

Watershed-Scale Tools

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Introduction

Focusing resource management efforts at the watershed scale is not new. It was a feature of the Organic Administration Act of 1897, an option in the Standard State Soil Conservation District Law of 1936, and the then Soil Conservation Service was brought into watershed management through the Watershed Protection and Flood Prevention Act (PL-566) in 1954. At issue in this paper are the lessons learned through these historical and contemporary efforts in designing and implementing resource management efforts at the watershed scale. A common metaphor in this effort has been to employ the expression of using “tools” to achieve the desired resource management objectives. A tool in the broadest sense is a means to accomplish a desired end, but in this context refers to the analytical, mechanical, structural and behavioral techniques used in pursuing water quality and conservation objectives. There is an extensive scientific literature that describes, analyzes and critiques the various tools that can be used in watersheds (see Mulla, Kitchen and David paper). It is important, however, to emphasize that tools are more than just the remedial practices installed or employed in a watershed. The changing nature of how one thinks about the causes and solutions to degradation in a watershed can also be thought of as an analytical or intellectual tool. This way of thinking about or analytical perspective used in the study of a watershed can be as important, if not more important, than the most innovative Best Management Practice or Best Available Technology. In short, it needs to be emphasized that a watershed tool is more than a technical fix applied to a problem. This paper employs this broad perspective by offering a different type of analytical tool by which to study watershed processes, and then provides an example of a novel application based on insights that emerged in the Wisconsin Buffer Initiative.

Our thesis is that the effectiveness and efficiency of any effort to improve the environmental performance of a watershed is directly related to the spatial congruence between the objectives of a policy or program, the spatial dimensions of the remedial practices, and the degradation processes themselves. For example, policies focusing on farms, remedial practices implemented on fields, and degradation processes occurring at the sub-field scale represents an ineffective and inefficient situation. Achieving the greatest effectiveness in the most efficient fashion in the use of watershed tools will occur when there is scalar congruence between policy, remedial tools and the degradation processes themselves. Scalar congruence, or emphasizing the point that space matters, can be used to organize how one analyzes or thinks about watershed processes, and hence may be considered a watershed tool.

Discussion

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The core scientific principle behind the spatial congruency thesis just proposed is that degradation within any watershed is not random. It is spatially and temporally patterned. The spatial and temporal pattern that emerges is highly dependent on the interaction between the appropriateness of the management behaviors or activities occurring and the relative vulnerability or resiliency of the specific location where this interaction occurs. These patterned interactions will change across time as climatic events, agronomic cycles and technology will change the values associated with the appropriateness of the behavior and vulnerability of the site where this behavior occurs. The dynamic spatial and temporal nature of degradation processes in agricultural requires that the tools employed address this phenomena.

This dynamic interaction between behavior and the biophysical setting is often simplified in models used in watershed activities by focusing on the average, typical, or recommended behavior. That is, rather than allowing the full range of behavior to be reflected in model parameters, it is often assumed that land user behavior follows recommended guidelines. This approach purposively limits variation to be accounted for by the model, and in effect, results in the biophysical measures of vulnerability to dominate the characterization of watershed processes. However, it is possible that more attention needs to be given to the exceptional rather than the average when designing and implementing watershed tools that explicitly involve the human dimension. Paying attention to the statistical exceptional behaviors within a watershed recognizes the potential for disproportionate impacts on system processes.

Disproportionality occurs within a system to the extent that high-impact, extreme events (Albeverio et al., 2006) of low frequency dominate system behavior. Infrequent but high-impact events can either directly determine system outputs, or structure the conditions within the system such the consequences of the event continue to influence the system long after the extreme event has ended; that is, a legacy impact (Bazzaz et al., 1998; Palmer et al., 2004). Acknowledging that disproportionality is a form of an extreme event could have significant long-term implications for USDA and USEPA efforts to induce improvements in the quality of the nation's water bodies. This is the case because the agricultural behaviors of land users are not all normal, average, or within recommended parameters. Research has found that distributions of behaviors that are especially salient to resource degradation processes (i.e., fertility practices) are often skewed so as to represent log-normal probability distributions (Shepard, 2000). If the behaviors represented by the "tails" of these distributions should occur in a particularly vulnerable biophysical place or time, then it is highly probable that these few locations could be contributing disproportionate impacts on overall watershed performance. It is a situation where the "tail could be wagging the watershed" or where the exceptional needs the focus of watershed tools.

As has been noted, disproportionality may emerge from the interaction of how a management practice is implemented (e.g., tillage, manure application) relative to the spatial and temporal biophysical settings (e.g., field unit, time of year) of these decisions (Nowak et al., 2006:156). These biophysical settings exhibit variability in their particular likelihood to generate runoff or resiliency for buffering water quality impacts during

runoff events. Given the variable contributions or impacts of these biophysical settings, therefore, the issue of the appropriateness of the management practices used within settings must be raised in watersheds affected significantly by human land uses. While this localized vulnerability does not represent average conditions or practices, the associated water quality impacts may be disproportionate relative to their delimited area or frequency of occurrence (Figure 1).

Consequently, these extreme situations may exert a critical influence on water quality, and are of particular relevance to watershed research, modeling, and management efforts. Both management practices and the biophysical resiliency of the settings where these actions occur may be described in terms of their probability of occurrence (Nowak and Cabot, 2004). Disproportionality is then a function of the magnitude of the multiplicative effect of these probabilities on overall water quality, as disproportionately large impacts will occur when inappropriate behaviors occur in vulnerable locations or times (Figure 2). A critical and as of yet unmet research need is an assessment of the optimal spatial scale to examine this interaction. That is, one could look for and address disproportionality at spatial scales ranging from sub-meter to the hydrologic basin scales. Finding the optimal scale conducive to effective federal, state or local policy will be a complex issue as the factors leading to this decision are dynamic. Both the appropriateness of a behavior or activity and the vulnerability of a location will vary across time due to short and long-term climatic variation, changes in agricultural technologies, and our increasing abilities to monitor and measure forms of degradation.

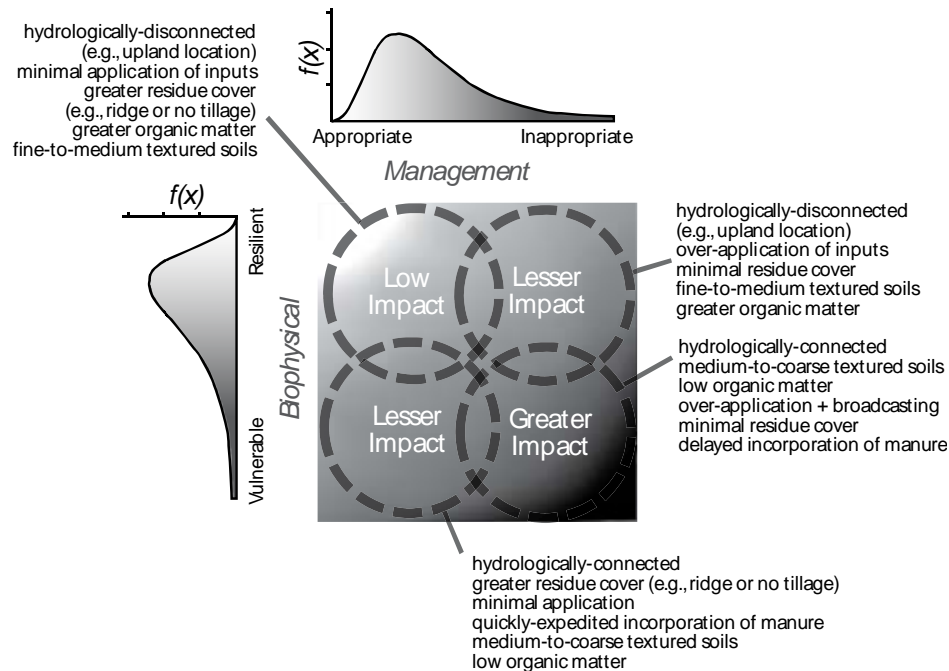


Figure 1: Watershed Impact of the Multiplicative Outcome of the Social and Biophysical

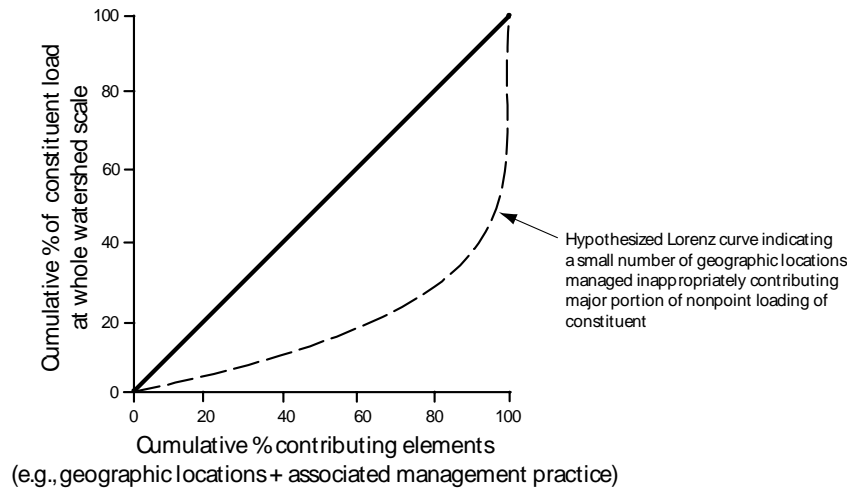


Figure 2: Disproportionality Hypothesis for Nonpoint Origins of Constituent Delivery (e.g., P Runoff from Agricultural Fields)

The argument up to this point is that ‘space and time matter’ in the design and implementation of both policy and remedial tools used in watersheds. This spatial dimension is important because it is highly probable that a small proportion of inappropriate behaviors in a small proportion of biophysically vulnerable areas are driving overall watershed water quality parameters. Recognizing the occurrence and salience of disproportionality raises a challenging question --- should we be designing tools for the average or the exceptional? For example, should the policies and remedial practices that attempt to address hypoxia in the Gulf of Mexico be designed for the entire Upper Mississippi Basin, or that small proportion of the entire basin that contributes a disproportionate amount of nutrients?

“We found that the vast majority of fertilizer pollution comes from a relatively small area of heavily subsidized cropland along the Mississippi and its tributaries where taxpayer funded commodity spending overwhelms water quality related conservation spending by more than 500 to 1.” (Environmental Working Group, 2006)

Another reason why ‘space and time matter’ is that many watershed remedial practices are incapable of optimizing remediation or prevention across forms of degradation. While there are ample watershed tools available for specifically addressing, for example, sedimentation, nitrogen leaching, or wildlife habitat, there are few practical tools available capable of addressing multi-media forms of degradation. A related theme is the trade-off that may occur when addressing one form of degradation, but then results in increasing the degradation from another form. Finding a “solution” for one form of degradation at one place in a watershed may exacerbate another form of degradation at this same location. While there is ample discussion of “systems” in the watershed literature, much of this discussion has not been translated into practical watershed tools capable of addressing systemic issues. At minimum, more attention needs to be given to

various optimization strategies to avoid disproportionality from occurring in one medium when addressing multi-media forms of degradation.

A final reason why ‘space and time matter’ is that the processes or outcomes occurring at any particular location within a watershed changes across time. All available watershed tools, implicitly or explicitly, are impacted by uncertainty. The stochastic variation found in climatic processes, behavioral patterns, technological changes, or cross-scale nonlinearities has required the resulting uncertainty to be addressed through simplifying assumptions in our approaches to designing and implementing watershed tools. Yet these simplifying assumptions (e.g., models based on the unrealistic assumption that all land users are adhering to recommended practices and rates in a uniform fashion across the space being modeled) are rarely the focus of research on watershed processes that result in the development of tools. It is possible that some of the more important breakthroughs on the development of innovative watershed tools may be found by examining the underlying assumptions in our current approaches. Specifically more attention needs to be given to understanding salient watershed processes that explicitly addresses the dynamic behavioral patterns of the land user. We believe that more attention on the potential for disproportionate contributions occurring within specific spatial and temporal frameworks may, in itself, be a valuable watershed tool. An example of how the concept of disproportionality can influence watershed management activities can be found when the state of Wisconsin began to look for new ways to address water quality degradation. Specifically, it examined the potential role of riparian buffers within agricultural watersheds.

The Wisconsin Buffer Initiative

The Wisconsin Buffer Initiative (WBI) emerged in response to a political controversy and evolved into a process where some of challenging spatial congruency questions raised earlier in this paper was addressed directly or indirectly. What resulted from this process was a unique watershed tool. That is, the analytical perspective and recommendations recognized the possibility of disproportionality, attempted to optimize across different potential watershed objectives, and explicitly addressed uncertainty through an adaptive management framework.

Re-designing Wisconsin’s nonpoint agricultural pollution abatement policy was the context for the WBI. Controversy emerged over the role of riparian buffers during the deliberations and public hearings on the re-design of this nonpoint pollution program. Some argued for standard-width (i.e., 30 ft) riparian buffers to be mandated for all the perennial rivers and streams in Wisconsin. Others argued that existing federal and state programs that promote buffers were adequate to address the overall objectives of the nonpoint program. Polarization on this issue in the Wisconsin Legislature and among the elected or appointed natural resource decision bodies threatened to bring the re-design process to a halt.

Resolution to this conflict was sought by the Wisconsin Natural Resource Board approaching the University of Wisconsin (UW) and asking for recommendations on how the application of “best available and complete science” could be used to determine

where in Wisconsin's diverse agricultural landscape riparian buffers would have the greatest impacts on water quality. A little over three years was given to the UW to meet this charge with a final product to be delivered on or before December 31, 2005. The response to this charge was the formation of a working group that included representatives from all the vested interests that had been involved in the conflict. Approximately twelve major environmental groups, agricultural organizations, conservation professional associations, and other salient non-governmental organizations were invited to participate in this process. University scientists from a variety of disciplines and representatives from state and federal agencies were also invited to participate. Participation was organized in accord with a "civic science" approach where all parties were treated as equals. That is, it was not the typical citizen participation process where the scientists provide their science-based recommendations with the expectation that local interest groups accept these conclusions. The meeting began with a "blank slate" other than the charge from the Natural Resources Board. Much of the time at the initial meetings were spent addressing the stereotypes and perceptions that these various vested interests had of each other in a constructive fashion. Moving beyond the past history of confrontation allowed for an open dialogue on what questions needed to be addressed, what would be a credible methodology to use in addressing these questions, and what type of information was needed to address the charge to the WBI? The scientists involved did not receive a clear charge on needed research on specific questions until after a full year of WBI meetings had been held.

Early meetings of the WBI were also spent discussing program expectations, prior findings in the scientific literature, available tools, and data availability. Three decisions were made early in this process. First, it was agreed that vegetative strips by themselves adjacent to streams or rivers were not adequate to address the complex forms of degradation occurring across the Wisconsin landscape. The group rejected the idea that riparian buffers are a "silver bullet" that would solve the state's agricultural nonpoint pollution problems. Instead, the participants in the WBI adopted a conservation systems approach to acknowledge that a compliment of practices that would have to be applied to the hydrologic contributing area of specific segments along a river or stream. Thus, the typical approach of recommending a uniform width buffer was rejected in favor a spatial and topographic approach for identifying areas where a conservation systems approach needed to be applied. The second decision was that fiscal constraints would prevent implementation of this approach on a wide scale basis. Consequently, the WBI explicitly addressed the scale question at the state, watershed, field, and sub-field levels in establishing priorities of where buffer technology needed to be implemented. This was based on engaging in an assessment process to determine where implementation of a conservation system including riparian buffers would have the greatest likelihood of inducing improvement in water quality. This second decision was accompanied by a significant amount of discussion as it implied that severely degraded or exceptional waters would receive a lower ranking than those watersheds with a higher probability of responding to the installation of riparian buffer systems. In other words, contrary to current policy, the WBI approach placed a lower weight on severely degraded waters (e.g., the 303_d or TMDL locations) as buffers would probably have little impact on these waters. Third, a decision was made that the current recommendations are based on the

best available science at this time. Yet this was not deemed sufficient to achieve long-term improvement in the state's waters. An adaptive management framework was recommended because of the ability to learn and adapt based on the consequences of earlier actions. It is a process designed to address incomplete understanding of cause and effect relations, and "surprises" that may emerge due to changing circumstances.

These early decisions resulted in three general questions that guided both research and the discussion of the final recommendations. These questions were:

1. How to identify the hydrologic units most likely to show demonstrable improvements with investment in riparian buffers as part of a larger conservation system?
2. What types of tools can be developed that can be employed at the local level to assist in identifying portions of watersheds where a buffer-based conservation system would be an effective option?
3. How do we develop techniques for determining the optimal placement and configuration of buffer-based conservation systems on designated landscapes?

The remainder of this paper will describe the responses developed to date regarding these three questions. More information on the Wisconsin Buffer Initiative can be found at: <http://www.drs.wisc.edu/wbi/>

Identifying the Appropriate Size Watershed

Watersheds vary in spatial scale due to their nested nature. Selecting the appropriate spatial scale to be both a focal point of policy, and appropriate to the potential tools that can be employed is a critical decision. Successfully implementing a remedial program in a large watershed could produce significant environmental benefits, but will be very expensive for a number of reasons. Implementing a program in a small watershed could be very cost-effective, but environmental gains will be highly variable and probably minimal relative to the larger basin. Yet WBI participants agreed that smaller watershed units would be more beneficial for two reasons. First, the adaptive management process requires some form of monitoring or feedback process. Measuring the impacts of installing buffer systems would be more direct in smaller watersheds as they impacts are less likely to be masked by other activities or legacy processes. Second, it was agreed that in smaller watersheds it would be more likely to get local land owners to accept ownership of their waters because of familiarity with the geography involved.

The characteristics of the resulting WBI watersheds relative to more familiar watersheds are presented in Table 1. At the coarse scale Wisconsin has 42 USGS 8-digit HUCs watersheds with an average size of 3400 km². The Wisconsin Priority Watershed Program, the program that was the focus of the re-design effort, was based on subdividing these 42 USGS watersheds into 334 watersheds each of an average size of approximately 434 km².

Table 1: Comparative Watershed Size and Number

USGS 8 Digit HUCs	Wisconsin DNR Watersheds	WBI Watersheds
N = 42	N = 334	1598
3400 km ²	434 km ²	47.4 km ²
1312 mi ²	167 mi ²	18.1 mi ²

The WBI watersheds are hydrologically complete, and developed on all the third order and some fourth order streams dominated by agricultural activities in Wisconsin. This resulted in 1598 watersheds being delineated with an average size of approximately 47 km². As noted, the decision was based on selecting a size where it would be feasible to determine if the watershed responded to the implementation of buffer systems, being small enough that the watershed would be viewed as manageable by local staff and residents, and being congruent with available data and other salient information. All watershed boundaries were identified in a GIS layer for further analysis.

Criteria for Ranking WBI Watersheds

The next question faced in the WBI process was “responsive to what?” That is, before deciding on appropriate watershed tools, it is first necessary to determine what types of degradation will be the focus of the intervention effort. For the WBI three different criteria were selected to screen the 1598 watersheds. These were sediment and nutrients (N, P and NO₃⁻) loads, protecting and enhancing native biological communities, and third, the trophic status of lakes, reservoirs or impoundments down-gradient from the watershed. Other criteria were proposed (e.g., biodiversity, wildlife habitat, etc.), but consensus was achieved only on these three. A spatially specific analysis was then conducted for each of these criteria for each of the 1598 watersheds.

Weighting of each individual WBI watershed was based on the following calculations:

1. Predicting nutrient and sediment loads based on a regression model developed around land use and watershed loading data derived from USGS and other monitoring sources. In each of these watersheds there was an attempt to quantify sources where buffer-based conservation steams would significantly reduce nutrients and sediments. Sources of nutrients and sediments associated with non-agricultural areas (urban or suburban), or sources associated with stream characteristics (bank slumping and stream bed erosion) had to be estimated and subtracted from the total watershed load.
2. The potential response of biological communities to conservation systems was developed around sediment sensitive fish species as being a good indicator for a wide range of aquatic organisms. This was calculated for each of the 1598 watersheds by examining trends in the counts of 19 sediment-sensitive fish species. Other factors associated with stream temperatures and cover was also considered. These data were used to predict potential species distributions, and assessing the potential for biological community response to sediment reductions.
3. Most rivers and streams in Wisconsin flow into or through a lake, impoundment or reservoir. Because of this fact, watersheds were ranked based on

the capacity of the lake, impoundment or reservoir to receive additional nutrients and sediments relative to its trophic status. A rating was assigned to each WBI watershed by calculating the potential for attenuation or prevention of eutrophication based on current water body conditions, monitoring data, and the likely response to reductions in phosphorus from contributing streams. Water bodies that were closer to the threshold of moving from eutrophic to a hyper-eutrophic state were rated higher than those below or above this point. Again, significantly degraded or exceptional water bodies received a lower score than those near this threshold.

Each of these three ranking criterion were then integrated in a GIS layer representing a composite ranking for each of the WBI watersheds. This allows for a rank order listing of all 1598 watersheds in the state from those most likely to respond to implementation of buffers as part of a conservation system to those least likely to respond.

It can be argued that the analytical procedures used to produce this ranked list of watersheds increased the congruence of the policy and program to salient processes occurring in these watersheds. Political and administrative decisions will have a ranked list based on explicit criteria related to “probability of response” to follow in allocating scarce fiscal and personnel resources. The next step in enhancing the spatial congruence will be to specify implementation procedures within the watersheds that are selected for implementation as part of the political and administrative decision process.

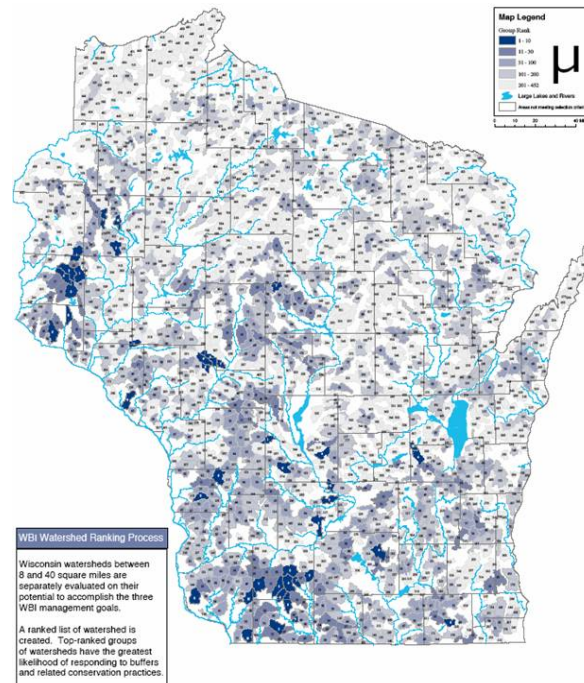


Figure 3: The WBI Ranked Watersheds

What Planning and Implementation Tools can be used at the Local Level?

As just discussed, the WBI developed a ranked list of 1598 predominantly agricultural watersheds based on the probability of responding to riparian buffers as part of a larger conservation system. This ranking was based on three criteria for which there was consensus among the members of the WBI advisory committee. The number of watersheds that will be selected for remediation is unknown as this will be a decision of the Wisconsin Legislature. Consequently, the WBI process had to develop a set of procedures and tools that could be used in any of the watersheds. Also, because of the diversity of interests associated with the WBI process, it was decided that a series of conditions should be addressed in deciding what tools need to be deployed in whatever watersheds are selected. The consensus was that whatever tools are selected should incorporate local knowledge and build on local expertise and experience. The watershed tools to be selected cannot solely be a top-down, science-driven set of procedures, but must address indigenous knowledge and local capabilities. Moreover, the selected tools need to recognize that these efforts are not occurring in a resource management vacuum. Instead they need to be compatible with ongoing conservation and nutrient management planning efforts. In essence, the agreement was that the state agencies would not come into the selected watersheds and implement the re-designed program, but that tools and procedures would be developed that allowed local interests to address areas of concern using existing programs and procedures.

These decisions led to seeking out data bases that would be universally available at the local level, and would involve activities that would be familiar to local conservation staff. Initially this resulted in four common sets of information requirements; digital elevation data, digitized soils data, land use information, and stream loading data. All of this information would be made available through a web based format that could be accessed by local officials and staff. This internet mapping site would be used to convey analysis results, support “what if” analyses, and data access (prototype: <http://144.92.119.47/website/opener.htm>).

There is a significant amount of variation in the resolution of digital elevation data across Wisconsin, and therefore it was decided that the next step within the watershed should be based on the universally available 30 m digital elevation models (DEM). The USDA-NRCS SSURGO digital soils data is also universally available. Digital land use data was also deemed to be readily available from such diverse sources as recent satellite imagery available through the University of Wisconsin, USDA-FSA offices, or local initiatives associated with local government (e.g., planning and zoning departments). The stream data will be more variable as USGA data is only available in selected locations and the monitoring that accrued as a result of the previous Nonpoint Priority Watershed Program is also variable.

Addressing Disproportionality within WBI Watersheds

All this data is used to determine priority areas within the selected watersheds; that is, those locations that have the greatest probability of contributing to stream

degradation based on the previous described information. Thus, the first level of spatial targeting was to identify small-scale watersheds in Wisconsin. The second level of spatial targeting focuses on selected areas within the watershed where local staff and citizens need to initially concentrate their efforts. Limiting the area within the watershed allows local staff to focus resources and efforts on those areas where there is the highest probability of degradation.

An example of this spatial targeting within a WBI watershed is illustrated in Figure 4. Figure 4 illustrates that available data can be used to identify the most vulnerable areas in a watershed. The WBI suggested that the implementation of buffer systems would be most efficient if initial analyses for inappropriate land management occur in these high-vulnerability areas before proceeding to the rest of the watershed.

This initial map will be reviewed by local conservation staff that may be aware of local efforts or situations that are not represented in the initial representations of potential priority areas.

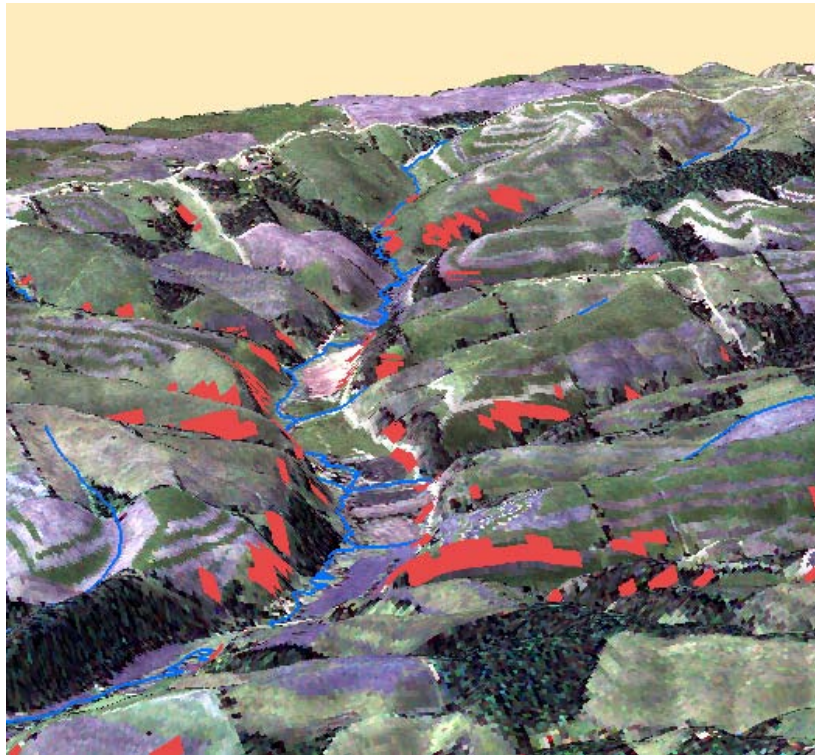


Figure 4: Example of Priority Areas for Assessment within a WBI Watershed².

² This figure is from a manuscript by Good, LW and Maxted JT. "Estimating soil and phosphorus loss potential in a small agricultural watershed." In Prep.

Following adjustments to this initial assessment, the priority areas will be assessed using a field-scale assessment tool (see Bundy and Mallarino paper). In Wisconsin this assessment will be built around the SNAP+ planning tool. This tool incorporates a phosphorus index with erosion calculations to provide a series of management options to the land owner. Fields selected through this initial screening process will be further evaluated by obtaining soil test, crop rotation and manure/fertilizer management data. The phosphorus index (PI) portion of this tool will have an important function to play in this field assessment as a PI value greater than 6 implies that intervention is needed. Only on those fields with a PI greater than 6 will riparian buffers as part of a larger conservation system be considered. Moreover, the land owner will have options within the SNAP+ that will allow them to change current practices (e.g., tillage, tilling on the contour, rotation, changes in manure distribution patterns) thereby reducing the PI below 6 within buffer technology being brought into play. This “what if” planning capability is an important part of the selected buffer implementation strategy as it gives the land owner a number of options to meet the phosphorus or soil erosion standards.

This has proven to be a contentious point in the WBI process as some conservation staff wanted an objective buffer standard (i.e., mandate a standard 30 foot buffer). Yet the logic of the WBI recommendation is that any riparian buffer has to be part of a larger conservation system to be effective. Installing a vegetative strip adjacent to a stream without addressing what is happening in the upland, contributing area increases the probability of buffer failure. Consequently, the WBI process recommended that the upland, contributing area must meet existing PI and soil erosion standards. If this is not possible, then upland practices have to be implemented to reduce these values as much as is possible, and a riparian buffer is then designed to address these resulting values. This has come to be referred to as a strategy where riparian buffers are viewed as the “last line of defense” rather than the “only line of defense.”

Placement and Design of Riparian Buffers

Only in those circumstances where the PI is greater than 6, erosion rates exceed the soil loss tolerance value, and all possible changes in current farming practices have occurred will a riparian buffer be designed. An important contribution of the WBI process was that this buffer would be designed to explicitly address the contributing area rather than current NRCS field office guidelines. The importance of this contributing area was developed in the WBI process through the application of the Precision Application Landscape Modeling System (PALMS). PALMS research demonstrated that standard width buffers are highly vulnerable to being breached by concentrated flow in select locations along the buffer. Consequently, the conservation system begins in the upland contributing area, and the buffer itself is designed to prevent concentrated flow from developing in a contributing area. This will require applying the conservation systems perspective up across the landscape while possibly considering neighboring fields.

The design and placement of these buffer-based conservation systems is based on diffusing water and energy on the higher areas of the landscape rather than trying to control and mitigate this energy in the riparian zone. The WBI recommendation thereby becomes a constellation of practices organized by topographic features. Realization that the classic “ribbon model” of riparian buffers would not achieve the goals of the WBI evolved from recognition that the effectiveness of any watershed tools is highly site-specific. Focusing the placement of these buffer-based conservation systems in areas of the agricultural landscape that have the greatest likelihood of causing degradation specifically addressed the charge from the Natural Resources Board to consider effectiveness and efficiency.

Conclusions

The field-specific design and placement of buffer technology is a direct result of policy process that asked where across the Wisconsin landscape riparian buffers were needed to achieve water quality objectives. It would be easy to view this buffer technology as the optimal watershed tool, the question addressed by this paper. Yet buffer technology, this systems approach to address the contributing area on a field(s) adjacent to a stream, is only a portion of the watershed tools that were needed in the WBI process. Important lessons were learned in this scientific and political process, i.e., civic science.

Perhaps the most important lesson is that one does not design watershed tools and then go looking for an application situation. Our thesis is that the process needs to be designed to optimize the spatial congruence between the objectives of a policy or program, dimensions of the tools, and the analytical capacity to characterize and understand salient local processes and situations within watersheds. Getting to the characterization of the appropriate watershed tool began with a political process that asked where and how riparian buffers should be employed in Wisconsin to achieve water quality objectives. Determining what type of intervention was needed was also a political process where scientists played an important role in providing analyses to allow targeting down across several spatial scales. The scientific analysis also reaffirmed that the agricultural lands bordering riparian areas are not all equal --- some are much more likely to have characteristics that lead to degradation of waters than others. Using largely available biophysical data to identify these vulnerable areas in order to guide local assessments for inappropriate behaviors was an important step in the WBI process. Recognizing the potential role of disproportionality in water quality degradation was addressed by developing techniques to identify these situations.

The next political decision, also led by scientific analysis, was that ribbons of riparian vegetative strips were not sufficient to achieve the water quality objectives. While this approach may be conducive to existing program protocols, science directed the WBI to design buffers on the basis of topographic features up-gradient from the riparian area.

The final political decision will be acceptance of WBI recommendations, and the degree to which implementation efforts are funded. The point being made is that

watershed tools are not purely an artifact of the latest scientific advances. The question of whether there will even be an opportunity to even use analytical, mechanical, structural or behavioral techniques to pursue a conservation objective is a political decision. Politics is not just a funding source or the point of origin for new conservation policies. It also needs to be considered in the selection or design and use of any watershed tool.

The second lesson learned in the WBI process is that we will probably never create any watershed tool that does not contain uncertainty or significant error. Hence the needs for an adaptive management approach to any application of these tools. Implementation, monitoring, and adjustment is a process determining our ability to answer questions such as where is intervention needed, to what extent did we achieve our goals, or how did that surprise or extreme event influence the performance of our tools? Adaptive management is based on our ability to acknowledge our ignorance, and design our tools and feedback mechanisms accordingly. A long-standing obstacle to this approach has been the costs associated with monitoring. The WBI addressed this situation by selecting relatively small watersheds where there is a greater likelihood of measuring changes associated with the installation of buffer systems. The sophistication associated with this monitoring effort is still being discussed. Various designs are being explored relative to optimizing the data needed to address three objectives; (1) collect data in a scientifically rigorous and valid fashion, (2) minimize personnel, equipment and laboratory expenses, and (3) be capable of demonstrating to local land owners that the installation of conservation practices work and have a positive impact on water quality.

The final step in the WBI process will be to test this approach and set of recommendations in a matched watershed experiment. Two relatively high-ranked WBI watersheds will be selected that are in close geographical proximity to each other. Monitoring equipment will be installed in both watersheds while one will be selected for the control while the other will be asked to follow WBI recommendations. The goal is to have the monitoring equipment in place by early summer of 2006, and the initial assessment for inappropriate behaviors beginning post-harvest in the fall of 2006.

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Appendix 1: Members and Participants in the Wisconsin Buffer Initiative

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3. Mike Dahlby, Wisconsin Association of Land Conservation Employees
4. Jeff Maxted, UW-Madison, Center for Limnology
5. Denny Caneff, River Alliance
6. Steve Ventura, UW-Madison, Soil Science
7. Gene Hausner, USDA NRCS
8. Richard Gordor, Farm Bureau Federation
9. Dennis Frame, Discovery Farms
10. Susan Butler, USDA FSA
11. Keith Foye, WI DATCP
12. Bob Oleson, Wisconsin Corn Growers Association
13. Christine Molling, UW-Madison, Soil Science
14. Larry Cutforth, USDA-FSA
15. Todd Ambs, Wisconsin Department of Natural Resources
16. Bill Hafs, Wisconsin Association of Land Conservation Employees
17. Gordon Stevenson, Wisconsin Department of Natural Resources
18. Jake Vander Zenden, UW-Madison, Center for Limnology
19. Matt Diebel, UW-Madison, Center for Limnology
20. Paul Kaarakka, UW-Madison, Soil Science
21. Karen Talarczyk, Green County Land Conservation Department
22. Todd Jenson, Green County Land Conservation Department
23. Jim Jolly, Brown County, Land Conservation Department
24. Jason Thomas, Green County USDA-NRCS
25. Rick Klemme, UW-Extension
26. Timm Johnson, Wisconsin Agricultural Stewardship Initiative
27. Tom Cox, UW-Madison, Applied Agricultural economics
28. Dean Dornink, Professional Dairy Producers of Wisconsin
29. Fred Madison, UW Soils, Discovery Farms
30. Kevin McSweeney, UW-Madison, Soil Science
31. Paul West, The Nature Conservancy
32. Larry Bundy, UW-Madison, Soil Science
33. Bob Oleson, Wisconsin Corn Growers Association
34. Don Baloun, USDA-NRCS
35. K.G. Karthikeyian, UW Madison, Biological Systems Engineering
36. Paul Zimmerman, Wisconsin Farm Bureau Federation
37. Rebecca Baumann, Wisconsin Land and Water Conservation Association
38. Dave Hogg, UW-Madison, Dean, CALS
39. Paul Miller, UW Madison, Biological Systems Engineering
40. Frank Scarpace, UW-Madison, Civil and Environmental Engineering
41. Laura Ward Good, UW-Madison, Soil Science
42. Pete Nowak, UW-Madison, Gaylord Nelson Institute for Environmental Studies