mitigation areas is likely to have the most cost-effective impact on water quality.

## Abbreviations used in this publication

BMPs – best management practices  
CLU – common land unit  
GIS – geographic information system  
GPS – geographic positioning system  
HRU – hydrologic response unit  
HUC – hydrologic unit code  
IDEP – Iowa Daily Erosion Project  
LIDAR – light detection and ranging  
NRCS – United States Department of Agriculture–Natural Resources Conservation Service  
PFC – Proper Functioning Condition  
RWA – Rapid Watershed Appraisal  
RUSLE – Revised Universal Soil Loss Equation  
SVAP – Stream Visual Assessment Protocol  
SWAT– Soil and Water Assessment Tool  
USDA-ARS – United States Department of Agriculture–Agricultural Research Service  
USEPA – United States Environmental Protection Agency  
USGS – United States Geological Survey  
USLE – Universal Soil Loss Equation  
WEPP – Water Erosion Prediction Project

A watershed is a unique land area generally bordered by hills and ridges that ultimately drains to a common basin or outlet such as a stream, river, lake, or wetland (Walter et al., 2007). Watersheds consist of multifunction landscapes and are composed of diverse but interconnected agricultural and nonagricultural land units, drainage basins, and streams. Varied hydrologic processes interact with soil type and land use at different spatial scales, resulting in areas within landscapes that can potentially generate, intercept, and treat pollutants. Most pollutants originate from relatively small parts of the watershed, thus the cost-effectiveness of BMPs differs across landscapes. Targeting practices is an approach to treat areas that are major pollutant

sources and effectively mitigate pollutant movement. A common goal of watershed management is to protect the environment while maximizing the aesthetic, social, and economic benefits of the watershed. Each watershed is different and its unique attributes must be characterized and diagnosed when planning, developing, and implementing a watershed management plan.

Watershed management is the implementation of a set of resource management practices with the goal of ensuring water quality while sustaining the ecosystems (Tomer, 2004). Watershed management is interdisciplinary and seeks to balance human needs with restoration of degraded lands or impaired water bodies, reduced pollutant loading or natural resource preservation, and/or enhanced resilience to human-induced and natural impacts. Water quality goals extend beyond agricultural production to encompass economic and social concerns as well as the beliefs and concerns of stakeholders, including farmers, other landowners, and community residents. Effective watershed management requires long-term planning and commitment on the part of these stakeholders.

### What is Targeting?

Walter et al. (2007) defined targeting as focusing preservation, conservation, and/or other practices on areas of the landscape at particular times where and when they will have the greatest benefit at the lowest cost. This assumes that targeted areas in the landscape are either especially sensitive to or strategically located for mitigation of the effects of human activities or natural events. Targeting identifies disproportionately large pollutant sources and targets BMPs to reduce pollutant delivery.

Targeting addresses the interaction of management, biophysical and socio-cultural systems, and objectives of the watershed plan while acknowledging that we are dealing with a changing situation. Accomplishing these objectives requires addressing different problem sources, regulatory requirements,

### Key Resource Materials

Several papers have been cited in this publication but the following five papers are especially valuable sources of information on targeting best management practices.

A Buffer Capability Index For Water Quality Planning. Dosskey, M.G., M.J. Helmers, D.E. Eisenhauer, T.G. Franti, and K.D. Hoagland. 2006. *J. Soil Water Conserv.* 61:344-354.

Vegetative Barriers for Erosion Control. Los, P., S.H. Anderson, and C.J. Gantzer. 2001. MU Guide G1653, University of Missouri Cooperative Extension, Columbia.

New Thinking About Farmer Decision Makers. McCown, R. 2005. p.11-44. *In* J.L. Hatfield (ed.) *The Farmer's Decision: Balancing Economic Successful Agriculture Production with Environmental Quality.* Soil and Water Conservation Society: Ankeny, IA.

Watershed Management. Tomer, M.D. 2004. P. 306-314. *In* D. Hillel. *Encyclopedia of Soils in the Environment (Vol. 4).* Elsevier Ltd. Oxford, UK.

The Science of Targeting Within Landscapes and Watersheds to Improve Conservation Effectiveness. Walter, T, M. Dosskey, M. Khanna, J. Miller, M. Tomer, and J. Weins. 2007. P. 63-89. *In* M. Schnepf and C. Cox.

and environmental objectives. An understanding of the nature and source of pollution, the hydrologic pathways of pollutant transport (e.g., upland erosion, sediment deposition, and channel bed erosion), the desired load reduction, the inventory of alternative practices, and measurable criteria for monitoring and assessing progress and impact are necessary. Targeting enables cost-effective and efficient use of local, state, and federal resources to improve water quality by promoting effective practices and/or focusing education, lobbying, or policy change efforts to the major pollutant sources.

A successful plan is dynamic and adapts to changes in the system that may occur from project activities, the emergence of new problems or opportunities, or changed perspectives and values (Figure 1). Stakeholders fine-tune their objectives, management plan, and activities based on improved understanding of ecosystem processes and impacts of interventions gained through experience, monitoring, and analysis of additional information (Walter et al., 2007; Watzin, 2007) (Figure 2). Monitoring and impact assessment might use modeling, research, and other evaluation methods to assess progress toward established goals.

Targeting ability has increased with improved understanding of watershed dynamics and advances in geographic information systems (GIS), remote sensing, other spatial data availability, and models for processing spatial and temporal data. However, effective targeting still requires quality information, good analytical tools, and motivated land managers to implement practices.

Engaged stakeholders and their needs, current conditions, acceptable timeframes for achieving impact, and the potential of alternative practices

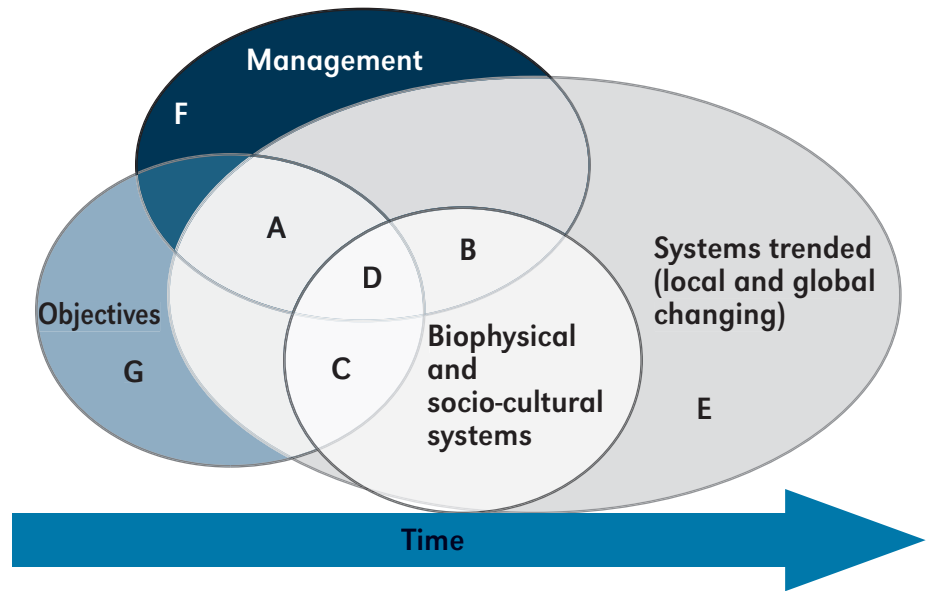


Figure 1. The interaction of objectives with management actions and the biophysical and socio-cultural systems under consideration. Targeting can aim to align objectives with management actions (A), management with the systems (B), or objectives with the biophysical and socio-cultural systems (C). Ideally, targeting should aim to align all three components simultaneously (D) with a clear understanding of where the system is going (E). Certain management options and objectives (F and G) are not in synchrony with the trends in the system (adapted from Walter et al., 2007).

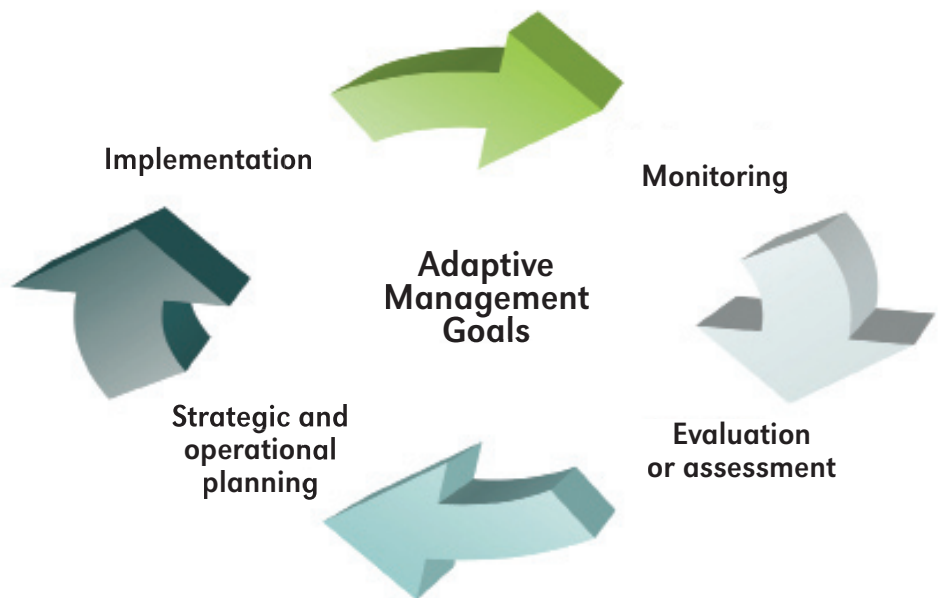


Figure 2. The adaptive management cycle of watershed management (adapted from Walter et al., 2007).

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Phosphorus loading of water bodies typically originates from small areas of the watershed that have relatively great runoff and erosion potential from a few rainfall events, while nitrogen loading of groundwater is spatially and temporally more diffuse.

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are essential considerations of successful targeting. A number of questions will arise as community-level stakeholders, agency professionals and scientists seek to target interventions: 1) What changes in watershed management will result in improved water quality? 2) What criteria are required for prioritizing the problems and potential solutions? 3) What are the stakeholder roles, including the sharing of costs, lost income, and inconveniences? 4) What incentive payments are available and will payments be given based on resource targeting or on entitlement? 5) How long will it take to achieve measurable and desired impact?

## Targeting Considerations

**The nature of pollutants.** Agricultural pollutants differ in the dynamics and interaction of source and transport (e.g., leaching, runoff, and erosion) with implications for choice of targeting method and conservation practice. For example, phosphorus loading of water bodies typically originates from small areas of the watershed that have relatively great runoff and erosion potential from a few rainfall events, while nitrogen loading of groundwater is spatially and temporally more diffuse. Targeting is most feasible for pollutants with more concentrated sources, while those with more diffuse sources are likely to require specific management over much of the watershed to be effective. This suggests that not one model but a variety of models and tools will be used by watershed residents, depending on the types of priority pollutants.

**Field-level versus landscape.** Scale is important in watershed planning and targeting. Pollutant delivery depends on inter-related processes occurring over interconnected fields and landscapes. Decreased sediment loss from a field may not result in reduced sediment loading downstream. Management effects on processes along the whole flow path need to be considered, including upland erosion, sediment deposition, and channel bed erosion. GIS tools can aid in such landscape analysis.

**Individual farmers versus communities.** Watersheds typically span multiple farms, small lot landowners, and large or small urban areas. Thus stakeholders in the environmental quality of a watershed are diverse with varied beliefs, attitudes, and values about protecting local waters and how it can be done most effectively. Problem identification, prioritization, planning, and selection and targeting of alternative practices should involve such diverse stakeholders in order to develop a watershed management plan that meets the needs of farmers and communities. When stakeholders participate in targeted management they are more likely to support and implement appropriate changes.

Incentive and/or cost-share payments may be made to individual farmers implementing an alternative practice as a means to more effective targeting, but should be allocated according to a stakeholder-approved watershed plan. Cost-effective environmental protection requires maximization of the interaction of incentive and/or cost-share payments with efficient targeting; that is, target the problematic landscape positions rather than the people. However, stakeholders engaged in allocating incentive payments may face pressure by stakeholders desiring different benefits such as recreation, landscape aesthetics, environmental protection, conservation, industrial development, and tourism, as well as production agriculture. Negotiated agreements for subsidized and voluntary actions addressing a range of needs will be valuable in assuring support by many stakeholders rather than a few.

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Target the problematic landscape positions rather than the people.

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**Local versus distant water bodies.** Land managers and community members are more likely to act to protect or rehabilitate local waters than distant downstream water bodies. Protection of the local waters may or may not benefit downstream waters and implementation of upstream BMPs that are not locally beneficial may require more incentive payment.

**Unintended consequences.** A practice that is appropriate in one part of the watershed or agricultural cycle may be inappropriate in another. Similarly, a practice that is effective in containing one potential pollutant may result in increased loading of another pollutant. No-till production of grain sorghum, for example, may reduce sediment and P loading of downstream waters but may increase atrazine loading because of a high probability of runoff events at the time when atrazine is commonly applied without incorporation.

**Absentee landowners.** Absentee landowners are often not community members but are essential partners, as conservation practices often require more years than the typical lease agreement to be effective and compensate for the investment. Stakeholders may need to motivate absentee and other non-operator landowners to participate in planning and implementing management actions.

**Urban situations.** Urbanization often results in pollution because of littering, landscape disturbances during construction, increased impervious surface area, and other activities that impair water quality. This often results in use of costly technology, such as storm water control and water treatment plants, to recover lost services. Obstacles to urban watershed management may include conflicting management objectives, political fragmentation, diverse public and private interests, unfunded federal mandates, bureaucracy, and changes in personnel ([www.umass.edu/ecologicalcities/watershed/index.htm#issues](http://www.umass.edu/ecologicalcities/watershed/index.htm#issues); verified 20 March 2008).

Residents need to realize that they live in a watershed but must also understand *how* to minimize their impact on it. Education may be needed to address: 1) basic watershed awareness using signs, storm drain stenciling, stream walks, and maps; 2) the role residents play in the watershed and communicating specific messages about positive and negative behaviors; 3) educating the development community, including the professionals, on how to apply the tools of watershed protection; and 4) providing opportunities for the public to actively engage in watershed protection and restoration.

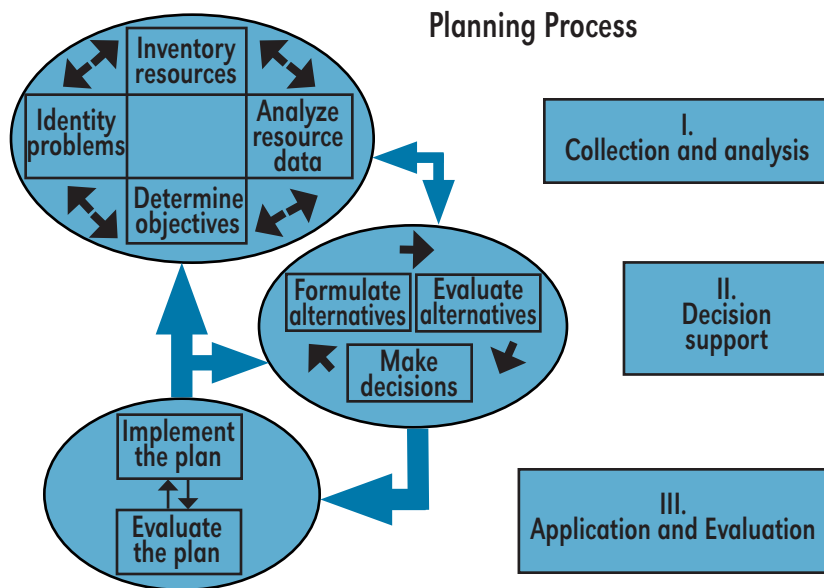
## Developing a Watershed Management Plan

A watershed management plan can be a voluntary, comprehensive plan for a watershed that considers the natural resource base as well as social and economic considerations. Watershed management planning, implementation, and/or assessment may be done by a formal or informal group of stakeholders, such as agricultural land owners or managers, urban landowners, homeowner associations, state and/or federal agencies, conservation clubs, schools, or other individuals or organizations. Local motivation and facilitation of the group is important. Stakeholder understanding of the bio-physical and socio-cultural components of the watershed, and their interactions, is also important to crafting an effective management plan that matches the unique characteristics of the watershed.

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A practice that is effective in containing one potential pollutant may result in increased loading of another pollutant.

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**Figure 3.** Watershed management planning may be viewed as a dynamic three-part, nine-step process (USDA-NRCS, 2003).

One approach to planning watershed management is a three-phase, nine-step planning process (Figure 3). The process begins with data collection and analysis to assess the natural resource conditions, needs and opportunities. Alternative solutions are formulated and evaluated, and a plan is developed. Solutions are implemented and successes are measured by collecting quality natural resource data. Decision makers, who can influence change within the watershed, need to assess the current activities and attitudes of the watershed community and develop a promising plan for implementation. Changes in water quality may not be immediately apparent and the decision makers need to motivate the watershed community to continue with implementation until the desired outcome is achieved.

Tomer (2004) presents the watershed management planning process in four phases: 1) problem identification; 2) watershed assessment; 3) identification and selection of management alternatives; and 4) implementation and evaluation. For each phase, key questions are raised, sources of information and analysis tools are suggested, and stakeholder roles are identified. Regardless of which approach is used for watershed management planning, local producers and landowners need to participate in the decision making process and buy-in to the watershed management plan; otherwise, the plan is destined to fail.

## Targeting Tools

Computerized mapping technology enables us to efficiently identify vulnerable locations and map them for conservation targeting. Identifying target locations can involve a variety of mapped data sources, including soil survey, topographic data, aerial photographs, and remote sensing data (often classified according to vegetation or land-cover type). With the wide availability of such data, overlaying of map layers to identify locations meeting targeting criteria can be a straightforward process once the criteria are known and accepted. For example, steep erodible soils that are near water bodies can be easily identified with GIS software and publicly available data; these areas are then targeted for erosion control practices. Refinements could be based on slope gradient, proximity to water, or erosion risks associated with specific practices on the targeted lands. As targeting criteria become more refined, however, stakeholder acceptance of these criteria may become more difficult. It is important to bear this in mind as targeting technologies evolve from simple map overlays to output from sophisticated models.

**Rapid Watershed Assessment (RWA).** The RWAs of the Natural Resources Conservation Service (NRCS) are summaries of resource concerns and opportunities ([www.nrcs.usda.gov/programs/rwa/index.html](http://www.nrcs.usda.gov/programs/rwa/index.html); verified 20 March 2008). They provide initial estimates of which conservation investments will best address resource concerns. The RWAs typically are done on an average of



1 million acre basis (8-digit hydrologic unit) and rely heavily on existing information incorporated through GIS. These data are combined with meetings with landowners and other stakeholders to assess current levels of resource management in the identified areas and to make recommendations for the local or watershed area.

The RWA is limited in detail because of the large land areas, with results tending to be qualitative rather than quantitative (Figure 4). The assessment is used to target areas from which more detailed information is collected for area-wide planning or development of community-based conservation plans.

**Sediment delivery.** The delivery of sediment from a source area to surface water is influenced by conservation practices, the distance to the water body, sediment delivery efficiency, and other factors. Targeting requires identification of major sources of sediment delivery to downstream water bodies and assessment of the cost-effectiveness of alternative practices for reducing sediment delivery. Various sediment delivery calculators have been developed to estimate sediment delivery to downstream water bodies and can be important tools in prioritizing areas for investing resources. These calculators account for soil erosion using models such as the Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE), and factor in the potential of sediment delivery to the downstream water body by considering implemented or proposed BMPs. These tools can be used in targeting BMP implementation.

The USDA-ARS Water Erosion Prediction Project model (WEPP; Flanagan and Nearing, 1995) is an alternative mechanistic, process-based erosion model for estimating event-based sediment loss and deposition on two-dimensional complex terrain under multiple vegetation scenarios. Runoff, erosion, soil moisture, evapotranspiration, biomass yield, and other factors are estimated on a daily basis. The Iowa Daily Erosion Project (IDEP; Cruse et al., 2006) brings NEXRAD radar-sensed rainfall, Iowa Mesonet weather data, and the Natural Resource Inventory (soils, topography, crop rotations, and tillage practices) together with WEPP to estimate erosion, runoff, and soil moisture status at the township level on a daily basis across Iowa. A methodology has been developed to estimate crop rotations and residue cover at the field level in order to reconstruct the rotation and tillage data needed to run the WEPP model (Gelder et al., 2007); this update will enable IDEP to estimate erosion at the field level using one year old crop data rather than 10 to 15 year-old crop rotations at the township level. Resource conservationists will be able to use the WEPP user interface to target the most erosive fields within a watershed or a state for conservation practices and to evaluate the effectiveness of targeted practices.

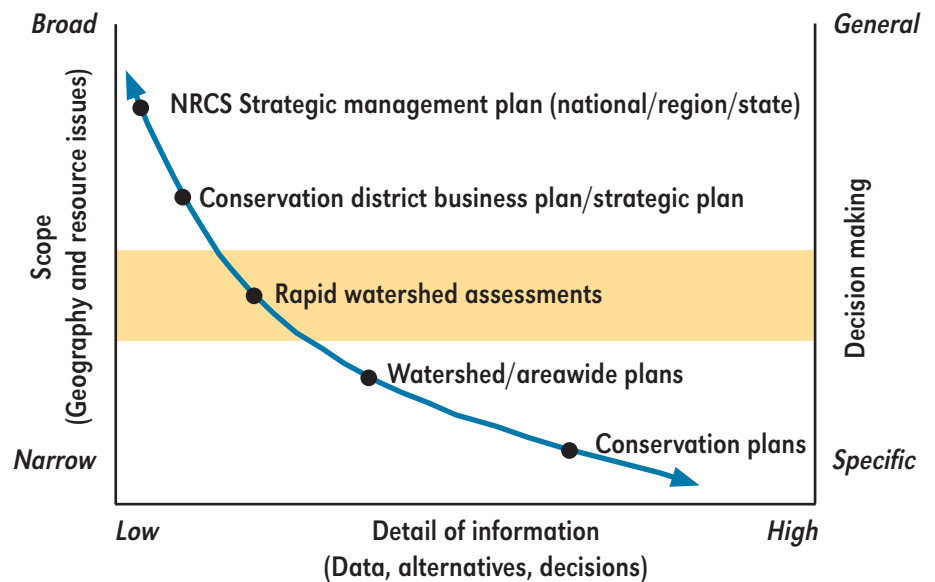


Figure 4. Rapid watershed assessment detail in relation to other types of plans (USDA-NRCS, 2007).

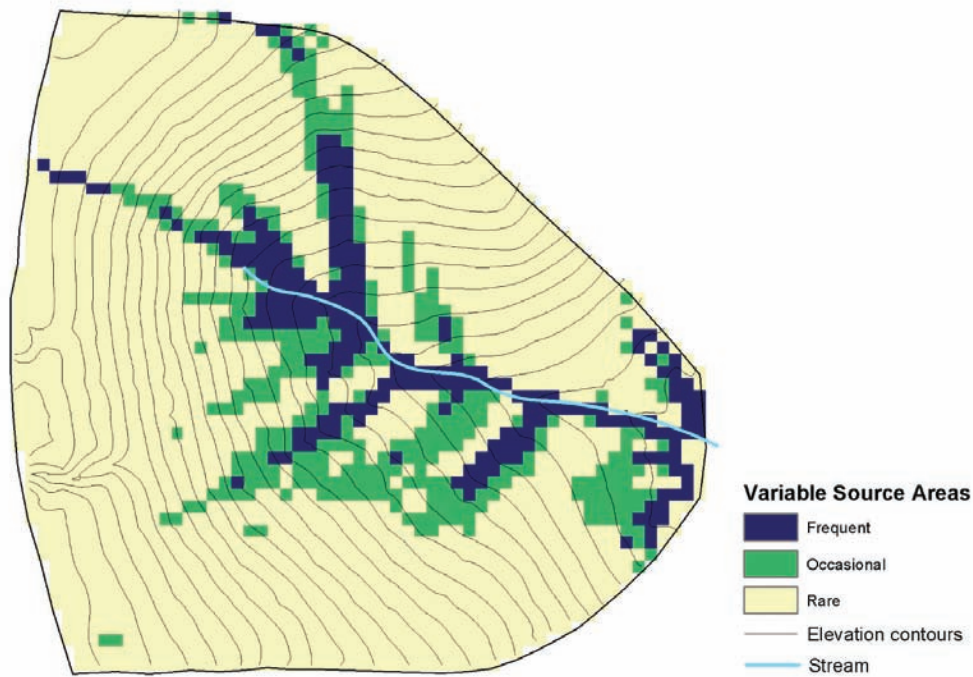


Figure 5. Example map of digital terrain modeling output highlighting variable source areas for runoff generation, where conservation measures would most be needed (Tomer, 2004).

### Simulation modeling.

Computer modeling of spatial processes at landscape and watershed scales to identify priority conservation targets has been used in a variety of settings. One of the models commonly employed is the Soil and Water Assessment Tool (SWAT; Arnold and Fohrer, 2005). This model provides comprehensive simulation of hydrologic and nutrient cycling processes for “hydrologic response units” (HRUs), which are major combinations of land management and soil type within watershed sub-basins. SWAT simulates hydrologic routing and stream processes to move losses from the sub-basins to the watershed outlet, the sub-basin losses being weighted averages of the HRU simulation

results. The model is not spatially explicit but can be used to identify, and then target, HRUs that may be critical to watershed water quality. The model is flexible and its utility for targeting will improve with ongoing research and model development expanding into new areas including watershed simulation of tile drainage (Green et al., 2006) and riparian buffer effects (Liu et al., 2007).

Hydrologic characterization through digital terrain modeling also provides spatially specific maps. Topographic data are used to calculate runoff flow directions across the landscape and the flow routing from uplands toward streams (Moore et al., 1991). Model output can then be used to locate areas on the landscape that are sources of runoff and/or sediment (Figure 5). Runoff-generating areas usually occupy a small fraction of a watershed area. These areas are sometimes called variable source areas, because they vary in size depending on rainfall amounts and intensities as well as antecedent moisture conditions. Low-lying areas prone to saturation and areas where overland (sheet) flow accumulate, and possibly form gullies, are the types of features that are typically mapped based on terrain modeling software. These areas must be addressed in conservation systems to reduce sediment movement and filter runoff (Gburek et al., 2002).

**Soil Survey.** Soil survey reports contain important information such as soil type, slope, and hydrologic characteristics which are important in targeting BMPs. Dosskey et al. (2006) developed an approach for using soil surveys to guide the placement of buffers considering the potential performance of buffers for sediment and water trapping (Figure 6). This screening tool can guide planners to areas where buffers may have the greatest benefit. In addition, the screening tool can be useful in evaluating the design of a buffer in a particular location because areas with lower sediment and water trapping may need a wider buffer to achieve a certain reduction in sediment or water loss.

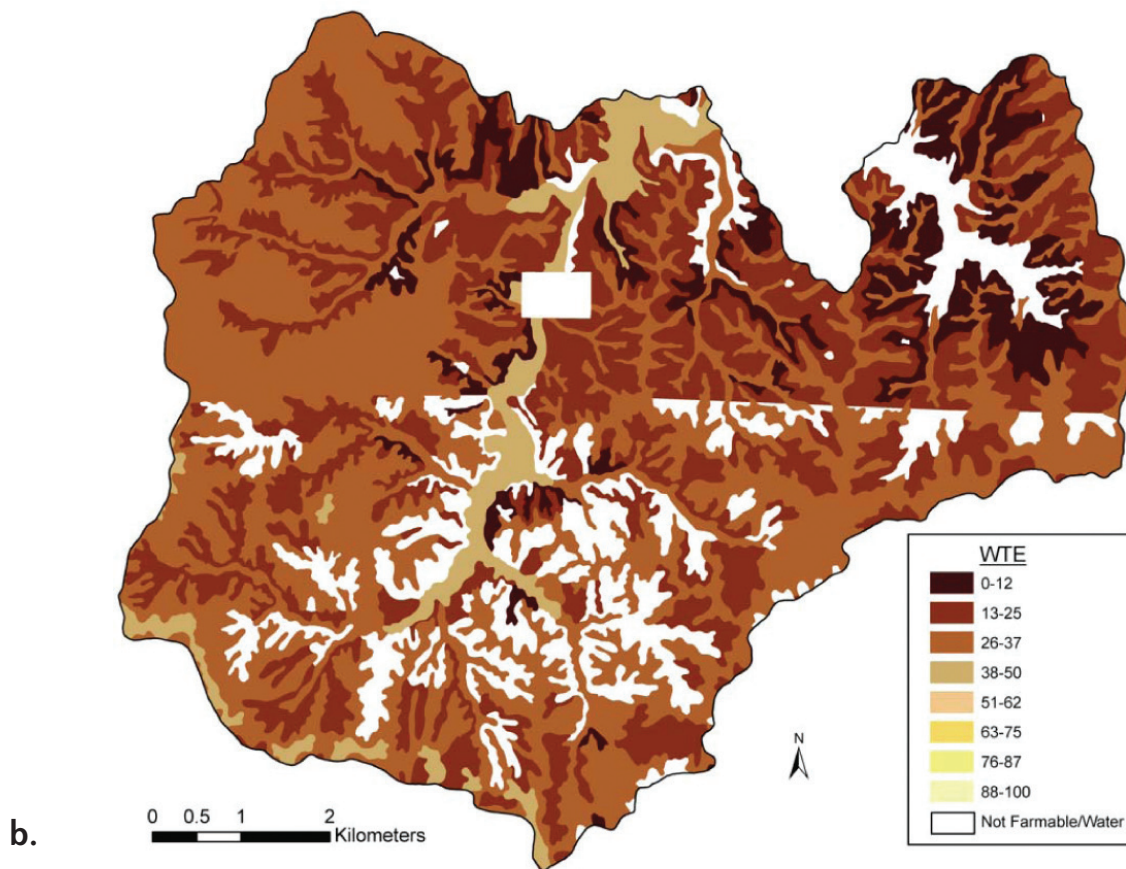
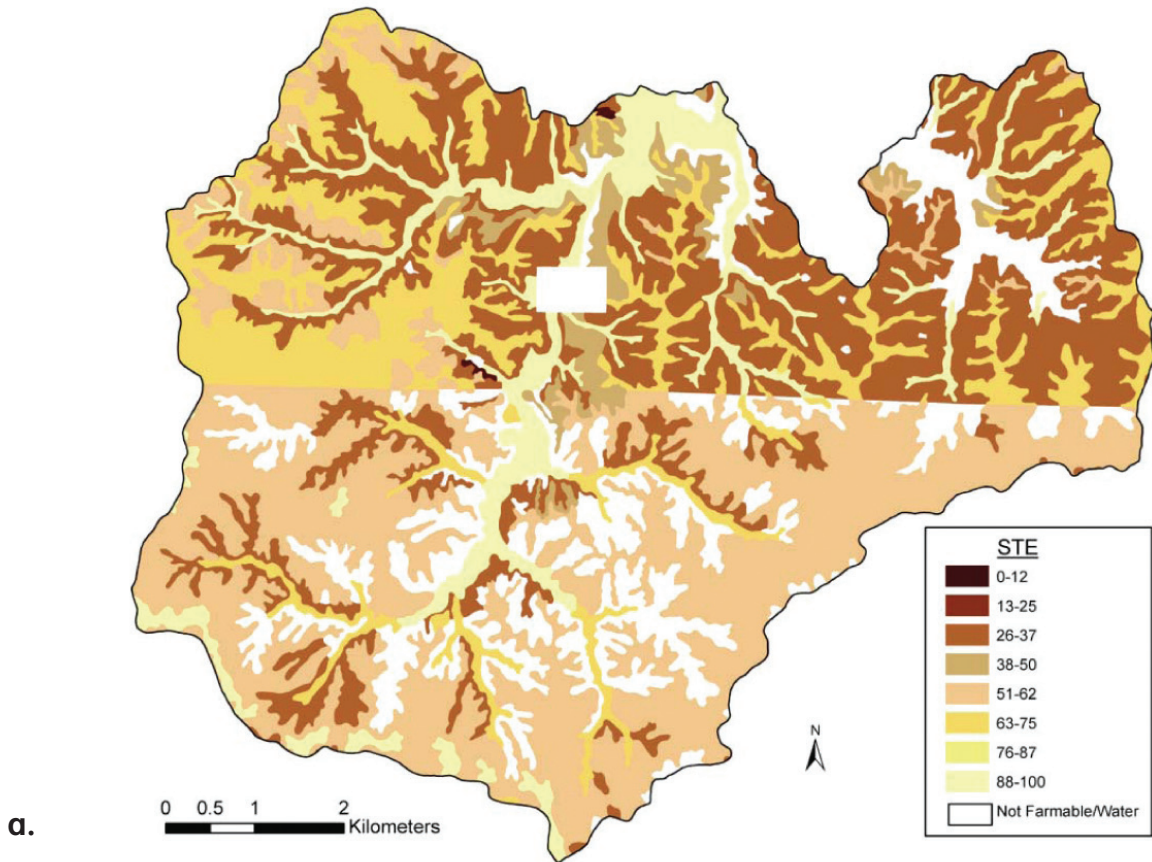


Figure 6. (a) Sediment trapping efficiency (STE; in percent) and (b) water trapping efficiency (WTE) for soil map units in the Cameron-Grindstone watershed in northwestern Missouri (the apparent discontinuity in the middle of the watershed is located along a county line) (adapted from Dosskey et al., 2006).



**Figure 7. Linking aerial video with global positioning receiver data provides the ability to map and target priority areas for riparian restoration efforts.**

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The Common Land Unit (CLU) is a digital map and data base of agricultural field boundaries that is maintained by the USDA Farm Service Agency.

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and transferred to computer mapping applications. These efforts to assess the distribution of vegetation, grazing practices, bank stability, and fluvial processes provide an understanding of stream mechanics and how hydraulic forces are influencing stream channel morphology and development (Figure 7). All these types of information may need to be considered in assessing a riparian corridor and determining where to target conservation efforts.

**LIDAR topographic surveys.** LIDAR stands for “Light Detection And Ranging.” The survey data are obtained through an airborne system that uses laser pulse return signals to map the land-surface elevation in great detail, providing a finished map product with grid cell sizes of 1 m (3 ft) or less. At this writing, LIDAR map data are available for limited areas. However, statewide LIDAR coverage is being acquired for Iowa and availability is expected to increase. This scale of topographic information provides opportunities and technical challenges to conservation planning. One of the challenges is the level of detail involved, and how to scale from field- to watershed-scale planning tools. Capability to process LIDAR maps to provide conservation targeting information will be developed through research and experience.

**Land use inventories and farm records.** Land use inventories are useful in identifying areas within a watershed that are significant pollutant sources. The inventories may include soil, slope, land use, and land treatment information. Land treatment information, however, has typically been gathered field by field; however, this process can be prohibitively time consuming and expensive for larger watersheds.

The Common Land Unit (CLU) is a digital map and database of agricultural field boundaries that is maintained by the USDA Farm Service Agency. A public version of the CLU layer is available at [datagateway.nrcs.usda.gov/](http://datagateway.nrcs.usda.gov/); verified 20 March 2008. The CLU database can be used as a tool to assess

**Field assessments.** Mobile computer equipment and GPS receivers are valuable for field-based assessment and targeting of watershed conservation efforts. Data from such equipment can be used to assess conservation practices in fields or along riparian corridors. Geo-referenced aerial photographs can provide a template to confirm map position, and then digitize and annotate conservation practices or other features that are of interest. Customized GIS software can be written for specific field applications that can greatly simplify the effort involved in field surveys and collation of results. Riparian assessments can be made based on visual observations. Aerial imagery provides rapid documentation of riparian corridor conditions within a watershed (Figure 7), which can be classified

land use across larger areas. Land treatment, conservation practices, cropping systems, and other variables can be added to the digitized CLU as attributes. The CLU layer can be overlain with other layers such as soils to indicate areas susceptible to soil erosion. The potential exists to update CLU information with real-time estimation of crop rotations and residue cover at the field level (Gelder et al., 2007).

## Integrating Local and Outside Knowledge in Targeting

Targeting must go beyond the environmental issues and encompass stakeholder beliefs, goals, experiences, skills, and social relationships. The experiences of farmers and other local stakeholders are linked to science and technology in setting priorities and targets and in selection and implementation of interventions. Farmers' knowledge of their fields and watershed provides a source of information for planning. Farmers know from observation over time and experience where their wet spots are located, which streams flood easily, where erosion, as well as sedimentation, is greatest, and where and when conservation practices may be most effective.

Agency and Extension personnel bring outside tools, information, and expertise to integrate with local knowledge. The challenge and opportunity is to integrate farmer knowledge with outside knowledge and tools, such as GIS, to enhance stakeholder understanding of the watershed and better manage lands for profitability and environmental sustainability. Decision support models that target solutions to water pollution must be relevant to the needs, habits, and experiences of the decision makers. Models should complement the knowledge and judgments of local stakeholders and facilitate appropriate interventions (McCown, 2005). Watershed management can be most effective by integrating local knowledge with outside knowledge, decision support tools, and land use techniques.

**Local knowledge and setting priorities.** People set priorities based on their understanding of their situation and are influenced by past experiences. When new real or perceived challenges or opportunities occur, new knowledge may be needed to enable adoption of practices and tools to adjust to the new situation. The listing of a water body as impaired, a fine for non-compliance with a regulation, and citations for excessive pollutant loss to water bodies can alert watershed stakeholders to a problem. Acknowledgment of the problem(s) requires action that in turn requires stakeholders to become more knowledgeable, generally building on personal beliefs and experiences, and integrating these with outside information. Knowledge of the problem may be increased through discussions with others experiencing similar situations. These conversations dissuade weak beliefs and unsupported information, and generate more robust and dependable ideas and beliefs (McCown, 2005). Through such discussions, stakeholders can identify common areas of concern and share information to expand their knowledge base and focus their efforts.

**Strategic targeting by stakeholders.** Stakeholder involvement in strategic targeting integrates local landscape and social information in developing and implementing watershed management plans and local watershed policies. Such involvement can foster ongoing learning while reducing potential for conflicts and decision gridlocks (Table 1). The process enables farmers and other watershed residents to learn and apply their knowledge and perspectives in the decision-making process as well as in implementation, evaluation of

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*Table 1. Effective strategic targeting*

1. Integrate rules and regulations to support unified policies.
2. Create flexible policies that include social, economic, and biophysical conditions.
3. Use planning and management processes to stimulate learning.
4. Link monitoring activities to intervention strategies on a systematic basis.
5. Recognize that policies and interventions are often experimental and can be improved with on-going evaluation and revision.
6. Build local knowledge while providing public information.

*Adapted from C. S. Holling, 1995*

impact, and plan revision. This requires a partnership and trust relationship among farmers and with water and land use professionals to develop planning, management, and monitoring strategies that address economic, social, and biophysical concerns.

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Targeting implies that incentive payments will largely be performance-based, with allocation to only some stakeholders and problems.

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The decision to accept alternative practices necessitates that the local stakeholder will compare current management with alternative practices. Outside knowledge may be important to such judgments, but firsthand observations and conversations with local people have been found to be major reasons given for change-of-mind decisions on environmental issues (Morton and Brown, 2007). Making watershed-level decisions requires looking beyond individual fields and farms to the overall watershed. This means that knowledge of field and farm-level experiences needs to be integrated with watershed characterization and BMP evaluation using GIS or other tools. Management practices are selected based on technical information as well as the beliefs, attitudes, and knowledge of the community.

Extension and natural resource professionals may facilitate local learning by improving stakeholder access to new information, providing decision support tools, and facilitating stakeholder discussions about water problems and potential solutions. They can facilitate enhanced interest in issues and potential solutions and encourage willingness to challenge existing practices and evaluate potential solutions. Stakeholders are more likely to learn and apply scientific and technical information when they understand the benefits.

**Incentive payments.** Incentive payments will probably continue to be important in targeting BMPs in watersheds. Incentive payments can be practice-based or performance-based. Targeting implies that incentive payments will largely be performance-based, with allocation to only some stakeholders and problems. Efficient targeting of the most sensitive areas with performance-based payments requires estimation of the minimum payment acceptable to farmers for a specific BMP and ensuring that the right producers are in the applicant pool (Claassen, 2007).

Incentive payments are potential sources of conflict and decision gridlock leading to distrust, frustration, and declining cooperation. Targeting may solve one problem but upset the balance of other local social and ecological systems (Holling, 1995). Such conflicts can be minimized by involving local stakeholders in the discussions of watershed goals, environmental problems, and targeting of solutions at field, farm, watershed, and basin levels with stakeholders sharing their situations, perspectives, experiences, and knowledge. Opportunities are created to apply local knowledge and perspectives in identifying solutions and allocating resources to priority problems while addressing the complexities of aligning stakeholders' objectives and expectations.

## Barriers to Targeting

The targeting of conservation practices may be affected by technical and institutional barriers and challenges.

**Technical barriers.** The effectiveness of targeting may be limited by inadequate data quality. For example, the USGS National Elevation Database is usually available at a 30-m (100 ft) grid size and lacks the detail needed for

terrain modeling in flat or gently rolling terrain (Tomer and James, 2004). Most of the agricultural production across the Heartland region is on such terrain. Thus, superior analytical methods for targeting are limited by input data quality. LIDAR provides a quantum leap in elevation data quality, but may provide too much detail for effective watershed modeling. These scaling issues are critical and require more research. Staying current with developments in watershed modeling and other technologies challenge researchers and other stakeholders who want to understand GIS targeting information.

**Institutional barriers.** Voluntary, first-come, first-served approaches have been part of the operating procedures in conservation planning agencies. Effective targeting may mean that landowners who are among the least interested in implementing new BMPs become the focus of conservation efforts. Implementing targeted conservation strategies may require that incentive payments be distributed differently than at present.

The technical and institutional barriers to targeting are related. A technical watershed characterization used to target conservation must be presented in formats that conservation planners and landowners can intuitively understand and apply to conservation planning. Conservation policies to support targeted implementation may depart from traditional approaches and political-legal processes may require that targeting technologies and criteria be defensible in court (Walter et al., 2007). Despite these challenges, however, the potential advantages of targeted conservation for natural resource management to society are clear (Khanna et al., 2003). These advantages warrant efforts to obtain the funding and implementation vehicles to practice conservation targeting on a watershed-specific basis.

## Targeting for Specific Situations

**Wetland nitrate reduction in tile-drained landscapes.** Since the 1980s, state and federal programs have been used to promote wetland restoration in the U.S. corn belt. However, most of these restorations have been primarily concerned with waterfowl habitat. Site selection has not focused on water quality functions such as nitrate removal. For maximum water quality benefits of wetlands, wetland restoration needs to be well targeted. In tile-drained landscapes, much nitrate is exported with the drainage water. Wetlands for nitrate reduction should be sited to intercept as much of this nitrate as feasible. Through modeling, Crumpton (2001) found that for Walnut Creek in central Iowa nitrate export from the watershed was reduced by less than 4 percent with conventional siting approaches, but by 35 percent with better placement of wetlands.

**Drainage water management for nitrate reduction in tile-drained landscapes.** Subsurface drainage water management can reduce nitrate delivery to water bodies through reduced drainage flow that results in reduced nitrate export. Drainage water management can include placing the tiles at a shallower depth, a practice that is widely applicable, and controlling drainage by water table management.

Controlled drainage is most suited to fields that need drainage and have less than 0.5 percent slope so that the number of control structures can be minimized. However, only about 3.5 percent of approximately 120,000 acres in a tile-drained area in north-central Iowa have slopes less than 0.5 percent and

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Effective targeting may mean that landowners who are among the least interested in implementing new BMPs become the focus of conservation efforts.

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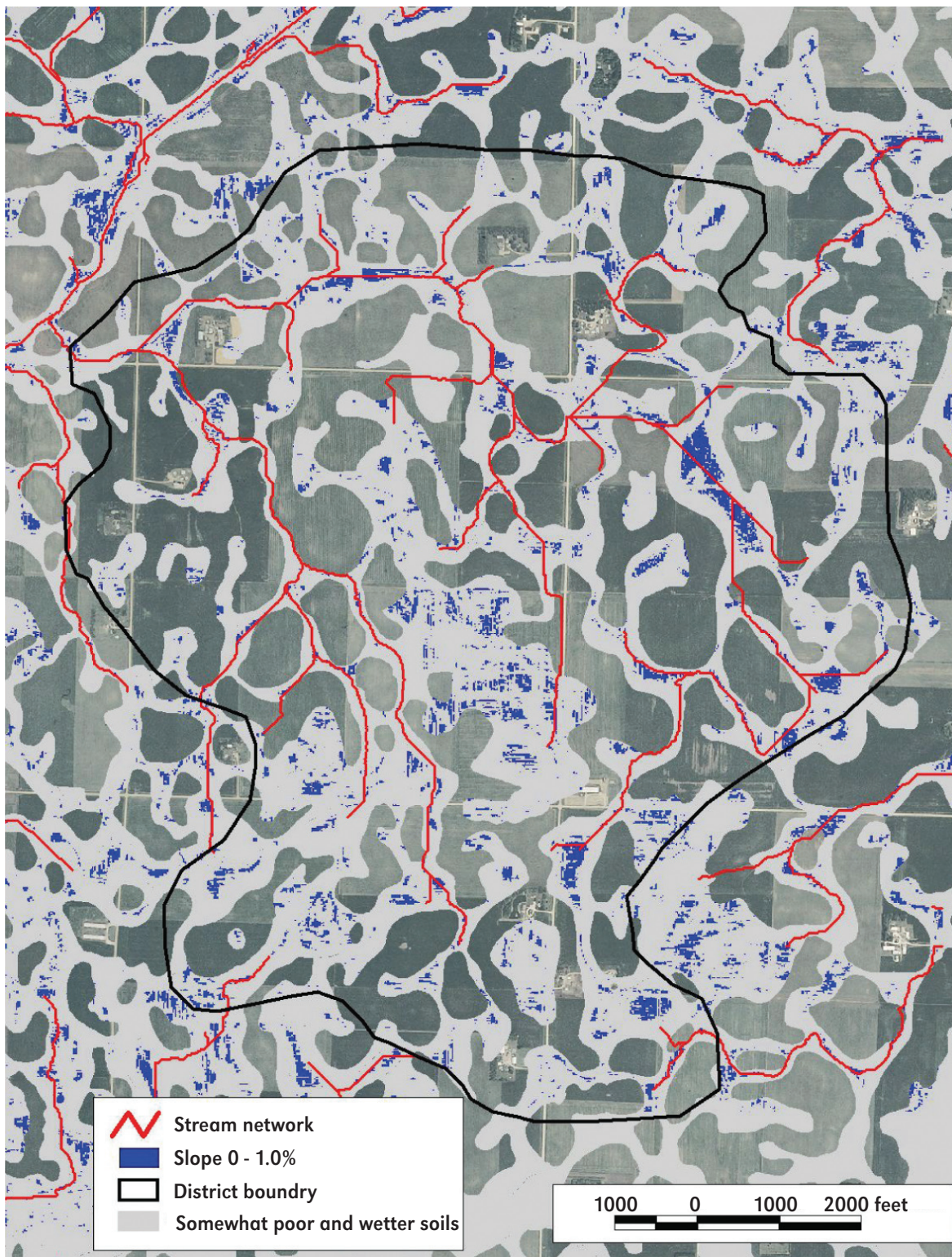


Figure 8. Map of a portion of a drainage area in north-central Iowa showing the 0-1 percent slope areas combined with the somewhat poor and wetter soils (Source: Helmers, M., Iowa State University).

soils presumed to need tile drainage. Even when using controlled drainage on slopes less than 1 percent, its applicability is limited (Figure 8). Therefore, controlled drainage can be effective in reducing nitrate export but its feasibility of broad application is limited because of topographic conditions. Finally, the cost-effectiveness of the practice is improved where control structures can serve relatively large areas. Overall, the practice should be targeted to where the practice can be most cost-effective and have the greatest impact of water quality.

#### Placement of vegetative buffers on hillsides.

Hillside vegetative buffers, spaced to accommodate specific widths of equipment for field operations, can reduce sediment, nutrient, and

pesticide losses from watersheds (Los et al., 2001). One type of vegetative buffer for hillsides consists of hedges of narrow strips of stiff-stemmed, erect grass (e.g. switchgrass and eastern gamagrass) of about 1 m width (Figure 9). The hedges, along with water-borne crop residues that lodge in the upslope edge of the grass, slow runoff velocity and cause ponding upslope from the hedges to enhance the deposition of transported sediments. The hedges capitalize on,





rather than minimize, the formation of berms with sediment deposited upslope and within hedges. Benefits of grass hedge systems include delayed and reduced surface runoff, trapped sediments, and facilitated benching of sloping cropland from soil movement by tillage operations. Stiff-stemmed grass hedges can substitute for steep-back or broad-based terraces. Vegetative barriers have been used on slopes of up to 15 percent gradient. Steeper slopes should probably have terraces.

Care must be taken during hedge establishment to prevent concentrated flow from eroding buffers. Once established, maintenance within concentrated flow areas and periodic monitoring for potential failure are required. Stiff-stemmed grass hedge systems can help stabilize waterways during establishment of cool-season grasses by redistributing the flow and preventing advancement of head-cuts up the slope. Grass hedge systems provide wildlife habitat and increase the biodiversity of the ecosystem.



*Figure 9. The photos show parallel switchgrass hedges in a field of soybeans in southwest Iowa. Grass hedges are placed on the contour to form barriers for reducing sediment, nutrient, and pesticide losses. These grass hedges were installed in a field where steep-back terraces are traditionally used.*

**Choice and placement of riparian buffers.** Riparian buffers are streamside plantings of trees, shrubs, and grasses that can intercept contaminants from both surface and ground water before they reach a stream and help restore impaired streams. Riparian buffers are typically planted along the edge of a crop field, adjacent to a stream. Buffers can intercept sediment and sediment-bound nutrients from runoff, but are less effective in removing dissolved nutrients and pesticides. Riparian buffers can also remove nutrients from shallow groundwater.

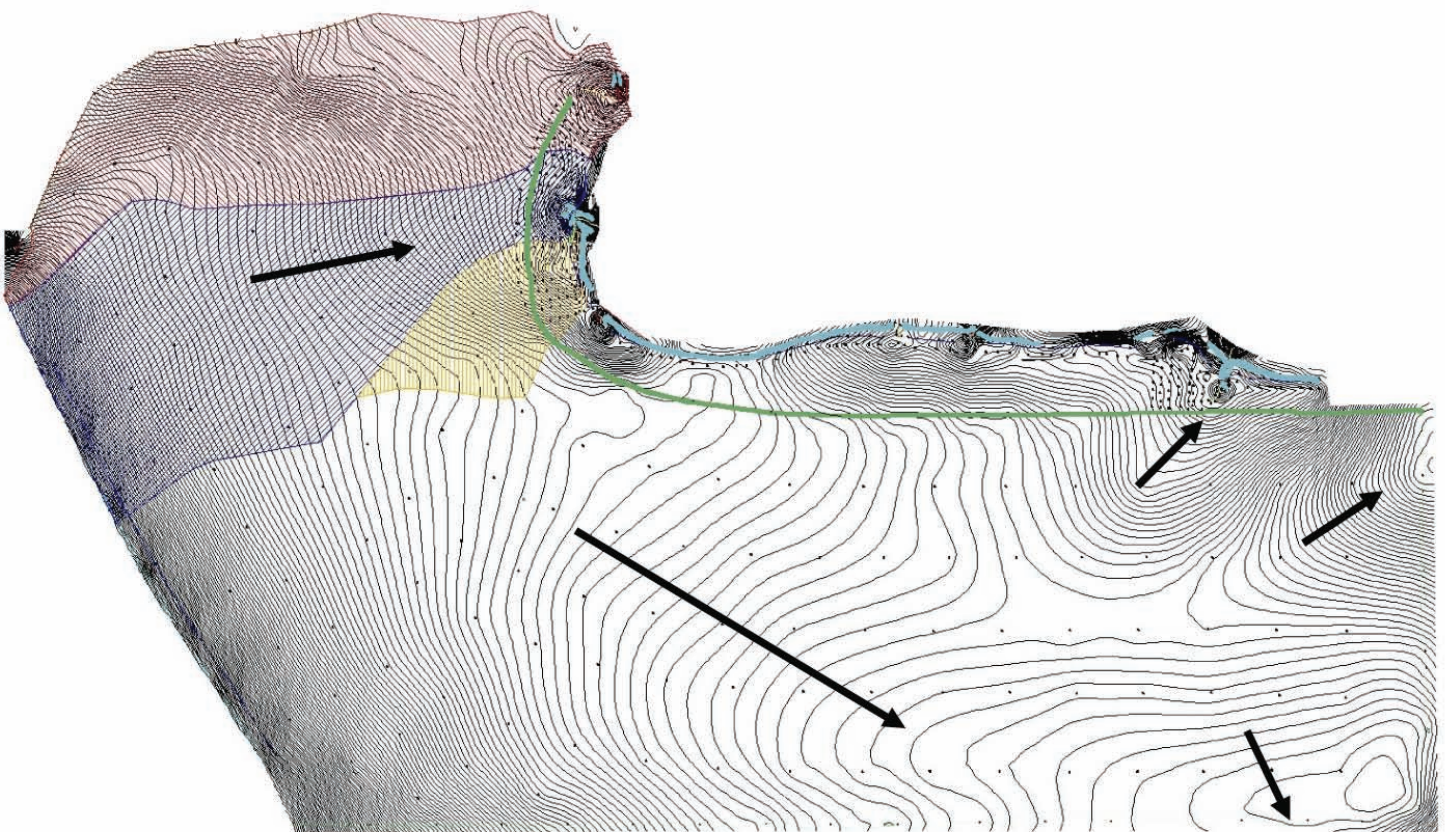
Riparian buffers can protect water quality through functions beyond sediment trapping and nutrient uptake. Infiltration rates are much greater within the buffer than the adjacent crop field, reducing runoff volume. Nitrate-N is taken up, transformed into biomass, and returned to the stream's aquatic life as organic nitrogen via leaf and litter fall.

A limitation, however, of USDA-sponsored riparian buffers is that they must be adjacent to a perennial stream, while many crop fields drain off to ephemeral streams or even roadside ditches that may convey the unfiltered runoff to streams. *Figure 10* shows a topographical map of a field in north-central Kansas, with a buffer established along the stream, but much of the field actually drains to a road ditch on the opposite side.

Buffers are most effective when shallow, slow moving sheet flow conveys runoff across the buffer. Small topographical differences, however, can cause most of a field's runoff to flow through the buffer at a few concentrated areas, thus leading to deeper, faster runoff velocity. This reduces runoff contact with the buffer surface area (organic mulch layer, plant roots, etc) and reduces trapping efficiencies because of increased flow velocities and reduced contact time with the buffer.

Effective buffer designs account for individual field topography, possibly with width varying according to the expected runoff volume that will pass through sections of the buffer. Typically riparian buffers are 75-150 feet wide, but much narrower buffers may be adequate for small, gently sloping fields. In other situations, much wider buffers may be needed.

Tomer et al. (2003) developed a protocol for selecting buffer placement for maximum effectiveness at the watershed level by analyzing topography. This protocol prioritizes buffer placement on nearly level sites below long slopes to maximum effectiveness so that the buffers receive large volumes of runoff,



**Figure 10.** Buffers must fit the field topography. A buffer was established along a stream on the north edge of the field, as shown by the curved green line. However, much of the field drains into roadside ditches on the south and east sides.

but the water moves through slowly because of the small slope gradient. Wider buffers are installed where more runoff is intercepted.

The stream condition should also be considered when designing riparian buffers. If a stream is actively cutting deeper or wider, with vertical banks, a planted buffer may erode into the stream. Such erosion can be reduced by setting the buffer back from the stream to allow for lateral movement of flowing water, or by stabilizing the streambank (such as with rock or cedar revetments).

**Table 2. Effectiveness of three types of riparian buffer vegetation for various purposes.**

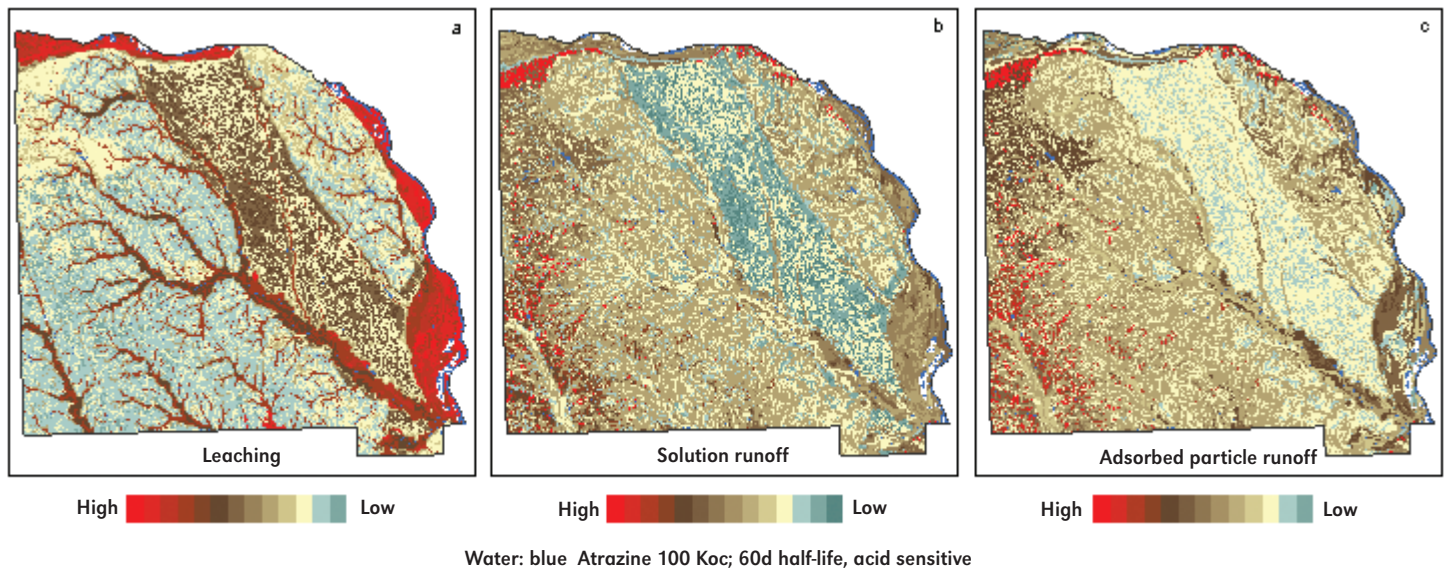
Benefit	Vegetative type		
	Grass	Shrubs	Trees
Streambank stability	low	high	high
Filter sediment	high	low	low
Nutrient retention	medium	medium	high
Pesticide buffering	medium	med/high	med/high
Flood damage protection	low	medium	high

**Adapted from Dosskey et al., 1997.**

Two qualitative methods for evaluating stream condition are the Stream Visual Assessment Protocol (SVAP) developed by NRCS and Proper Functioning Condition (PFC) developed by the USDA Forest Service and Bureau of Land Management. The SVAP uses 10-point scales to rate various parameters, resulting in a mean overall score interpreted as: 7.5-8.9 good; 6.1-7.4 fair; and ≤6.0 poor. The PFC assessment uses a 17-point checklist that relies on the collective professional judgment of the team to assign a rating: functioning properly; functioning at risk — upward trend; functioning at risk — downward trend; or non-functioning.

The stream assessment may identify the primary impairment to the stream such as sedimentation, excessive nutrients, or high levels of fecal coliform bacteria. Matching vegetation type to the pollutant impacting the stream will lead to a more effective buffer. Information of riparian vegetation types (Table 2) can be used with stream assessment to match buffer types to the primary pollutants of concern.

**Targeting pesticide BMPs.** Pesticide movement in soil and water is affected by its solubility in water, adsorption (retention) by soil and persistence, as well as volatilization and photodecomposition. Hydrophilic (water-loving) pesticides generally have more potential for movement in water than lipophilic (oil-loving) pesticides. Pesticides with greater adsorption by soil, indicated by greater values for the soil adsorption coefficient (Kd) or the organic carbon partition coefficient (Koc), are less likely to be moved by leaching or runoff than pesticides with low Kd or Koc. Pesticides with large Kd or Koc values can be transported to surface waters with soil particles by erosion. Adsorption and solubility are generally inversely related with less adsorption expected as solubility increases. The persistence of an applied pesticide is indicated by its half-life, with degradation primarily through direct or indirect microbial action and therefore greater under conditions of high microbial activity. Pesticide loss by volatilization following surface application increases as the pesticide’s vapor pressure increases, and as air temperature and wind speed increase. Soil incorporation or irrigation shortly after surface application of highly volatile pesticides is recommended to reduce vapor loss. Photodecomposition



1:635,000

**Figure 11.** Pesticide properties affect the potential for movement to ground or surface water. The spatial variability in the potential for atrazine transport a) by leaching, b) in solution runoff, and c) through adsorption to soil particles that may be moved by erosion is illustrated for Saunders County in Nebraska. The maps were created using a process-based index model, the Soil Survey Geographic (SSURGO) database and the physicochemical properties of atrazine within a GIS framework (Source: Maribeth Milner, University of Nebraska–Lincoln).

of light sensitive pesticides may be significant immediately following surface application to soil or plants. Pesticide characteristics need to be considered in targeting BMPs. Less mobile (large  $K_d$  or  $K_{oc}$ ) and less persistent (shorter half-life or “low residual”) pesticides may be preferred where the risk of leaching to groundwater is high, such as on sandy soils of low organic matter and shallow depth to ground water. Such pesticides may be preferred where there is a high risk of solution runoff to surface waters, such as on land with or near concentrated water flow and with surface application (especially with good ground cover by crop residues) at times when the probability of runoff events is high. On highly erodible soils, the risk of transport to surface waters is greater with less mobile and more persistent pesticides. The maps in *Figure 11*, created using a process-based index model, illustrate how spatial variability in a landscape may be expected to influence atrazine movement to surface and ground waters via leaching, solution runoff, and particle-adsorbed runoff.

## Enhancing Capacity for Targeting in Watershed Management

Efficient watershed management requires that the public, decision-makers, and scientists cooperate in devising effective strategies through the integration of ecological, social, and economic approaches. Better and more user-friendly decision support systems are needed to help decision-makers understand and evaluate alternatives (Pezzoli et al., 2006). Three areas in which advances are needed include: GIS and cyberinfrastructure technology; connecting policy and decision making; and determining program success and adaptive management.

**GIS and cyberinfrastructure technology.** Developments in GIS and cyberinfrastructure technology are enhancing the ability of scientists and resource managers to analyze complex socio-environmental systems and apply this analysis in watershed management. Remote and real-time data

acquisition, data management and computing abilities in GIS and related tools are increasingly available for supporting identification and targeting of pollution problems, and evaluation of practices and strategies. Further advances are needed to better: 1) predict watershed responses to natural and human-induced changes at different scales of time and space in order to select efficient and cost-effective environmental monitoring programs; 2) transfer results across space and time scales; and 3) facilitate outreach and stakeholder participation through consensus-building and decision-making.

Improvements are needed in geospatial digital libraries and interactive, web-based mapping portals (G-portals) that offer geo-referenced materials (maps, images) and geospatial tools with which to analyze and visualize them. One such tool integrates document and GIS approaches, allowing users to select and navigate through a spatial interface, while jumping over at any point to a document interface (Pezzoli et al., 2006). For example, one could target a particular area, search for records matching various criteria (type of project, type of record, best practice involved, type of habitat), bring up matching records for that area, review and browse the documents, and further explore the “digital watershed” database, through a combination of refinement steps involving additional spatial-narrowing or record searches. Linking environmental modeling efforts to advanced sensor webs and information systems will provide new opportunities to initiate experimental forecasts of new watershed management variables, assess impacts and responses, and advance scientific knowledge of complex environmental systems.

**Connecting policy and decision makers.** Regulations are sometimes needed to correct behavior, but such regulation may not give the desired results. Environmental legislation is difficult to implement. Legislative incentives and education are needed that will promote intelligent and meaningful long-term decisions (Trevors and Saier, 2007). Unfortunately, environmental policy is still largely driven by a highly problematic “command and control” paradigm. Discretionary permits are typically conditioned with performance criteria for mitigation success, but an easily accessible, standards-based system for digitally storing impact or mitigation information is needed. The lack of capacity to track, prioritize, compare, evaluate, or visualize mitigation project data in a regional context, against other relevant data, raises many problems. The formation of watershed partnerships, discussed elsewhere in this document, has emerged as a favored strategy to improve regional economic and regulatory efficiencies in environmental management, especially water pollution prevention.

**Determining program success and adaptive management.** Success is evaluated from monitoring data, including documentation of the baseline or current situation and implemented practices, and determination of whether the desired outcomes are being achieved and if the assumptions and hypotheses that drove the selection of practices and their placement were correct. Indicators must be used that relate to the conservation practice and desired outcome, along with a measurement schedule, and the timeframe within which an outcome is expected. Open communication among stakeholders is required, with plans on information sharing and corrective action when progress is unsatisfactory. This provides a basis essential to effective adaptive management that is discussed elsewhere in this document.

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Improvements are needed in geospatial digital libraries and interactive, web-based mapping portals (G-portals) that offer geo-referenced materials (maps, images) and geospatial tools with which to analyze and visualize them.

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**Research needs.** There are significant gaps in our knowledge about conservation practices that must be filled: 1) surface and ground water interconnectivity and flow paths; 2) the contribution of eroding banks and beds of actively adjusting stream and river channels to sediment and nutrient load; 3) treatment thresholds necessary for positive impacts in the watershed and downstream; 4) cost effectiveness of BMPs for improved water quality; 5) the effects of interconnections of land use, soil pollutant concentrations, hydrologic connections, geomorphic conditions, and discharge at the farm and watershed scale on water quality and ecological integrity; and 6) the timeframe or time lag within which improvements in water quality are expected.

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*Applying knowledge to improve water quality*

# Heartland

## Regional Water Coordination Initiative

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