Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada

Watershed Evaluation of Beneficial Management Practices (WEBs)

Technical Summary #2

Economics Component

Four-year review (2004/5 - 2007/8)

Ducks Unlimited Canada
Conserving Canada's Wetlands

Canada

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Beneficial Management Practices (WEBs)

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Agriculture and Agri-Food Canada 2010

Introduction

The Watershed Evaluation of Beneficial Management Practices (WEBs) is a national project led by Agriculture and Agri-Food Canada (AAFC), with Ducks Unlimited Canada as a major funding partner. WEBs was initiated in 2004 to measure the environmental and economic performance of selected agricultural beneficial management practices (BMPs) at a watershed scale. Research is carried out at seven micro-watershed sites across Canada (Figure 1).

Figure 1: Location of WEBs watersheds across Canada

For the purposes of this study, BMPs are science-based farming activities designed to help minimize potential environmental impacts, such as sediment and nutrient runoff into water bodies.

WEBs has applied a suite of BMPs at each site and has begun studying their environmental and economic impact at the small-watershed (300–2500 hectare) level. The selection of BMPs for testing in WEBs has been specifically tailored to the unique conditions of each watershed (Table 1). As a result, each site employs a suite of BMPs which may not directly correspond to practices in other WEBs watersheds.

Table 1: WEBs BMPs Applied by Watershed

	WEBs BMPs	Salmon River	Lower Little Bow River	South Tobacco Creek/ Steppler	South Nation	Bras d'Henri and Fourchette	Black Brook	Thomas Brook
Riparian	Cattle exclusion fencing (and off-stream watering)	✓	✓		✓			✓
	Off-stream watering without fencing		✓					
	Grazed versus mechanical harvesting			✓				
In-field	Manure management		✓			✓		✓
	Zero versus conventional tillage			✓				
	Crop rotation					✓		
	Perennial cover		✓	✓				
	Reduced herbicide use					✓		
Runoff	Diversion terraces and grassed waterways						✓	
	Storm water diversion (farmyard runoff)							✓
	Holding pond (cattle containment runoff)			✓				
	Small reservoirs			✓				
	Buffer strips		✓				✓	
	Suite of surface runoff control measures					✓		
Drainage	**Controlled tile drainage**				✓			

WEBs is not designed as a test of BMP effect across differing watershed conditions*

* **It is important to note that comparing the effect of individual BMP's across multiple watersheds and/or the assessment of any one BMP under a wide range of different watershed conditions is beyond the scope of WEBs.**

Each of the seven WEBs watershed sites across Canada includes the following components:

- *Biophysical evaluations* measure the impact of individual BMPs or a suite of BMPs on water quality and other environmental factors at a watershed scale.
- *On-farm economic assessments* determine the costs and benefits of implementing BMPs.
- *Hydrologic modelling* contributes to a better understanding of background and watershed interactions and facilitates the extrapolation of findings to other locations.
- At two of the project sites, *integrated modelling* combines hydrologic, economic and producer behavioural aspects into a multi-faceted decision tool to facilitate long-term planning.

WEBs is focused on water quality, a likely predictor of other environmental impacts such as soil quality, air quality and biodiversity. In many cases, additional environmental parameters such as soil or riparian health are being examined.

The history of conditions and trends at each of the seven WEBs sites is generally well understood, due to past activities and data collection by local watershed associations or multi-agency teams. It is anticipated that these sites will continue as long-term benchmark locations for watershed health.

This technical summary compiles the economic findings of the project's first four years (2004/05 - 2007/8) from each of the seven WEBs project watersheds. It also includes the executive summary from the farm [producer] behaviour component of the integrated economic-hydrologic model, and the full report on WEBs metadata. A compilation of findings from the biophysical research conducted under WEBs is available in a separate companion document entitled: "Watershed Evaluation of Beneficial Management Practices (WEBs), Technical Summary #1: Biophysical Component – Four-year review (2004/5 - 2007/8)". A compilation of findings from the hydrologic and integrated modelling research is available in a further companion document entitled "Watershed Evaluation of Beneficial Management Practices (WEBs), Technical Summary #3: Hydrologic and Integrated Modelling Components – Four-year review (2004/5 - 2007/8)". These documents are available in print and PDF format in both official languages.

A condensed report "Watershed Evaluation of Beneficial Management Practices (WEBs): Towards Enhanced Agricultural Landscape Planning – Four-year review (2004/5 - 2007/8)", providing an overview of the WEBs project and summarizing the findings from all three of these Technical Summaries, is available in print and PDF format.

For further information on WEBs, please refer to our website at www.agr.gc.ca/webs or email us at webs@agr.gc.ca

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Watershed Evaluation of BMPs (WEBs)

On-Farm Economics Summary

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Compiled for the WEBs project
AESB/AAFC, Regina

February 2009

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I would like to thank the watershed economists who provided me with a copy of their reports and willingly answered questions that I had concerning the interpretation of these reports. Also, representatives of AAFC – AESB who provided comments on an earlier draft are thanked for their input.

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Executive Summary

As is well known, farmers are generally assumed to be price takers (unable to set their sale price) and as such are unable to pass cost increases on to their buyers, as might be the case in other industries. Thus, it seems reasonable to assume that farmers will not willingly reduce their net incomes from the adoption of Beneficial Management Practices (BMPs[1]) unless they are motivated by altruism or they are compensated for doing so. BMPs can be defined as management practices that reduce farming practices' deleterious impacts on the environment when compared to the employment of conventional farming practices. All of the research papers identified in this report contain cost information relating to BMP adoption and/or maintenance and in almost all cases farms would be made worse off by adopting BMPs. Unfortunately, if farmers are finding it difficult to generate a positive net farm income without adopting BMPs it is highly unlikely that they will adopt a BMP until such time as their net farm income improved or they were compensated for adoption.

This situation is clearly evident in the ***Salmon River (BC)*** watershed report where the model ranch was losing money before BMP adoption was considered. The BMPs investigated are expensive in terms of their investment cost ($8,000 - $9,000 per km for fencing and $6,000 for an off-stream watering facility). The ranchers interviewed for that report all agreed that pollution is bad and that benefits might accrue to society (both ranchers and non-ranchers alike) from the adoption of BMPs but they could not entertain BMP adoption unless the cost could be covered. As salmon fishing and both recreation and domestic uses of water are highly valued in this area of British Columbia, it is expected that non-farm benefits from BMP adoption might be large and potentially widespread. The question remaining thus focuses on a valuation of these benefits and a determination of compensation to be paid farmers for adoption and by whom.

For the ***Lower Little Bow River (AB)*** watershed, two reports present information on costs associated with restricted cattle access to a watercourse and manure management off-site from cattle feedlot facilities. These subjects were covered in the two separate reports, as follows:

1. Restricting access to a watercourse for cattle is expensive and the degree of expense is a function of the level of protection that one desires in the riparian area, in that the cattle might be allowed feeding access to the riparian area or they might be totally excluded from it.

2. For manure management, the WEBs research team estimated costs to transport and spread cattle manure in partial replacement for commercial fertilizer. Again, there is a cost associated with this activity but a lower cost than transporting and dumping the manure, which would have consequences for the environment.

A comparison between conventional and zero tillage systems in the ***South Tobacco Creek/Steppler (MB)*** watershed generated inconclusive results at the field level yet when the results were scaled up to the farm level, from a tillage perspective net revenues for cereal crops were increased under zero tillage whereas from a yield perspective canola performed better under conventional tillage. When this was discussed with farmers in the watershed, they stated that they would likely prefer the conventional system due to the increased machinery investment required for zero till, which they felt was not warranted. A manure effluent holding pond was constructed for a cattle feedlot to investigate management of manure and rainfall runoff, where the runoff was used for controlled crop irrigation as opposed to being allowed to drain into watercourses. No yield increases resulted from this activity and no additional benefits to flora and fauna were estimated, although these might be expected from this management activity.

The ***South Nation (ON)*** watershed was the one watershed that found positive benefits accruing to the adoption of a BMP; controlled tile drainage. This BMP controls the water table for crops by reducing root zone flooding or increasing the availability of water for crops, depending on the prevailing conditions in the field. The resulting benefits were increased yields for corn and soybeans sufficient to more than cover the installation and operating costs of the system. Thus, it might be expected that farmers would adopt this BMP to their advantage without need for compensation payments.

[1] All BMPs are assumed to be risk-neutral when compared to each other and with conventional practice. It can be acknowledged that adopting a new practice carries with it an element of risk but this is not addressed in most studies identified in this report. It is assumed here that BMPs would reduce profit. In fact they might be expected to increase profits but it was found by all researchers associated with this project that in fact they do reduce profit in the absence of a full estimation of their potential benefits.

Bras d'Henri and Fourchette (QC)

1. The ***Université Laval*** study pursues two objectives. In the first part, the paper focuses on the farm and operator characteristics conditioning the adoption of BMPs. It was found that larger farms are more likely to adopt BMPs. Thus, if water degradation correlates with farm size, a low BMP adoption rate might still bring about significant improvement in water quality. The adoption of riparian buffer strips was sensitive to farmer age perhaps because as farmers age they tend to become more secure financially and thus more capable of giving up productive land for buffer strips. The second part of the paper analyses the technological relationships between the production of good outputs, crops and livestock, the production of bad output, water quality degradation, and the use of BMPs. Results from their cost function approach suggest that BMPs increase cost, especially manure controls, that the marginal abatement cost rises slowly except near the end of the abatement process and that there are important economies of size in crop production.

2. The ***McGill University*** modelling study indicates that it is likely more economically efficient to achieve pollution abatement at the watershed level than at the farm level. This is because some farms are quite flexible in terms of crop and animal production mix, and thus in adjusting their pollution output (and pollution control), whereas other farms are not. In terms of paying compensation to encourage BMP adoption, it would therefore be less costly to compensate the watershed as a whole than the individual farmer and the farms within the watershed could allocate the compensation between themselves.

The ***Black Brook (NB)*** watershed report presents a comparison between two cropping systems for runoff control; up and down versus contour cropping for potato production. These BMPs were investigated, as soil erosion and water stress are both common in the watershed, which can result in serious soil loss and/or a reduction of potato yields. In 2006, the first year investigated, water stress was not a factor and thus potato yields were significantly higher than on average and consequently benefits to yield in terms of water conservation strategies were not apparent. In 2007, water stress was once again evident and contour cropping was found to result in significantly increased potato yields when compared to up and down cropping.

The ***Thomas Brook (NS)*** watershed report presents a case farm study where various BMPs (such as livestock fencing and off-stream watering) are compared in terms of their resulting gross margin (GM). All of the BMPs resulted in a decline in GM, although when anticipated benefits were added back on one of the BMPs (increased milk yield resulting from utilizing clean drinking water for cows) the resulting GM reduction was slight. A trade-off modelling analysis between GM and nitrate pollution was carried out which illustrates the estimated relationship between nitrate pollution for various levels of GM generated at the farm level all the way to the watershed level. As farm size increases in terms of GM, the estimated level of nitrate pollution increases.

In summary, only one of the BMPs investigated in the seven watersheds studied proved not to be too costly and non-profitable for farmers to incorporate without compensation. Benefits, both on-farm and/or off-farm, associated with BMP adoption were estimated in only one watershed. Without a further comprehensive estimation of these benefits it is not possible to make decisions as to viability and/or ranking of BMPs for pollution control or remediation.

Introduction

Agriculture has become increasingly the focus of attention as a result of society's interest in the environment. Because farming activities, such as the raising of livestock, often impact the environment in a negative way by producing environmental "bads", farmers are sometimes labelled as being poor stewards of the land. This may be an unfair characterization as it is not in their best interest to destroy the land base from which they earn their living. It is also unfair in that farming practices might negatively affect others yet be deemed to be "good" farming practices. In this case they can hardly be deemed to be bad stewards of their land. However, farmers will quite rationally react to economic stimuli as they attempt to survive with the aim of passing their farms to the next generation. Unfortunately, these stimuli may result in agricultural activity that is seen as being deleterious to the environment. If, as a society, Canadians wish to protect the natural environment from these "bads", then it will be up to Canadians to provide incentives to farmers to encourage them to change their production practices to improve the situation.

One approach to change relates to the use of Beneficial Management Practices (BMPs). These production practices are designed to reduce the negative environmental impacts of agricultural production. An example of such a practice would be the fencing of streams and the provision of off-stream watering facilities for livestock, which is designed to remove cattle from watercourses and thus reduce stream-bank and riparian degradation, and manure and urine contamination of streams. This is turn will be expected to have benefits for both farmers and society. Potential benefits to farmers relate to increased production, as livestock tend to grow and produce output (e.g. milk) more efficiently if provided with clean drinking water. Off-farm benefits will relate to improved water quality for consumptive purposes, either in the household or for recreation, and improved habitat for aquatic species and wildlife. Unfortunately these benefits will not come without a cost and thus there is a question as to who, the farmer or society, should pay that cost. This report has been prepared to focus our collective attention on this cost-benefit trade-off.

During the period 2004–2008 a selection of Beneficial Management Practices (BMPs) were investigated in seven watersheds across Canada as part of the WEBs project[1]. This project was designed to investigate the environmental and economic potential for promising BMPs to play a part in the alleviation and/or the remediation of pollution problems in watersheds across Canada. The BMPs were chosen to suit the watershed and its specific pollution problem and thus it was never intended that a comparison of BMPs would be performed across watersheds. The chosen BMPs were subjected to experiments by physical scientists to determine their efficacy for pollution reduction and/or remediation. Most of the watershed teams had at least one economist attached to the team whose mandate was to put an economic face on the scientific experiments. This report presents a synthesis of the reports prepared by site economists, or their representatives, for the seven watersheds studied across Canada. The intent of the basic work was primarily to assess the on-farm economic viability (costs and potential benefits) of applying the selected BMPs to these watersheds to alleviate the negative impacts of pollution associated with agricultural practices. Table 1 presents the BMPs investigated in each watershed.

It must be noted from Table 1 that not all BMPs were investigated in every watershed. However, there is some commonality between watersheds that allow for a degree of inter-watershed comparison. Such is the case for restricted cattle access which was investigated in four watersheds. At the other end of the scale zero tillage versus conventional tillage was investigated in just one watershed. Some very general results for these watershed/BMP combinations are presented in Table 8 at the end of the report.

The specific BMPs under investigation can be grouped into four main categories as follows:

- Riparian Management – 3 BMPs variously tested across 6 watersheds
- In-field Management – 5 BMPs variously tested across 4 watersheds
- Runoff Management – 6 BMPs variously tested across 5 watersheds
- Drainage Management – 1 BMP tested in 1 watershed

[1] The acronym WEBs stands for Watershed Evaluation of Beneficial Management Practices.

Table 1: WEBs beneficial management practices

	WEBs BMPs	Salmon River	Lower Little Bow River	South Tobacco Creek/ Steppler	South Nation	Bras d'Henri and Fourchette	Black Brook	Thomas Brook
Riparian	Cattle exclusion fencing (and off-stream watering)	✓	✓		✓			✓
	Off-stream watering without fencing		✓					
	Grazed versus mechanical harvesting			✓				
In-field	Manure management		✓			✓		✓
	Zero versus conventional tillage			✓				
	Crop rotation					✓		
	Perennial cover		✓	✓				
	Reduced herbicide use					✓		
Runoff	Diversion terraces and grassed waterways						✓	
	Storm water diversion (farmyard runoff)							✓
	Holding pond (cattle containment runoff)			✓				
	Small reservoirs			✓				
	Buffer strips		✓				✓	
	Suite of surface runoff control measures					✓		
Drainage	**Controlled tile drainage**				✓			

WEBs is not designed as a test of BMP effect across differing watershed conditions*

* **It is important to note that comparing the effect of individual BMP's across multiple watersheds and/or the assessment of any one BMP under a wide range of different watershed conditions is beyond the scope of WEBs.**

Source: Agriculture and Agri-Food Canada, 2008.

Research Objectives

From the above list it is clear that each of the BMP groups may provide on-farm benefits and they will be expected to have impacts outside the farm gate as well. Thus, it is important to think of the BMPs both in terms of costs to the farmers involved and the potential benefits that might accrue from their adoption to both farmers and non-farmers. The WEBs economists were encouraged to submit research proposals that they deemed appropriate to the watershed/BMP mix with which they had an association, subject to data availability. Table 2 presents a brief summary of the objectives specified by each research team. All of these address issues of costs and benefits of BMP adoption although each uses slightly different wording. This difference in wording has implications in terms of the specific research approach that each team employed.

Table 2: WEBs research objectives for economic leads by watershed

Watershed (research group)	Research objectives
Salmon River (BC)	• Evaluation of off-stream watering and fencing of riparian areas in terms of costs and benefits to a selected ranch business
Lower Little Bow River (AB)	• Evaluation of on-farm costs and benefits for permanent cover or buffer strips, off-stream watering and fencing riparian areas • Evaluation of the optimal application rate for manure for a beef cattle finishing operation taking into account manure application regulations, fertilizer guidelines, and phosphorus applications over varied time periods
South Tobacco Creek/Steppler (MB)	• Comparison of tillage practices (conventional versus zero till) • Identify relationships between BMPs and yield/quality of agricultural commodities in terms of future trends and water quality • Identify economic potential for chosen BMPs by farm types
South Nation (ON)	• Evaluation of net on-farm benefits of controlled tile drainage and restricted cattle access
Bras d'Henri and Fourchette (QC) (Laval)	• Determination of the likelihood that selected BMPs might be adopted by farmers • Identify the costs of reducing bad outputs (such as pollution) and implementing BMPs to alleviate their impact
Bras d'Henri and Fourchette (QC) (McGill)	• Estimate net farm income impacts of adopting BMPs and other management practices at both the farm and the watershed levels • Estimate the relationship between net farm income and pollution reduction • Evaluate the policy alternatives of pollution reduction
Black Brook (NB)	• To assess the level of adoption and on-farm costs and benefits of up-down cropping versus waterway diversions
Thomas Brook (NS)	• To assess decision considerations and costs of implementing selected BMPs • Evaluation of profitability and environmental quality impacts of introducing livestock exclusion fencing with off-stream watering, storm water diversion drainage, and nutrient management planning for a representative mixed crop-dairy farm

Research Methods

The WEBs objective given to all site economists, as a guideline when they submitted their original research proposals was that they should focus their work on ***"… the relative environmental and economic performance of selected BMPs"***. This objective centred on an on-farm focus, although some of the economists were allowed to submit proposals that might address both an on-farm and off-farm focus as well. All of the modelling approaches taken by the economists, Table 3, are employed to provide an indication of benefits and costs of implementing selected BMPs at the farm level. However these benefits and costs might also be borne by those outside the farm and indeed outside the watershed in question.

The studies undertaken in the Bras d'Henri and Fourchette watersheds by the Université Laval and McGill University might be looked at as "bookends" that span the spectrum of research foci for all EBs groups. A major component of the work carried out by the Université Laval team investigated the characteristics of local farmers that might indicate their willingness to adopt a selected BMP. This information may be of use in the policy-making process, to help decide where to place financial aid. Those characteristics found to be insignificant with respect to BMP adoption might best be overlooked, whereas emphasis can be placed on encouraging adoption by keying in on significant characteristics. They also investigated technological relationships through a cost function approach. Generally, BMPs raise costs, and more

Table 3: WEBs: BMPs, research method and number of farms/farmers participating by watershed

Watershed	Research method	# Farms or farmers participating
Salmon River (BC)	Financial statement farm-level models.	• A typical ranch was developed based on a questionnaire answered by selected producers in the study region
Lower Little Bow River (AB)[1]	Stochastic and dynamic farm-level model (Ross et al); Non-linear programming (Smith and Miller).	• A representative cow-calf enterprise used by Ross et al • A representative feedlot used by Smith and Miller.
South Tobacco Creek/Steppler (MB)	Enterprise farm budgets, scaled from field to farm level with projected yields based on historic yield information within the watershed.	• 35 farmers with 354 fields for in-field observations, scaled up to 3 representative farms by size for the watershed (200ha, 400ha and 800ha) • Yield data taken for 1991 – 2006 • Tillage systems have been studied in the watershed since 1998
South Nation (ON)	Enterprise farm budgets.	• Survey to determine a 2005 Balance Sheet for representative farms in the watershed • Response rate was 7/20 farmers (35%)
Bras d'Henri and Fourchette (QC)[2]	Université Laval: Econometric analyses.	• Mail survey sent to 1,319 farmers with 378 returned (29% response rate)
	McGill University: "Inter-regional" optimization model.	• 65 farms in an economic model which is integrated with biophysical models.
Black Brook (NB)	Cost-benefit analysis of BMPs. Whole farm analysis.	• Benchmark sites chosen for in-field research • Based on historic data series starting in 1988
Thomas Brook (NS)	Optimization models integrated with biophysical models using SWAT models.	• Farmers surveyed as to their ranking of management and site characteristics, motivations, and decision considerations associated with BMP adoption

[1] Two reports were submitted for the Lower Little Bow River; (1) Ross et al, and (2) Smith and Miller.
[2] The Quebec watershed was analysed by two economic teams; Université Laval and McGill University.

so for manure controls. They also found that size effects matter in production and abatement. The marginal cost of reducing sediment/improving water quality increases slowly throughout the abatement process, except near the end and falls with the level of crop production, thus giving an advantage to large farms. At the other end of the spectrum the McGill University team focused their work at the watershed level. This can also provide input to the policy-making process in terms of where to target financial resources, if required, to compensate farmers for any losses that result from BMP adoption. All of the other reports present work on BMPs that fit somewhere on the continuum between these —bookends" with the emphasis being placed on costs of adoption or operation of BMPs to farmers in the watersheds.

As previously mentioned, no comparison of BMPs across watershed was intended due to differences between the watersheds in terms of growing conditions and the potential suitability of the BMPs to that watershed. As previously illustrated in Table 3, a variety of research methods were employed by site economists that would make inter-watershed comparisons questionable. The range of research methods employed is a result of the choice made by the site economists as to their chosen approach to meet the research objectives that they outlined in their proposals. The following section briefly describes the range of economic research methods employed in WEBs. The specific approach that was applied to each study will be identified later.

Enterprise farm budgets

These are designed to allow for the determination of net income (or some facsimile of farm profit) at the enterprise level, where enterprise is defined as the farming activity or BMP rather than the whole farm. They can be used in conjunction with investment values for the farm to generate rates of return for BMP investments. The net income determined might be ***Net Farm Income*** (sometimes called farm profit) which is defined as total revenue (farm output, such as crop yield, multiplied by the unit price of the activity) less total costs. Alternatively it might be ***Gross Margin***, which is defined as total revenue less variable (operating) costs, or a modified gross margin. Typically farms of similar type (e.g. grain farms) might be expected to have similar operating costs per production unit (hectare). This would tend to result in these farms having very similar gross margins per production unit even if the farms were of different physical size. However, their ownership costs (e.g. mortgage interest) can be very different due to both farm size and debt levels where it is typical to see older established farms with low debt levels and younger farmers having high debt levels. Farms with different levels of debt might therefore have similar Gross Margins (per production unit) for growing grain crops yet have quite different Net Farm Incomes per production unit. Thus, for comparative purposes the Gross Margin (or modified gross margin) is a more useful tool[1].

Financial models

These models (whole farm) are designed to generate financial statements such as (1) a balance sheet, (2) an income statement, and (3) a cash flow statement for a farm business. The resulting financial statements can then be used to determine whether the studied BMP is expected to add to the farmer's equity (economic survivability – balance sheet), net income (profitability – income statement), and to do so without unduly stressing the cash position (ability to pay debts – cash flow statement) of the farm. Enterprise budgets will be estimated (or taken from published sources) as support material for the financial statements.

Optimization models

These models are designed to determine the —best" result subject to a series of constraints. Typically they can be set up to optimize (or seek out) the best level of net farm income (or gross margin) for a farm given a set of constraints, such as farm size and crop and animal choices during one period of time. The model would typically use enterprise budgets as input information. An —inter-regional" optimization model seeks the best such solution given many farms trading with each other in an —inter-regional" sense. Unless explicitly stated, these models will not take account of risk and thus are deterministic (have one answer). Although risk is a reality, deterministic models are often used when they are already large as an added stochastic (risk) element might make them insolvable.

Stochastic and dynamic models

Optimization models generally produce a deterministic solution for one period of time, which means that an assumption has been made concerning the certainty of the outcome. This is done to allow large and complicated models to successfully solve in a reasonable period of time. Stochastic and dynamic models are often seen as an extension of optimization models that explicitly take risk into account (stochastic portion) which

[1] This is the approach used by those that prepare farm budgets in Quebec.

means that the result is presented subject to some uncertainty, while also accounting for change (dynamic portion) in the chosen target variable, such as farm profit, over time. Generally these models will be employed where we wish to determine the best BMP fit for a specific farm situation. Thus, the models are designed to simulate farmer decision making as closely as possible. These models are generally quite complicated and thus are often used to derive solutions for individual farm situations. Due to their complexity they are rarely used to solve large inter-regional trading problems.

Econometric analyses

An econometric model was designed to analyze binary decisions concerning the likelihood that farmers might or might not adopt BMPs. It provides statistical inferences about the significance of chosen variables, such as age and education, as they relate to a farmer‘s willingness to adopt a BMP. This information is of use at the policy level where it can help to direct government‘s human and financial resources. The cost function and the cost shares of inputs were regressed on input prices and the quantities good and bad outputs produced (crops, livestock and sediments) to fully characterize the technological relationships between good and bad agricultural outputs. The econometric estimator, the seemingly unrelated regressions estimator, allows for these equations to be influenced by some common unobservable factors. Information regarding the presence or absence of economies of size in production and abatement can be derived as the impact of BMPs on costs. The sensitivity of input demands to prices can be also be ascertained.

Biophysical models

These models are designed to estimate the pollution and sediment coefficients that are required as constraints for optimization models. Although described last in the list, they must be run before the economic models to provide biophysical input for the economic models. Thus there is an integration of the biophysical and economic models. All of the above mentioned economic modelling approaches benefit from the availability of the biophysical data.

Results by Watershed[1]

Salmon River (BC)

A computer model (financial statement model) was developed for a typical ranch business to represent ranch businesses throughout the study region. Unfortunately, the results of the model showed that the typical ranch business would generate a ***negative*** net farm income of $16,953 and suffer a ***negative*** annual operating surplus of $1,753 ***before*** investing in the BMPs under consideration[2]. This means that the business could not make principal payments on the farm loans although all interest charges on farm debt were covered. The lack of surplus cash in the farm business also means that the farm operator's labour contributions cannot be covered, as well as an allowance for depreciation on all depreciable property such as farm machinery and fences. Finally, a lack of surplus cash means that there is no allowance for a contribution towards management or the owner's equity. The end result is that this ranch could survive in the short run without considering the BMPs but would eventually fail financially in the long run if this lack of cash continued. This is without considering further capital investment in BMPs. The ranchers interviewed in the Salmon River watershed stated that with the above financial situation there was no chance that either of the studied BMPs would be adopted. This could change if the ranch was able to generate a positive net farm income with surplus cash. As most farmers have no control over the sale price received for their output, whether they are able to generate positive net farm incomes and operating surpluses is a function of market forces as well as their management skills.

Fencing of riparian areas was carried out at three sites along a stretch of the Salmon River and it was determined that this activity would require an initial capital outlay of $8,000-$9,000 per km which is a sizeable financial commitment. An off-stream watering system was developed at one of the three project sites with an estimated cost of setup as supplied by the rancher of approximately $6,000, again a not insignificant sum.

Farm level benefits such as increased calving percentage, improved herd health, reduced herd mortality and increased weaning weights have been reported in the literature resulting from cleaning watercourses in terms of a reduction of direct cattle access. The site economist commented that benefits were not explicitly determined, although they had been expected from the adoption of the BMPs (fencing riparian areas and off-stream watering). Off-farm benefits in terms of improved water quality for household use, recreation and improved aquatic habitat might be expected but were not considered in the study. The ranchers interviewed for the study acknowledged that benefits would be expected from the BMPs but these benefits would be felt off-farm rather than within the farm gate. Given the aforementioned financial picture of the farm business, benefits from BMPs would have to be greater than the negative net farm income reported and would have to result in a positive cash figure if farmers could be expected to become involved with the adoption of these BMPs. It should be obvious to the reader that farmers cannot be expected to pay for BMPs if they are not compensated for doing so.

Salmon River Economist	Research method	BMPs	# Farms or farmers participating
Terry Peterson	Financial models	• Restricted cattle access with off-stream watering	Typical ranch financial information developed by the consensus research methodology with groups of farmers and surveys to represent ranches in the study region.

[1] Selected details of BMPs by watershed are presented in Table 8 at the end of the results section.
[2] Operating surplus is a cash concept in that it is calculated as cash sales less cash expenses. Net farm income is total sales (cash plus inventory adjustments) less total costs (cash and non-cash). Depreciation on machinery and buildings may be a large figure. As a non-cash item is doesn't have to be "paid" each year but it should be expensed.

Lower Little Bow River (AB)

Land conversion

Land conversion BMPs involves delineating a 30-foot buffer strip from the water's edge and seeding a 36-foot field between the riparian buffer and cultivated or cropland to permanent cover (perennial grasses). The grass can be harvested for hay, grazed or left unused. In other words, a 66-foot strip of cultivated or cropland bordering the river is withdrawn from field crop production and replaced by riparian buffer and a permanent grass cover. The use of fertilizers and crop protection chemicals is reduced and once established all tillage practices are terminated. Three land conversion BMPs were investigated, as follows: BMP1 is permanent cover with sale of hay and cattle grazed on the aftermath. Cattle have free access to the riparian zone and can directly drink from the river. BMP2 is permanent cover with controlled grazing where a fence is used to control cattle grazing in the riparian zone and access to the river. BMP3 is permanent fence is erected between the permanent cover and cropland creating a 66-foot grass-riparian buffer. Cattle are excluded from this buffer and the river.

Land conversion cost from crop to grass cover was estimated to be $408 per acre. Based on the modelling approach utilized, this converts to an implementation cost of $15,783 for a riparian protection level of 25% (39 acres protected) to $63,130 for a riparian protection level of 100% (155 acres protected)[1] where the protection level is decided upon by the farmer. With a 25% protection level the farm gross margin is expected to decline over a 20-year horizon by $14,591 (BMP1), $24,449 (BMP2), and $48,125 (BMP3) and for the 100% level of protection the expected declines in gross margin over the 20-year horizon were $53,055 (BMP1), $92,489 (BMP2), and $200,121 (BMP3). This works out to be between $1,360 and $1,291 per protected acre which is a reduction in the farm's cash flow of 0.3 – 4.3%. Contrary to the farm example in the Salmon River watershed, the benchmark farm was profitable before adoption of these BMPs so the farm is capable of making the switch if a relatively small acreage is protected. However, strictly from a business perspective, the farm would presumably only make the switch if the net effect was positive, which it is not.

Off-stream watering

Three off-stream watering (OSW) BMPs were looked as, as follows: BMP4 (OSW and riparian buffer) where cattle continue to graze the 30-foot riparian buffer and have free access to the river. BMP5 (OSW and controlled grazing) where the cattle are allowed to graze the riparian area in a controlled manner using a temporary fence, and BMP6 (OSW and cattle exclusion) has a permanent fence, which completely excludes cattle from the riparian buffer and the river. The OSW system cost $33,465 to install, which was $84 per head[2]. This cost includes the watering system and the construction of a dugout to hold the water. Annual maintenance cost is estimated at about $18 per cow. For BMP4 this resulted in a 20-year decline in cash flow of $32,834 or $82 per cow. For BMP5 the cost of installation was $89,420 ($1,433 per acre) for 25% protection and $257,288 ($1,031 per acre) for 100% protection. Over the projected 20-year horizon the declines in cash flow were $88,465 ($1,400 per protected acre) for 25% protection and $255,355 ($1,009 per protected acre) for 100% protection. On a per-cow basis, these results translate into a loss of $221 per cow to $1,009 per cow, respectively. For BMP6 the installation costs for 25% and 100% protection were $87,045 ($1,377/protected acre) and $256,356 ($1,014/protected acre). The reductions in cash flows were estimated to be $104,703 ($1,657/protected acre) for a protection level of 25% and $320,193 ($1,267/protected acre). This translates into cash flow losses of $262 per cow and $800 per cow, respectively, depending on protection level. Again, these results show a negative net effect for these BMPs, which is not encouraging for adoption.

Lower Little Bow River Economist	Research method	BMPs	# Farms or farmers participating
Carlyle Ross	Stochastic dynamic optimization models	• Restricted cattle access with off-stream watering • Manure management • Permanent cover	Representative feedlot and cow-calf facility developed based on norms for the region.

[1] The level of riparian protection, 25%, 50%, 75% or 100% corresponds to 39, 77, 116 and 155 acres, respectively.

[2] The installation was capable of handling a cow herd of 500 head. The herd size was in fact 400 head in this case.

Manure

At the present time Alberta regulations governing manure applications are based on the nitrogen requirement of crops. Unfortunately, this results in an over-application of phosphorus because (cattle) manure has an N:P ratio of approximately 2:1 but plant requirements are generally greater than 4:1. Thus, as livestock manure is applied to satisfy the crop's nitrogen requirement, phosphorus is applied at twice the recommended rate. Unfortunately, as farmers must deal with the manure that results from their farming activities it may be most cost efficient to apply manure at rates in excess of regulations close to their farms to minimize transport costs. This can lead to pollution problems, which have provided impetus for this study. The research in the Lower Little Bow River watershed determined that applying manure at the2:1 nitrogen/phosphorus ratio reduced net returns for crops by $0.23 per tonne of manure applied due to manure transport costs and crop yield changes. This reduction in net returns is measured against the net returns base value generated when manure was applied at rates greater than the 2:1 recommendation to generate optimum net returns.

When the analysis was run based on the 4:1 nitrogen/phosphorus ratio designed to meet crop phosphorus requirements (thus under-applying nitrogen) net returns were reduced by $1.55 per tonne of manure applied when compared to the nitrogen based rate. This results due to an increase in transport costs and yield responses, which were reduced. The application of manure using the 4:1 ratio was analyzed under an alternate scenario, as follows. The application rate was tripled but the application was made every third year as opposed to annually as for the previous results[1]. This approach reduced net income by $0.95 per tonne of manure applied compared to the nitrogen rate allowing for transport costs and yield responses. This means that if one decides to apply manure to satisfy the phosphorus rate it would be more cost effective to follow the triple/third approach.

South Tobacco Creek/Steppler (MB)

Based on a field comparison of tillage practices over time (1998-2006) there was no discernable difference between the net revenue generated for cereal crops under zero tillage or under conventional tillage regimes. When this was scaled up to the farm level in the watershed it appears from a tillage perspective that zero tillage produced slightly higher net revenue, whereas canola performed better under conventional tillage from a crop yield perspective. That said, producers in the watershed preferred conventional tillage due to the lower machinery investment required compared to zero tillage.

Conversion of (annual) cropland to permanent cover (forage) was found to increase net incomes due almost entirely to lower costs of tillage, fertilizer, chemicals and crop haulage. Thus, farmers were better off converting annual cropland to permanent cover based on costs where no livestock income or costs were taken into account[2].

A holding pond was investigated as a BMP with the expectation that returns would be positive due to benefits from irrigation and control of *E-coli*, sediment retention and runoff control. The holding pond is designed to accumulate waste from the cattle feedlot, along with rain runoff from the feedlot, which can then be used for controlled irrigation as opposed to allowing the effluent to enter watercourses in an uncontrolled manner. The capital cost for the pond (2,922 m^3) was $29,928 and annual labour costs associated with the irrigation activities were estimated to be $224. No yield increases could be attributed to the holding pond and other benefits were not explicitly measured.

South Tobacco Economist	Research method	BMPs	# Farms or farmers participating
Mohammad Khakbazan	Enterprise farm budgets	• Riparian area development • Zero versus conventional tillage • Permanent cover • Holding ponds and/or small reservoirs	35 farmers (354 fields) scaled up to 3 representative farms by size (200ha, 400ha, 800ha). Yield data 1991-2006 and tillage systems studied since 1998.

[1] Interest in this approach has been shown by some jurisdictions in North America.

[2] This should be investigated further in terms of a complete analysis (costs and returns) and over a wide spectrum of crop and forage prices as this analysis was carried out before the recent increase in crop prices.

Riparian buffer development was investigated in the South Tobacco Creek watershed with the following results. The cost to adopt 281 acres of riparian buffer for a period of 20 years was estimated to be $468 per acre of the riparian area for an average producer. This cost includes fencing, watering facilities for cattle, and the opportunity cost of lost crop due to the riparian buffer strip replacing saleable crop[1].

Although manure management was not explicitly cited as a BMP under consideration in the South Tobacco Creek watershed some work was carried out to compare net returns with hog and cattle manure versus commercial fertilizer. It was found that both hog and cattle manure reduced the average net return due to yields being reduced when compared with either commercial fertilizer alone or with commercial fertilizer in combination with manure. This result tends to support the results from the Lower Little Bow River watershed.

South Nation (ON)

Controlled tile drainage is a system whereby the flow of water in sub-surface drains can be controlled so that water can be led away from root systems when water is in excess or water can be kept close to root systems (sub-surface irrigation) when water is in short supply. The system differs from conventional drainage in that water control structures are added to the drainage system. By controlling sub-surface water in this way it is expected that crop yields will be increased. The annual marginal cost to install and operate a controlled drainage BMP (over and above conventional tile drainage) was determined to be less than $13.49 per acre. For a sample crop operation of 395 acres, the annual cost would amount to less than $5,332 in total. This cost includes capital and operating costs.

As expected, controlled tile drainage resulted in yield increases for corn (4.4%) amounting to a net present value (NPV) [2] of at least $116 per acre over the life of the project. For soybeans the increased yield (7.4%) amounted to a NPV of $161 per acre over the project's life[3]. As the estimated NPVs are positive it indicates that this investment was deemed to have positive economic results for both of these crops and thus the investment would be justified.

The restricted cattle access BMP has two distinct components; fencing and off-stream watering. Three fencing systems were compared; page wire, barbed wire, and electric fencing. The annual cost per metre for a page wire system would be $3.35 plus maintenance costs, which would be expected to be minimal. For a 600-metre fence, as purchased for the WEBs research project, this would amount to an annual cost of $2,010[4]. For a barbed wire system the annual cost was estimated to be $1.23 per metre without maintenance costs, which works out to be $738 for a 600-metre fence. For an electric fence the annual cost would be $1.42 per metre without maintenance, which is $852 annually for a 600 metre fence. The annual costs for electricity should be added to the above costs. These were determined to be approximately $10.00 per year for this length of fence.

As the cattle now only have restricted access to water, due to the imposition of the BMP, there is a need for a pump to supply the off-stream watering facility. A number of alternate designs were looked at as follows: Standard pump, solar pump, windmills and gas-powered pumps. The standard pump was cheapest with an estimated cost of $750 - $920 plus $446.25 for the structure. The annual cost over a 20-25 year horizon for this pump was calculated to be $61.14 with negligible maintenance costs. Solar pumps were expensive as were windmills and thus they were not considered for this project [5]. A water bowl would be required and including installation costs the capital cost for this equipment was estimated to be $258-$303 per bowl. Maintenance costs would be negligible. Given the above information the best watering system would be a standard pump with a water bowl.

South Nation Economist	Research method	BMPs	# Farms or farmers participating
Philippe Crabbé	Enterprise farm budgets	• Restricted cattle access • Controlled tile drainage	Survey to determine balance sheet for representative farm. Response rate 7/20 (35%).

[1] These values are taken from an estimated trade-off curve covering 57 to 617 acres of riparian buffer in the watershed. The cost of adoption tends to rise sharply after 281 acres, so this size is identified as a reasonable limit.

[2] Net present value is the value of all future revenues and costs discounted to the present. This allows for comparisons between alternate investments.

[3] These NPV estimates account for the capital and operating costs previously identified for this BMP.

[4] These costs are based on 2006.

[5] This information was taken from the literature. Due to the expense of these installations, no effort was made to estimate costs for this project.

Bras D'Henri and Fourchette (QC) – Université Laval

An investigation was carried out to determine (a) which personal or business characteristics might influence the adoption of BMPs, and (b) the likelihood that the BMPs would be adopted. It was found that some characteristics would be significant (would influence adoption) but the strength of the significance results was not found to be constant across characteristics. The characteristics that were found to be significant over the 1 - 10% range are listed as follows:

Age: For each 10-year increase in age, would probability of adoption of BMPs change? Are older farmers more likely to be BMP adopters than younger farmers?

Gender: Would female farmers be more likely to adopt BMPs than male farmers?

Education: For an increase in education level attained what is the probability of adoption for BMPs? Would more educated farmers be more likely to be BMP adopters than those with less formal education?

Residence on- or off-farm: Will living on-farm increase the probability of adoption of BMPs versus living off-farm?

Crop production: For each 100-acre increase in cultivated land base what is the likelihood of adoption of BMPs? Would larger crop farmers be more likely to adopt BMPs than smaller crop farms?

Animal production: For every $100,000 increase in output of livestock and livestock products what is the probability of adoption? Would larger animal farm units be more likely to adopt BMPs than smaller animal farm units?

Machinery: For each increase in investment of $100,000 what is the probability of adoption? Would larger or more modern farm units be more likely to adopt BMPs than smaller and/or less mechanized farm units?

Environmental club: Would membership in such a club increase the probability of adoption?

Telecommunications access: Would this access increase the probability of adoption?

Price of labour: Would an increase in the price of labour impact the rate of adoption? Would those farmers paying more (per hour) for hired labour be more likely to adopt BMPs?

Results of this analysis are presented in Table 4.

The level of significance is indicated (1%, 5%, or 10%) with the strength of significance being inversely related to the numerical value. A couple of examples are presented to interpret the information in Table 4. Reading the table vertically, age has a weaker relationship with the adoption of crop rotations than does the education level of farmers. Thus we can say that more educated farmers will be more likely to adopt crop rotations that less educated farmers and this interest in adoption is more striking than the effect of age on the adoption decision.

Age is however an important characteristic because as farmers age their ownership in the farm (percentage of owned equity) typically increases and thus there is reduced pressure for debt repayment. Thus, older farmers might be in a better position financially than younger farmers to accept the financial costs associated with the creation of riparian areas as these may have to be created from land presently allocated to production. It should be noted that age, education level, and increasing size of animal production unit are all highly significant with respect to the adoption of riparian buffer strips. Age has been noted above in this situation. Education level implies more knowledge about these buffers will aid such a decision by farmers and being a farmer involved with animal production implies an interest in the alleviation of pollution related to manure from these units.

Agricultural production unfortunately can result in the generation of ~~"~~bad" outcomes (e.g. pollution). The second part of the Université Laval research found that implementing BMPs to reduce these bad outcomes is costly. However, based on estimated pollutant loadings, only those BMPs associated

Bras D'Henri and Fourchette Economist - Laval	Research method	BMPs	# Farms or farmers participating
Bruno Larue	Econometric analysis	• Riparian area development • Manure management • Crop rotation • Reduced herbicide use • Buffer strips	Survey sent to 1,319 farmers. 378 returned (28.7% response rate).

Table 4: Probability of BMP adoption in the Chaudière watershed

Characteristic	Crop rotations	Riparian buffer strips	Herbicide control and reduction	Injection of solid manure	Injection of liquid manure
Producer characteristics					
Age	10%	1%			
Gender				5%	5%
Education level	5%	1%		10%	5%
Residence: on or off farm					5%
Farm characteristics					
Crop production size	10%		1%		
Animal production size	1%	1%		1%	1%
Machinery			10%	1%	
Environmental club			10%		
Telecommunication access			10%		
Operational variable					
Price of labour	1%			10%	

with manure handling were found to be significant. This does not mean that the cost effect of the other BMPs is zero; it simply means that the range of possible values is very wide and that negative values have a probability in excess of a certain threshold (e.g., 5%). It was determined that costs to reduce the bad outcomes would be expected to decline as operational size increases for crop producers. Thus there was found to be evidence of economies of size where increased investment costs, although larger in total, would be lower on a unit of pollutant basis. On the other hand, the reverse was found to be the case for animal production.

Bras D'Henri and Fourchette (QC) – McGill University

The pollutants studied and included in the economic models were: sediment, phosphorus, nitrogen, *E-coli* and atrazine. The economic analysis was carried out in three stages, as follows:

1) The economic model was run to determine the total amount of each pollutant being produced by each farm in the watershed.
2) The total amount of each pollutant in the watershed (the sum of each farm's production of each pollutant in stage 1) was progressively reduced in 10% increments to see (a) the maximum possible reduction, and (b) its cost at each incremental step of reduction. This model was identified as the WATERSHED LEVEL model.
3) The total amount of each farm's pollution (from stage 1) was progressively reduced in 10% increments. This is known as the FARM LEVEL model.

Using sediment as the illustrative pollutant and the analysis carried out at the WATERSHED LEVEL, results for a progressive 10% reduction in sediment are presented in Table 5. The initial 10% reduction in sediment, amounted to 94 tonnes and costs $3,359 which is the reduction in total net farm income for all farms in the sub-watershed. This reduction in sediment produced a 1,019 kg reduction in phosphorus, an increase of nitrogen of 779 kg, and a reduction in atrazine of 2 kg. There was no change in *E-coli* output as a result of the 10% sediment reduction. The greatest reduction in sediment (70%) resulted in a cost to all farms of $78,555 and an impact on the other pollutants studied as follows: a 7,214 kg reduction in phosphorus, a reduction of 8,285 kg of nitrogen, a

reduction of 28.7 kg of atrazine, and a reduction of 0.13E+12 in *E-coli*. Similar results were generated for the other pollutants. These results indicated that the maximum achievable reduction in the pollutants resulted in the following costs: phosphorus $170,525, nitrogen $201,456, *E-coli* $351,802 and atrazine $43,914. The costs associated with phosphorus and *E-coli* indicate the potential economic impact of a pollutant reduction on the livestock industry.

The maximum achievable reduction in sediment resulted in the following impacts on the BMPs studied: total linear metres of 1-metre buffer strips were reduced by 21%, 3-metre buffer strips were reduced by 85%, and 5-metre buffer strips were increased 149% over the base solution. There was a 19% reduction in the use of a dribble bar to spread liquid manure. Hay hectares were increased by 854% and corn hectares were reduced by 40%.

Bras D'Henri and Fourchette Economist - McGill	Research method	BMPs	# Farms or farmers participating
Paul Thomassin	Inter-regional optimization model	• Riparian area development • Manure management • Crop rotation. • Reduced herbicide use • Buffer strips	65 farms included in a model that integrates a hydrologic model with an economic model.

Table 5: Cost and environmental impact of sediment reduction (watershed level model)

SEDIMENT	COST[1]	P	N	ATRAZINE	*E-COLI*
100%		100%	100%	100%	100%
90%	$ 3,359	91%	105%	95%	100%
80%	$ 9,152	79%	88%	86%	100%
70%	$ 16,358	67%	77%	71%	100%
60%	$ 25,349	52%	66%	54%	100%
50%	$ 38,679	46%	61%	41%	100%
40%	$ 56,516	41%	53%	40%	94%
30%	$ 78,555	35%	46%	32%	91%

Again using sediment for illustrative purposes, the results for the analysis carried out at the individual FARM LEVEL are presented in Table 6.

Table 6: Cost and environmental impact of sediment reduction (farm level model)

SEDIMENT	COST[1]	P	N	ATRAZINE	*E-COLI*
100%		100%	100%	100%	100%
90%	$ 10,158	89%	92%	87%	98%
80%	$ 21,829	78%	78%	76%	97%
70%	$ 34,608	67%	70%	64%	94%

[1]Cost is the reduction in net farm income (NFI) resulting from the reduction in the pollution under consideration.

As shown in Table 6, the maximum pollution reduction was just 30% as compared to 70% for the watershed model. In the FARM LEVEL model each farm must meet the required pollutant reduction whereas in the watershed model the required pollution reduction is applied to the watershed, thus farms may produce different levels of the pollutants. Those farms that can easily and economically adapt to the pollution reduction required can in fact reduce more than other farms to help offset the reductions for those farms that cannot so easily make their reduction targets. A comparison of the results in Table 6 with those from Table 5 indicates that: a 30% decrease in sediment costs $34,608 at the FARM LEVEL but only $16,358 at the WATERSHED LEVEL. Thus, it was more economic or efficient to reduce sediment at the watershed level because those farms that can economically reduce the pollutant will contribute more to pollution reduction than those farms that have economic difficulty doing so. Farms that have production quota (e.g. dairy farms) will find it difficult to reduce pollution as they cannot reduce their dairy herds in these models. This relationship of watershed model being more efficient than the farm model was also the case for other pollutants with the exception of atrazine.

Black Brook (NB)

A yield and quality survey was carried out during 2006 and 2007 for two potato varieties, Russet Burbank and Shepody. The yield of Russet Burbank in 2006 was 46.5% higher than the average yield for the previous 18 years due to beneficial weather, in particular an absence of water stress that is common in the region. Due to the lack of water stress in 2006, the hypothesis that soil and water conservation practices would increase yield and reduce runoff could not be supported for either potato variety.

The research compared up and down versus contour cropping where contour cropping utilizes diversion terraces that control the rate of water run-off, and thus water loss, from the crop. Up and down cropping includes waterways that channel water down the slope, thus concentrating water erosion to specific channels. In 2006 there was no significant difference by variety for these cropping systems but in 2007 yields were significantly higher from contour cropping as compared to up and down cropping. In 2007 there was also a significant difference in marketable yield from contour cropping. This results from better water retention control.

Costs were estimated for the comparison between production methods, and are presented in Table 7. These costs included construction cost, maintenance cost, net production income forgone, field crop inefficiencies, and spraying inefficiencies. The total annual costs were estimated to be $84.38 per ha of protected land for diversion terraces (contour cropping) and $69.92 per ha for waterways on protected land (up and down cropping). The breakeven cost per hectare for a 2-year rotation for these production systems is $168.75 and $139.83 respectively. Assuming a marketable sale price of $132 per tonne, the yield to break even would be 1.28 tonnes per ha for contour cropping and 1.06 tonnes per ha for up and down cropping.

Black Brook Economist	Research method	BMPs	# Farms or farmers participating
Jérôme Damboise	• Cost-benefit analysis of BMPs • Whole farm analysis	• Diversion and grassed waterways • Buffer strips	Benchmark sites chosen for in-field research based on data series begun in 1988.

Table 7: New Brunswick soil conservation structure annual cost per hectare of protected land

	Diversion terraces	Waterways (up and down cropping)
Construction cost (annual perpetual cost)	$19.56	$28.69
Maintenance cost	$8.03	$2.96
Net production income forgone	$30.88	$12.35
Field operation inefficiencies (5%)	$19.76	$19.76
Spraying inefficiencies (25%)	$6.15	$6.15
Total annual cost	$84.38	$69.92
Breakeven cost/ha for a 2-year rotation	$168.75	$139.83
@ $6.00/cwt or $132/t need an increased marketable yield/ha of protected land of:	1.28 t/ha or 11.4 cwt/ha	1.06 t/ha or 9.4 cwt/ha

Source: Damboise 2008. Table IV.

Thomas Brook (NS)

An optimization model for a representative case farm was constructed and run to set a base level against which a number of scenarios were compared in terms of farm gross margin generated. The gross margin for the base case was $29,177 per year. This is not a high number, particularly in light of it being calculated ***without*** investment costs, which implies that the net farm income (NFI) for this case farm would be much lower. This in itself is not important for the analysis. What is important relates to the changes that result from the modelling process (scenarios) when they are compared to this base value. The scenarios investigated, along with the resulting projected gross margins (GM), are as follows:

1) Inclusion of variable costs of implementing and maintaining livestock fencing with off-stream watering (GM = $25,264).
2) Inclusion of both variable costs and assumed on-farm benefits (milk production increased by 5 kg per day and weight gain increased by 0.136 kg per day) from use of restricted cattle access (GM = $27,012).
3) Inclusion of both exclusion fencing and storm water diversion (GM = $2,341).
4) Nitrogen fertilizer application reduced to 90% of base case (GM = $28,143).
5) Nitrogen fertilizer application reduced to 80% of base case (GM = $25,509).
6) Nitrogen fertilizer application reduced to 75% of base case (GM = $25,071).
7) A farm income diversification into small fruits (GM = $79,556).

It is clear that all of the above BMP scenarios investigated (with the exception of #7) resulted in farm income declines although each BMP resulted in different levels of income reduction. Note that scenario number 7 was not directly a BMP scenario; rather it was clearly a diversification scenario from the status quo. The second scenario produced interesting results in that the on-farm benefits offset some of the costs but not quite enough to make a farmer indifferent between the status quo and the adoption of the restricted cattle access BMP. It would not take a large compensation payment for the farmer to adopt the BMP. The third scenario resulted in the largest reduction in GM. However, the adoption of the storm water diversion BMP would be expected to generate off-farm benefits due to improved water quality for society‘s use. These off-farm benefits have not been estimated in the analysis at this time.

Scenarios 4, 5, and 6 address the issue of reducing the rate of fertilizer application, which would hopefully lead to a decline in pollutants leaving the farm. An estimation of the impact of this management practice on the GM for the model farm was carried out. The result indicates that a 25% reduction in fertilizer applied resulted in a 14% reduction in GM.

Scenario number 4 concerns the in-field manure (fertilizer) management BMP. A relatively small reduction in commercial fertilizer resulted in a GM that was close to the status quo. Again, it would not require a large compensation payment to encourage the adoption of this BMP. This reduction in nitrogen application led to a reduction of nitrates in the groundwater by up to 20% below the pre-BMP level. However, further reduction in nitrate

Thomas Brook Economist	Research method	BMPs	# Farms or farmers participating
Emmanuel Yiridoe	Optimization model	• Restricted cattle access • Manure management • Farmyard runoff management	Survey of farmers for their ranking of management and site characteristics, motivations, and decision considerations with BMP adoption.

pollution (beyond the threshold level) resulted in substantial trade-offs in farm returns. A trade-off analysis between GM and nitrate pollution was performed which resulted in the following limits: For a GM of $29,177 (the base case status quo for the case farm) there was a N pollution level of 65.4 kg per year, and for a GM of $460,144 (extrapolated for the watershed) there was a nitrate pollution level of 230 kg per year. Thus, to reduce nitrate pollution levels there must be a substantial reduction in farm returns. The trade-off analysis was performed to see the extent of pollution and farm level GM resulting from extrapolating the base case farm across the whole watershed.

Aggregated Results

The economic component for each watershed site was not begun until 2-3 years into a 4-year study. Thus, the fullness of the economic data is not as complete as would be liked. Therefore, in many cases economic data were taken from published sources when actual site-specific data were not available. Thus, the results presented for each watershed are often not based on actual observed data values; rather they are estimates based on the models used and the assumptions explicitly or implicitly cited for these models. This means that most of the economic results must be seen as being preliminary and deserving of improvement with improved data input.

As mentioned previously, an inter-watershed comparison was not planned and a perusal of Table 8 shows that such a comparison would be difficult even if the same BMP were investigated in different watersheds[1]. In some cases establishment costs have been determined while in other cases annual costs have been calculated. In all cases but one it is acknowledged that farm costs will increase, or net incomes will decline, with the adoption of BMPs based on the available information. Thus, the adoption of these BMPs would be non-profitable and as such not be attractive to farmers.

The adoption of the permanent cover (grass) BMP resulted in conflicting impacts in the Lower Little Bow River watershed (reduced net income) and South Tobacco Creek watershed (increased net income). It must be acknowledged that not all benefits and costs were estimated in these two watersheds. This requires further investigation.

On-farm benefits of BMP adoption were derived in only one watershed, South Nation, and these were found to be large enough to more than cover the on-farm costs associated with the BMP, thus making it profitable and potentially attractive to farmers. In one other watershed, Thomas Brook, an on-farm benefit was associated with one BMP but this benefit was not large enough to cover the on-farm costs of that BMP. Other watersheds reported that on-farm benefits might be expected based on information in the literature, but as yet these benefits remain to be estimated.

There is a need for benefits to be estimated for more BMPs across more watersheds so that decisions concerning adoption can be made with full information. These benefits should eventually include both on-farm and off-farm benefits. Based on the information contained in this report, it appears that just one BMP in one watershed was found to be profitable, from a farmer‘s perspective. However, this number could increase dramatically if all benefits (private and public) were to be identified and estimated for all watersheds.

[1] Table 8 is a re-presentation of Table 1 including brief results for watershed/BMP combinations.

Table 8: BMP results – Costs and benefits (where known)

WEBs BMPs	Salmon River (BC)	Lower Little Bow River (AB)	South Tobacco Creek/ Steppler (MB)	South Nation (ON)	Bras d'Henri & Fourchette (QC) Laval	Bras d'Henri & Fourchette (QC) McGill	Black Brook (NB)	Thomas Brook (NS)
Riparian – Restricted cattle access (fencing)	• Expensive to install with capital costs of $8,000 - $9,000/km • Not profitable[1]	**Without Fencing** • Cropland conversion cost $408/ac • Implementation cost varies from $15,783 to $63,1302 • This reduces GM or cash flow by $14,591 ($377/ac) to $53,055 ($343/ac) **With Fencing** • Implementation reduces GM by $24,449 ($632/ac) to $200,12[1] ($1,292/ac)[2] • Not profitable		• Annual fencing costs vary by type from $3.35/m (page wire) to $1.23/m (barbed wire) • Annual cost of $61.14 for water pump and bowl over 20-25 years • Not profitable				• Expensive • Annual operating costs of $177.60 lead to a 13.4% reduction in GM • Can be partially off-set with improved milk yield and weight gain • Not profitable
Riparian – Off – stream watering (no fencing)	• Expensive to install with capital costs of $6,000 for each system • Not profitable	**Without Fencing** • Cost $33,465 or $84/cow • Implementation reduces GM by $32,834 ($82/cow) over 20 years **With Fencing** • Implementation cost between $55,924 ($140/cow) and $256,356 ($641/cow)[2], which reduces GM by $88,465 ($221/cow) and $320,194 ($800/cow)[2] • Cash loss per protected acre are $885 and $1,267, respectively • Not profitable						
Riparian area development or enhancement			• Riparian buffer strip cost $468/ac over 20 years • Not profitable		• Older farmers more likely to create these compared to younger farmers	• Not explicitly studied. (See Buffer Strips)		

WEBs BMPs	Salmon River (BC)	Lower Little Bow River (AB)	South Tobacco Creek/ Steppler (MB)	South Nation (ON)	Bras d'Henri & Fourchette (QC) Laval	Bras d'Henri & Fourchette (QC) McGill	Black Brook (NB)	Thomas Brook (NS)
In-field – Manure management		• Transporting manure reduced net income by $0.23/t of manure. If manure spread as recommended for crops, losses = $1.55/t of manure • Losses reduced if manure spread at triple/third rate • Not profitable	• Crop net returns reduced from applications of hog and cattle manure[3] • Not profitable		• Expensive to implement • Costs tend to increase along with an increase in size of animal unit • Not profitable	• The use of a dribble bar tends to increase as phosphorus and *E-coli* pollution levels are reduced • Not profitable		• Expensive • A substantial reduction in farm returns is required to reduce nitrate pollution levels • Not profitable
In-field – Zero vs. conventional tillage			• No clear winner between zero tillage and conventional tillage • Preferred choice is crop specific • Profitability unclear					
In-field – Crop rotation					• Expensive but cost declines as farm size increases • Not profitable	• A switch from corn to hay will decrease pollution • Not profitable		
In-field – Permanent cover		• Conversion cost for crop to grass of $408/ac • 20-year reduction in Gross Margin of $14,591 - $53,0552 • Not profitable	• Conversion from annual crops to permanent cover resulted in increased net income without consideration of livestock income and costs • Profitability unclear					
In-field – Reduced herbicide use					• Expensive • Cost declines as farm size increases • Not profitable	• Switch from corn to hay decreases pollution • Not profitable		

WEBs BMPs	Salmon River (BC)	Lower Little Bow River (AB)	South Tobacco Creek/ Steppler (MB)	South Nation (ON)	Bras d'Henri & Fourchette (QC) Laval	Bras d'Henri & Fourchette (QC) McGill	Black Brook (NB)	Thomas Brook (NS)
Runoff – Diversion and grassed waterways							• Annual breakeven cost of $84.38/ha • Uncertain	
Runoff – Farmyard runoff management								• Operating costs of $62.55/year • Adding diversion to restricted cattle access results in a 92% reduction in GM • Not profitable
Runoff – Holding pond			• Expensive • Capital costs of $29,928 and annual labour costs of $224 for irrigation • Not profitable.					
Runoff – Small reservoirs			• Not explicitly researched (See holding pond above)					
Runoff- Buffer strips/shelterbelts		• These are used as part of the BMP technique for the Riparian BMPs • Not profitable.			• Expensive • Cost declines as farm size increases • Of more interest to older and more educated farmers • Not profitable.	• Reducing linear metres in 1-m strips and increasing linear metres in 3-m and 5-m buffer strips reduces pollution • Not profitable	• Annual breakeven cost of $69.92/ha • Not profitable	
Drainage – controlled tile drainage				• Annual cost of $13.49/ac results in a 4.4% yield increase for corn (NPV of $116/ac) and a 7.4% increase in yield for soybeans (NPV of $161/ac) • PROFITABLE				
Probability of adoption of BMPs					See Table 4.			

[1] ***Not profitable*** means that no potential profit exists for these BMPs based on the present analysis which may not include an estimate of potential benefits.
[2] Depending on BMP system and level of protection required.
[3] Manure management was not explicitly chosen as a BMP for the South Tobacco Creek watershed.

Discussion and Conclusions

Pollution in its various forms, including agricultural pollution, is receiving more and more attention in the press. Thus farmers are being asked to address this issue in the way in which they operate their farms. In order to help them in this endeavour, Beneficial Management Practices (BMPs) have been identified as having the potential to alleviate pollution resulting from agricultural practices. A selection of BMPs was chosen for study in seven WEBs watersheds across Canada, where the watersheds were chosen to represent selected geographical and farm differences. These BMPs were subjected to biophysical analysis (agronomic and hydrologic) as well as an economic assessment.

The watershed economists submitted detailed research reports of their work, and this report is based on their individual findings. Each of the economic reports is technical in nature and thus suited for a specific audience. This summary has been written to disseminate the results of their work to a wider audience.

Information was generated in each watershed related to the costs associated with the adoption and maintenance of BMPs. Emphasis reflected an on-farm approach. It is clear that in virtually all cases the adoption of a BMP would add cost to a farm operation and thus reduce the farm's operating profit. Although all economists reported that benefits might be expected from BMP adoption, these benefits were estimated in only one watershed. More work thus needs to be done on this issue.

There are two possible ways to cover the BMP adoption and maintenance costs, which are: (a) setting a commodity sale price high enough to cover the increased costs, and (b) the payment of some form of compensation to the farmers/ ranchers so that they could be encouraged to adopt the BMP. The first of these might be possible if the buyers of farm output would pay more for a product produced using BMP technology as opposed to being produced without this technology. This would mimic the price premiums attached to organic products.

Two reports from the Bras d'Henri and Fourchette watersheds have begun to address the policy issues related to compensation payments that might arise from the adoption of BMPs. One report provides some guidance as to which farmers might be willing to adopt which BMP. The other report addresses questions concerning compensation that might have to be paid to farmers to offset costs that are associated with BMP adoption. It is clear that assessing compensation, while theoretically relatively easy, in practice would be a difficult task. Questions relate to (a) the amount of compensation that would be required to motivate BMP adoption, and (b) who would pay the compensation.

All of the above comments are presented in isolation to the valuation of benefits that might accrue to pollution abatement as only one of the studies (South Nation) estimated these benefits. If more estimates were generated as to benefits and benefactors (farmers, watershed residents, society at large) it might then be possible to rank the BMPs so that limited funds might be allocated to best advantage. It is recommended that further work towards the benefits of BMPs include even greater emphasis in terms of (a) absolute value, (b) who should pay (polluter or affected party), and (c) how the compensation should be allocated.

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Results from the Farm Behaviour Component of the Integrated Economic-Hydrologic Model for the Watershed Evaluation of Beneficial Management Practices Program

Summary of Phase 1 Progress

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Executive Summary

This report summarizes preliminary results from the Farm Behaviour component of the South Tobacco Creek Integrated Modelling Project (STC Project) which is being undertaken as part of the Watershed Evaluation of BMPs (WEBs) Program. WEBs is a partnership between Agriculture and Agri-Food Canada (AAFC) and Ducks Unlimited Canada (DUC) established to evaluate the economic and environmental performance of BMPs for water quality at the watershed scale.

Water draining from South Tobacco Creek eventually enters to Lake Winnipeg which is degraded from the cumulative effects of nutrient loading, particularly phosphorus. Many jurisdictions across the world, including Canada, use payments programs to encourage land owners to change land management practices in order to reduce non-point source pollution. BMP incentive programs in Canada, such as Greencover, rely on fixed payment schemes which pay producers a set amount for BMPs, regardless of costs or benefits. In order to improve the performance of payment programs many jurisdictions have instituted auction type mechanisms. The purpose of the Farm Behaviour component of the STC project is to examine the performance of various types of payment programs for BMPs relative to reducing phosphorus loads from STC.

Theoretical and empirical evidence from conservation auctions suggest that the performance of auctions depends on several factors which affect the bidding behaviour of producers during the auction, and therefore the cost-effectiveness of auctions over other types of payment programs. In particular, some producers actually benefit from BMPs, however under certain auction rules these producers would be paid the same amount as high cost producers; alternatively, producers with low costs of adopting BMPs may not always provide the greatest benefits in terms of pollution abatement depending on their location in the watershed, and physical features of their land.

We assessed the relative performance of different payment programs by developing producer response functions for adoption of Beneficial Management Practices (BMPs). Producer adoption responses under different incentive schemes were tested using experiments with student subjects and limited trials with producers. We examined four BMPs: construction of holding ponds, riparian management, forage conversion, and conservation till. The results of the adoption response experiments conducted under WEBS were used to draw preliminary observations on BMP policy design and form the basis for recommendations for further research.

The farm behaviour project focuses on addressing the following two questions:

1) Does BMP adoption at a given farm make the individual farm household better or worse off from an economic perspective?

2) How much will it cost the government to get farms to adopt BMPs under different payment programs?

Since producer heterogeneity is key to understanding the performance of conservation auctions, we examined the costs and benefits of BMPs at the individual farm level and developed on-farm costs for each BMP for each producer in the watershed. The basic components of the model are described below, however the details including underlying assumptions regarding baseline farm behaviour, are outlined within the body of the report. We used the on-farm cost model to generate aggregate cost functions for BMPs for the watershed and to parameterize the policy experiments related to conservation auctions.

Preliminary estimates of environmental benefits of individual BMP adoption were provided by Dr. Wanhong Yang using results from a SWAT model developed under a separate component of the South Tobacco Creek WEBS project. Based on this information, we were able to evaluate the performance of various auction formats in terms of cost effectiveness, distribution of payments amongst producers, and environmental benefit.

The results from the Farm behaviour component of the South Tobacco Creek project are preliminary, and are currently being refined. Therefore it is difficult to draw generalized conclusions at this point. Further experiments are being conducted to complete the data collection during FY 08-09 through Interim WEBS funding. Nonetheless main findings to date are summarized below:

1) The four BMPs assessed differ in terms of their cost as well as their ability to deliver environmental benefits. Unfortunately, there is no BMP that dominates across farms at all abatement levels. Farms have heterogeneous costs in terms of BMPs, and some farms are cost effective at supplying abatement using one BMP, but not another.

2) This suggests that if water quality benefits (e.g. phosphorus reduction) can be quantified through modelling by BMP and by farm, then water quality should be the contracting unit for the auction rather than the BMP. This would allow producers to select the most cost effective BMP for supplying water quality benefits, and then decision makers could allocate contracts based on ranking the costs of abatement.

3) At the next stage of the research we will test for synergies between farms – i.e., whether the joint production function for water quality between farms differs from the sum of individual production functions. This will have implications for how the payment scheme should be designed.

4) Incorporating _fairness‘ types of allocation rules for conservation dollars, such as maximum participation in conservation programs is inefficient in terms of cost and environmental benefits. If fairness, or using conservation payments as a form of extension to learn about on farm costs of BMPs is the goal of the auction, then fixed payment programs which are open to everyone may be more desirable.

5) The performance of the auction depends on the shape of the cost function for BMPs and/or pollution abatement, as well as whether uniform (pay everyone the highest bid) or discriminatory pricing (pay everyone their own bid) rules are applied. In future research we will be investigating to what extent we can generalize results about the performance of uniform versus discriminatory pricing rules in this context.

In conclusion, this research has allowed us to investigate individually the performance of incentive payments for individual BMPs. The results of the analysis provide us with a baseline of information by which we can begin to assess more complex conservation program issues, such as how to optimally select multiple BMPs within the watershed, and whether/how to spatially target BMPs.

On-Farm Costs and Benefits of BMPs

On-farm net costs of BMPs include direct costs (capital outlay and subsequent maintenance) and indirect or opportunity costs related to foregone revenues from business as usual. Benefits of BMP adoption include improvements in soil structure, texture, and nutrient availability. The methodology for estimating BMP follows four steps:

1) Estimating baseline or business as usual farm income (the opportunity cost);
2) Estimating changes in yields and costs for BMPs;
3) Projecting yields, revenues, and costs for assumed BMP for period 2006-18;
4) Calculating net farm income for the projection period.

The crop yield models revealed that the role of farm specific variables such as land quality and individual producer management techniques is in general large and statistically significant, suggesting significant BMP cost heterogeneity. Table 9 summarizes total adoption costs for each BMP, assuming that all producers in the watershed adopt. The final column of Table 9 summarizes the total budget we estimate is available to producers in South Tobacco Creek based on existing Farm Stewardship Program payment levels. The two columns together show that there is a significant budget shortfall if the goal is 100% BMP adoption in the watershed. Findings on BMP specific costs are outlined below.

Zero tillage

Zero tillage has a positive impact on wheat yield but negative impacts on yields for canola, and oats. The effect of zero tillage on barley and flax was not statistically significant; Zero tillage increases the cost of production for wheat. The combined effect of adopting zero tillage for crop yield and crop production costs is captured through a net income model, which shows that adopting zero tillage increases net income for wheat but decreases net income for barley, oats, flax and canola. The combined effect over the rotation is that increasing the level of adoption of zero tillage in the watershed will be costly. Furthermore, producers in the watershed indicated during a focus group that they find zero tillage costly because of wet conditions in the fields.

Forages

Forage yields and revenues increase with the amount of time forages are in the ground. At the same time, costs of forages decrease over time, although the reasons for this are not immediately clear. One reason could be that forage needs less fertilizer over time; however the decline in fertilizer use with time is not statistically significant. Indirect benefits of forage production come from improved soil nutrients. When combined with increased use of nitrogen in subsequent crop rotations, forages led to a future _yield boost' for wheat and canola crops of approximately 1.5 lbs/ac and 0.9 lbs/ac, respectively. Owning cattle significantly improved incomes on forage lands, possibly because cattle return forage nutrients to the soil. In terms of land characteristics, slope seemed to have a positive effect on income and a negative effect on cost of adopting forages – possibly because soils on slopes were less likely to be water logged. Overall *increased* forage conversion was costly for every producer, ranging from $7/acre/10 years to $608/acre/10 years. In addition there was greater variation in costs of forages than costs of zero tillage.

Table 9: Summary of estimated total costs of BMP adoption for South Tobacco Creek

BMP	Number of eligible producers in STC	Estimated total costs (10 year contracts)	Government budget (National Farm Stewardship payments)
Riparian mgmt.	6	$294,884	$100,434
Holding ponds	12	$112,462	$56,231 (~$57/head)
Zero-till	36	$1,444,175	$433,253 (~$94/acre)
Forage conversion	36	$2,860,727	$858,218 (~$62/acre)

Riparian management

Riparian management costs include costs of off-site watering devices and fencing, as well as opportunity costs associated with lost crop production. In total, six producers in the watershed had land that was eligible for riparian management. Costs of increasing the number of areas under riparian management increase linearly in the sample, suggesting that fencing costs and off-site watering costs overwhelm the variability associated with lost farm income from not cropping the riparian area. Riparian management costs range from $16,603/field/10years for a 16 acre field to $98,000/field/10years for a 100 acre field. Lack of heterogeneity suggests that riparian management is not a good candidate for using an auction as a price discovery mechanism. Instead payments based on observable fencing and watering trough costs should be considered. For this reason, riparian management was not considered for the policy experiments discussed below.

Holding ponds

There are currently 12 livestock producers in the watershed who could adopt holding ponds. Suitable locations for holding ponds were identified based on drainage area. The number of head of livestock was used to determine the required volume of excavation. The first six producers would require a total payment of close to $20,000 to fully cover the costs of excavation. Preliminary analysis of abatement costs for the holding pond BMP show a greater degree of heterogeneity in the *costs per unit abatement* versus the *costs per head* of livestock. The heterogeneity is related to the physical features of the farm landscape as well as the different production practices and operations on each farm. In addition, the ranking of producers in terms of costs per unit of pollution abatement is completely different than for costs per unit of livestock.

Adoption Rates of BMPs

Government programs for encouraging adoption of BMPs include education and awareness, appealing to stewardship motives, and cost sharing arrangements with producers based on fixed prices for practices. However, since producer costs for BMPs are heterogeneous, high cost producers tend to not participate in these programs, even if their contribution to pollution abatement might be significant. Furthermore, current uptake for at least some BMPs in Canada is low, suggesting greater incentives are required. The ultimate costs and benefits of conservation payment programs depend not only on private costs and benefits of BMPs that accrue to producers, but also on the way in which incentive payment programs are implemented. Based on Farm Stewardship Program schedules for fixed payment programs, we can see that there is a large gap between the amount of money available for BMPs through government programs and the cost to producers.

In order to allocate conservation budgets more efficiently, many jurisdictions have experimented with reverse auctions for conservation contracts (e.g. Bush Tender, Australia; Conservation Reserve Program, USDA). Auctions encourage producers to reveal private information about the costs of BMP adoption which can be used to improve performance of conservation programs. The performance of auctions is sensitive to the problem context and varies according to auction design features. We tested auction design features for three BMPs: zero tillage, forage conversion, and holding ponds. The design options tested in our experiments are summarized in Table 10.

Goal of the auction

Auctions may have different objectives. On the one hand the goal of an auction may be to maximize environmental benefits of BMP payments given a target budget. However an alternative goal may be

Table 10: Summary of experimental testing of auction design rules

Auction goal	Ranking rule	Holding pond	Zero till	Forage
Budget based	Max Participation	2 Uniform, 2 Discriminatory		
	Max Coverage	2 Uniform, 2 Discriminatory	2 Uniform , 2 Discriminatory	2 Uniform , 2 Discriminatory
	Max EBI[1]	2 Uniform, 2 Discriminatory		
Target based	Max Coverage	2 Uniform, 2 Discriminatory		
	Max EBI	2 Uniform , 2 Discriminatory		

[1] EBI refers to the environmental benefits index, which in this case is maximizing phosphorus abatement.

to minimize the costs of meeting a fixed environmental target. Different goals can affect the performance of the auction. The advantage of a budget constrained auction is that the program's cost is well-known in advance, there are no financial surprises and it can be easily planned. However, there is uncertainty about the level of environmental quality improvements that can be achieved with the budget based approach. The advantage with the target based approach is that there is more certainty about environmental quality, however costs are uncertain. In addition, producers can use assumptions about environmental quality goals to game' the auction.

Bid selection criteria

Bid selection criteria are the specific rules which are used to rank winners. Three bid selection rules were tested. ***Maximum Environmental Benefit*** (performance based) rules rank offers based on the maximum level of phosphorus abated per dollar. Unfortunately while this is the most cost effective way to meet an environmental target, it requires knowledge of abatement levels by field and farm, which is often not available to the decision maker. Also, the efficiency goal of the auction may be in conflict with the social goal of the auction which is to increase learning and participation in programs***. Maximum Coverage*** (activity based) ranking rules are used as a proxy for abatement when performance can't be measured directly. In this case programs are ranked according to the number of hectares (or alternative units) under a specific BMP. Finally, ***Maximum Participation*** rules rank offers based on the number of producers that adopt the BMP for a given budget. Note that many payment programs, including the Canadian farm stewardship program, focus on participation levels of producers as a measure of success";

Payment format

The payment format specifies whether everyone receives the same payment per BMP. Under uniform payments everybody receives the amount of the cutoff (highest cost) bid while under discriminatory payments everybody receives the amount of their own bid. These two payment formats affect the cost and political acceptability of auctions.

Criteria for evaluating results

Economic efficiency is the cost of abatement per unit of pollution. At the time of the experiments we only had abatement levels for the holding pond BMP so we were able to calculate this measure for all treatments employed for this BMP, but not for any others. This work is slated to be completed during the Interim WEBS project year, 2008-09. Dr. Yang's hydrologic model provided abatement levels of phosphorus, nitrogen and sediment. For the holding pond BMP these pollutants were highly correlated and linearly related. So we focused on efficiency in terms of cost per kg of phosphorus abated since phosphorus is a pollutant of significant interest in Manitoba.[1] We also report on the total amount paid to winning bidders above what their actual costs were. The surplus of payments over costs is referred to as an information **"rent"** which accrues to some producers who have better information about their costs than the government. Finally, we evaluate the auction formats based on the **environmental benefit**, measured as the level of phosphorus abatement where information was available. We refer to this abatement performance as EBI (environmental benefit index).

A priori, we expected that under the max participation strategy more producers would win the auction, while the max EBI approach would result in fewer winners than either of the other two ranking strategies. The max participation strategy with the uniform price rule was expected to yield the highest portion of rent. Indeed under the uniform pricing rule, a considerable portion of the total payment is rent, since producers receive the highest payment. It was not possible to calculate baseline rents for discriminatory pricing rules for this study.

Results

- The maximum EBI strategy clearly performs the best in terms of overall abatement. The discriminative pricing approach generated slightly less abatement compared to the uniform pricing strategy. However this finding is based on two experimental trials using each pricing rule, so we are reluctant to draw firm conclusions regarding the pricing rule design at this stage of our research.
- The maximum participation strategy performed quite poorly in terms of cost for both uniform and discriminatory pricing rules. This coupled with its overall lower level of abatement achieved suggests that it is not a good candidate for designing auctions for pollution abatement unless the goal is educational, or if the government is willing to pay a high premium to achieve other social objectives related to increased participation. We conclude

[1] This was also mentioned to us in meetings with WEBs management staff in Edmonton in August 2007.

from these findings that the maximum participation approach to selecting offers is clearly not a cost effective strategy for abating pollution in this watershed.

- The maximum coverage approach performs significantly better than the maximum participation approach and was a reasonable approach for auction design when performance based information is unavailable. The maximum coverage approach is much closer to meeting EBI in terms of costs.
- Preliminary evidence suggests that average costs of auctions per unit of activity, as well as by amount of abatement seem to vary depending on whether the auction uses uniform or discriminative pricing rules. The performance of one pricing rule over the other seems to depend on the shape of the cost function, and on the number of participants in the auction. Further research is required to fully understand the relationship between the shape of BMP cost functions and the performance of uniform versus discriminatory pricing.
- In the laboratory we examined the potential difference between fixed budget and fixed target auctions for the holding pond BMP. The results suggest that the budget constrained auction results in more cost effective conservation with uniform pricing rather than discriminatory pricing rules. However, our results are preliminary pending further rounds of experiments to confirm our findings.
- We were fortunate to be able to attend the 2008 Annual Meeting of the Deerwood Soil and Water Association on March 10, 2008. At this meeting we were permitted to bring our laboratory and host three sessions of experiments with producers and several other participants. These sessions were not strictly the same as those we ran at the University of Alberta with students as it was impossible to tightly control the conditions. The final auction conducted during this meeting provided some interesting, if non-conclusive results. In particular, prices converged to the expected price for both the students and the producers, mirroring similar comparative findings emerging from Australian and US research.

Implications for Future Research

- Our auctions to date have involved single BMPs. While this was necessary given the information we had and the need to establish policy baselines it is apparent that the combined effect of BMPs on producer costs and cost effective environmental improvements must be considered in future experiments. In other jurisdictions producers face a —menu" of BMPs and select one or more from this list given the available incentives. In order for this to occur we first need to develop an overall abatement supply function for the STC watershed possibly including more BMPs such as wetland retention and restoration. Continuing on this vein, spatially explicit models of BMP adoption should be considered. Spatial optimization model can be used to develop auction targets. In considering auctions in this framework, —smart markets", where an optimization model is included in each auction round to select winning offers, should be considered.
- The experiments conducted to date have not allowed communication among the players. This is obviously an unrealistic situation as producers often share extension information, and are also likely to share information about the auction. This could undermine the competitiveness of the auction. In addition, policy options should be expanded to test could include some group incentives. Watershed associations are growing in number in Canada and devolving some responsibility for pollution abatement to the local level may be worthy of examination. In future we propose to examine group payment strategies and to understand how to develop auctions to reduce opportunities for players to collude (or to collude for environmental benefit).
- This research has allowed us to examine experimental approaches for evaluating auction design, and understand their strengths and weaknesses. As a result of this work we have developed a mobile experimental computer laboratory that we tested at the Deerwood annual meeting. We think that further experiments with producers need to occur, and having this lab will greatly facilitate this endeavour.
- Auctions for conservation contracts are appealing because they capture private information about individual costs to producers of BMP adoption. However while heterogeneity of producer costs make auctions attractive, at the same time this heterogeneity affects the performance of auctions under different types of auction formats and rules. Therefore it is important to ‗test bed' auctions for specific applications prior to policy implementation.

WEBs Metadata - Final Report

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Acknowledgements
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Executive Summary

Overview of WEBs

The Watershed Evaluation of Beneficial Management Practices (WEBs) is a national project launched in 2004 to evaluate the environmental and economic impact of selected agricultural beneficial management practices (BMPs) at a watershed scale. WEBs studies are taking place at seven watershed sites across Canada. The project consists of four major components: biophysical evaluations, economic evaluations, hydrologic modelling and integrated modelling.

WEBs is led by Agriculture and Agri-Food Canada, while Ducks Unlimited Canada has contributed significant funding and 40 other partners contribute technical and in-kind assistance.

WEBs data management needs

Data management needs were discussed at the first WEBs Annual Technical Workshop in February 2005. The project required a means of data management to ensure data tracking and sharing with a high level of data security.

The original WEBs data management proposal included data centralization and researchers would receive assistance cleaning and organizing their data sets. However, researchers and data owners expressed concern over confidentiality and security, ownership, and intellectual property and publication rights. A centralized data storage system was therefore deemed inappropriate for WEBs.

The approach taken

A viable solution to WEBs data management needs is the use of ‗metadata‘ to track, manage and share the data collected in the project. Metadata is data about data; a means of describing the data that has been collected and analyzed without compromising data security and confidentiality.

Publicizing metadata informs others of the research conducted in a particular location and in a particular discipline. Benefits include avoiding duplication in data collection, promoting collaborative opportunities in research, and providing data collection guidelines to WEBs watershed projects.

Securing the metadata

Questionnaires were created for each of the major disciplines of the WEBs project: environmental conditions (hydrology, water quality and geospatial data), economics (e.g. livestock, land use, agronomics, input prices, machinery costs, commodity prices and items in the questionnaire developed as a guide to secure data from producers), modelling, and demographics (age, gender, education, family, external employment and location of residence).

The questionnaires were geared towards addressing the multiple disciplines and their diversity of surveys and specific analytical approaches, the diversity of the landscapes being studied, the diversity of the BMPs being tested, and the variety of farming enterprises and watershed demographics.

There exist several standards that describe what to include in a metadata entry in the fields of biology and geospatial studies. These standards were also taken into consideration in developing the metadata. Format and questions were geared towards the complex multi-disciplinary nature of the project and its data management needs. This complexity includes the multiple disciplines and their diversity of surveys and specific analytical approaches taken, the diversity of the landscapes being studied, the diversity of the BMPs being tested, and the variety of farming enterprises and watershed demographics.

Sample questionnaires were first circulated to WEBs researchers for their input, and for testing of questionnaire clarity and completeness.

WEBs metadata products

Various products resulted from the WEBs metadata development process. Questionnaire responses were summarized into tables which can lead to the development of metadata publications, both internally to WEBs and externally to public and other research groups through papers such as this one. The economics metadata survey can provide new WEBs economists with examples of the types of on-farm financial data that they might consider collecting without having to request financial statements. The demographics data let WEBs researchers assess the propensity of producers to adopt BMPs. Both the metadata responses and questionnaires can be considered products of WEBs with the potential for future development of an online WEBs metadata database.

Lessons learned

Once an approach was found that avoided the need for a centralized database, WEBs researchers agreed with the use of metadata as a means of data management. With the exception of the modelling groups, the response rate to filling in the questionnaires was 100%, though deadlines for metadata completion were well exceeded by most sites. While response rate was 100%, deadlines for submission were greatly missed and it was determined that getting early buy-in to such a process was a necessity.

Conclusions

The value of the current metadata collection and process to WEBs is three-fold. First, metadata provides a means of data management and tracking without infringing upon privacy issues or data confidentiality. Second, by making existing study sites aware of the type of work being done elsewhere, all sites are familiar with what others are doing and may choose to adjust their individual approach accordingly. Finally, WEBs metadata questionnaires could help other watershed projects with their analysis of the effects of BMPs on water quality.

The development of a metadata management strategy for a multi-disciplinary project such as WEBs can be useful to other studies examining water quality, economics, modelling and associated changing management practices in agricultural watersheds. As with the development of metadata clearinghouses for biological and geospatial sciences, coordination with other groups performing similar research could contribute to the creation of a metadata clearinghouse for information collected at a watershed level.

Future developments

While the WEBs metadata protocol has addressed the project‘s data management needs, there remain some weaknesses. These include the need to: incorporate the use of commonly accepted terminology, clarify definitions surrounding the grading or rating of data quality and availability; and secure timely cooperation from researchers for completion of questionnaires. These weaknesses can be addressed through the development of an enhanced metadata protocol, and through communicating the benefits of metadata to individual watershed sites and the project as a whole.

Introduction

The Watershed Evaluation of Beneficial Management Practices (WEBs) is a national project which commenced in 2004. WEBs involves seven watersheds across Canada, with the goal of evaluating a number of beneficial management practices (BMPs) at the watershed scale in terms of water quality and economic costs and benefits. To date, the effectiveness of BMPs has been tested primarily on plots or small fields, with the effects of BMPs being evaluated at the micro-watershed scale. These results are to be extrapolated to larger watersheds using modelling techniques.

WEBs projects are being undertaken with the participation of various partners and the landowners/producers in each watershed. Funding was provided largely through Agriculture and Agri-Food Canada's Greencover Canada program, with Ducks Unlimited Canada as a major funding partner. To provide an insight into the scope of the WEBs project, each of the watersheds and its associated characteristics, needs, and environmental concerns are briefly discussed by region, below.

Western Canada

Salmon River: The 150 000 hectare Salmon River watershed is located in south central British Columbia and consists of livestock (cattle and dairy) and forage production. The management practices under investigation along three 3-5 km-long transects of the river are livestock-based, consisting of off-stream watering and restricted cattle access to stream banks.

Lower Little Bow: In south western Alberta, within a 2600 hectare subset of the 55 664 hectare Lower Little Bow River watershed, WEBs is examining the effect of buffer strips, manure management, conversion of annual crop land to forage, and off-stream watering (with and without fences) on water quality. This watershed contains a mix of: cow-calf operations, dryland and irrigated row-crop farming, and intensive livestock operations.

South Tobacco Creek: A 260 hectare WEBs sub-watershed within the larger 7500 hectare South Tobacco Creek watershed in south central Manitoba is examining the BMPs of: conversion of annual crop land to forage; enhanced riparian areas; holding pond development for cattle containment areas; and small reservoirs to reduce nutrient loading. Zero tillage and conventional tillage practices are also being investigated. The land use in the watershed is annual crops and forages and cattle, with some specialty crops grown.

Central Canada

South Nation: The South Nation watershed, near Ottawa, Ontario consists of 381 000 hectares of land, of which approximately 60% is farmed with a mix of livestock and cash crops. The WEBs study on two sub-watersheds of 450 hectares each, is examining the effect of restricted cattle access and controlled tile drainage on water quality.

Bras d/Henri/Fourchette: Consisting of two micro-watersheds of 300 hectares each, the Quebec Bras d'Henri/Fourchette project is examining the effect of crop rotation, reduced herbicide use, hog slurry management and surface run-off control on water quality.

Atlantic Canada

Black Brook: In the Black Brook watershed, in north-western New Brunswick, vegetated riparian zones and grassed waterways are being investigated for their influence on water quality. Of the 1450 hectares that make up the watershed, 65% was under agriculture with 50% of this growing potatoes in rotation with grain, peas or forage.

Thomas Brook: The Thomas Brook watershed is located in the Annapolis Valley, consisting of 760 hectares of land. Mixed agricultural practices in Thomas Brook include tree fruits, berries and vegetables along with corn, soybeans, grains and pastureland. Nutrient management plans and farmyard runoff management are the two main BMPs that are being examined in this watershed.

WEBs Data Management Goals

The goal of data management in WEBs is to develop a means of centralizing a similar level of data accounting for all watersheds. Given the inability to house complete data sets in one location for reasons related to confidentiality and privacy, as well as data ownership issues, another means of data management needed to be approached. Metadata (i.e., a dataset about the data) filled this data need and participation from the WEBs watersheds was expected to be 100 percent.

The description of the watersheds in the introduction of this report is, in a way, metadata. There are a number of methods to report metadata, depending upon the data that is being collected. A metadata record generally consists of a number of elements that describe the subject being examined. These cover the "who, what, why, when, where and how" of the research. Questions

answered by metadata include: who produced the data, what the data consists of, why the data was collected, how reliable the data is, how the data might be accessed and what restrictions there might be on the use of the data.

The goal of this report is to provide the reasoning behind metadata collection to WEBs participants and partners, and to circulate the metadata collected to date.

WEBs data management issues

Large data sets

The data sets associated with the WEBs project can be quite large. The number of years that data was collected in each watershed is shown in Table 11. Typical data sets consist of about five years of hydrologic information and only about one year of economic data—with two extreme exceptions—the South Tobacco Creek and Black Brook watersheds. At the South Tobacco Creek watershed, for example, the pre-study, on-farm field data collected over 16 years includes more than 100 variables such as yield, land management practices and chemicals applied, for more than 350 fields. Nevertheless, although these variables were available for use in the economic analysis (for example), similar economic and/or hydrologic data had not been simultaneously collected. Hence, due to the diversity of background data collection within the WEBs watersheds, the data sets available for economic and hydrologic analyses between watersheds vary greatly.

Centralized data storage concerns

The concept of WEBs data management was conceived at the first WEBs Annual Technical Workshop in February 2005. The proposed data management protocol was to involve data centralization combined with help from data management personnel in cleaning up and organizing data sets. However, this approach raised a number of concerns amongst researchers and data owners regarding the centralization of WEBs data:

Intellectual property rights - The foremost concern came from biophysical scientists and economists regarding intellectual property rights, including their data sets being made available to others before research, analysis and papers were completed. Though a concept of access restriction and password protection of data was proposed, participants in the WEBs project felt that there was too much at risk to proceed with a centralized database.

Confidentiality issues - Many of the WEBs watershed leads require written confidentiality agreements with local producers who wish to keep their farming practices private (i.e. names and land identifiers linked to individual producers cannot be revealed).

Data ownership - While much of the data collected was initiated under the WEBs project, several sites had data collection that commenced well before WEBs was conceived. Additionally, data is used in the WEBs project that is collected through provincial, federal, university and

Table 11: Years of data for watersheds in WEBs project

	Hydrologic/Environmental			Land Use/Economic		
	Start	**End**	**Total**	**Start**	**End**	**Total**
Salmon River	2004	2008	5 years	2007	2007	1 year
Lower Little Bow River	2004	2008	5 years	2005	2006	2 years
South Tobacco Creek	2004	2008	5 years	1991	2006	16 years
South Nation	2004	2008	5 years	2007	2007	1 year
Bras d'Henri	2004	2007	4 years	2007	2007	1 year
Black Brook	1992	2007	16 years	2006	2007	2 years
Thomas Brook	2004	2008	5 years	2007	2007	1 year

cooperation programs, with WEBs not owning the data. Hence, centrally storing this data under the WEBs name would not be appropriate.

Concerns related to the centralization of data sets are not limited to researchers and data owners. Time requirements - Due to the size of the project and the variability between sites in terms of data collection and reporting, development of a centralized database would be a time consuming task.

Diversity of data sets- Each component (environmental, economic, hydrologic) of each watershed had its own list of data requirements, and these separate components are stored and analyzed data in a method that was most practical for their watershed. Due to the diversity of the watersheds (as previously discussed), this translates into very diverse data sets.

Comparative analysis - A centralized database wherein data could be queried and compared, would require that data be comparable between watersheds. For example, the yield of canola at one site might be reported in bushels per acre while another site maintained their data in tonnes per hectare. Or a hydrologic variable having the same unit of measurement might be sampled/tested differently. Thus, there is always the risk that database users will make comparisons between —non-comparable data", thereby drawing incorrect conclusion.

Minimum data set needs

The WEBs data management proposal included the concept of a minimum data set, wherein a common set of variables across all WEBs watersheds would be collected and reported in terms of standard units of measure and coding, based upon a pre-defined protocol. A committee of experts in the appropriate fields would develop a protocol for the biophysical/environmental, economic, and hydrologic components in order to meet minimum criteria for anticipated analytical work in WEBs. Each of the current WEBs watersheds and those applying in the future would be expected to meet these minimum data collection standards. Any additional data collected at the sites due to varying local practices or environmental concerns would not be held to this data collection protocol.

In terms of chemical water quality properties, such a minimum data set was established at the beginning of WEBs, as reflected in most current watersheds (Table 12). It was, however, recognized that the development and implementation of such a protocol for other project components (i.e., economic, hydrologic) in the middle of the project could be difficult. Additionally, many watersheds had data dating back years before the inception of the WEBs project, so requiring data that conformed to a centralized protocol might not be retroactively available. However, the development of a future guideline or protocol, which drew upon the strengths of that data already being collected within the existing seven existing WEBs watersheds, could prove useful for watersheds joining WEBs.

Metadata and WEBs

Metadata is a means of documenting the work that has been done. Publicizing and publishing metadata informs others of the research conducted in a particular location and in a particular discipline. This can be very important to both the researchers and the community in which the research is being done, as it informs others of work completed and can help avoid duplication and promote collaboration and partnerships.

Benefits of metadata

The numerous benefits of metadata to the WEBs project are discussed below.

1) **Extension of data life and validity:** Strong metadata can extend the life and value of data by making it available to others well after the project has been completed. For a government agency, metadata can help limit repeated collection of the same data and the required funding to do so.

    - Although the development and maintenance of metadata might have administrative costs, these can be far less than that of re-collecting the same data for future work. A value can be placed on metadata based upon the age and character of the data holdings, without having to spend time and money on investigating the actual data set. It can then be determined whether a stored data set should be maintained, updated or removed from the system.
    - Metadata can extend the life of the work and data sets of retired researchers. It can provide a sense of continuity, allowing for the researcher to consider retirement options without worrying about what will become of their work.

2) **Data inventory:** In a larger scale, multi-agency research project such as WEBs, metadata can provide a means of data

Table 12: Water quality parameters

		Salmon River	Lower Little Bow	South Tobacco Creek	South Nation	Bras d'Henri	Black Brook	Thomas Brook	
Water chemical	TP	YES	YES	YES	YES	YES	YES	YES	7 out of 7 sites collected this type of data
Water chemical	TDP	YES	YES	YES	YES	YES	YES	NO	6 out of 7 sites collected this type of data
Water chemical	TPP	YES	YES	YES	YES	YES	NO	NO	5 out of 7 sites collected this type of data
Water chemical	DRP	NO	YES	YES	YES	YES	NO	NO	4 out of 7 sites collected this type of data
Water chemical	TN	YES	YES	YES	YES	YES	YES	NO	6 out of 7 sites collected this type of data
Water chemical	TDN	YES	YES	YES	YES	YES	NO	NO	5 out of 7 sites collected this type of data
Water chemical	TPN	YES	YES	YES	YES	NO	NO	NO	4 out of 7 sites collected this type of data
Water chemical	NO3N	YES	YES	YES	YES	YES	YES	YES	7 out of 7 sites collected this type of data
Water chemical	NH4	YES	YES	YES	YES	YES	NO	NO	5 out of 7 sites collected this type of data
Water physical	Sediment	YES	YES	YES	YES	YES	YES	YES	7 out of 7 sites collected this type of data
Water physical	Turbidity	YES	YES	YES	YES	YES	NO	YES	6 out of 7 sites collected this type of data
Water physical	pH	NO	YES	YES	YES	YES	YES	YES	6 out of 7 sites collected this type of data
Water physical	Temperature	NO	YES	YES	YES	YES	YES	YES	6 out of 7 sites collected this type of data
Water physical	Stream Water Depth	NO	YES	YES	YES	YES	YES	YES	6 out of 7 sites collected this type of data
Water physical	EC/Conductivity	YES	YES	YES	YES	YES	YES	YES	7 out of 7 sites collected this type of data
Water physical	DO	NO	YES	NO	YES	YES	NO	YES	4 out of 7 sites collected this type of data
Water pathogens	Fecal coliforms	YES	YES	NO	YES	NO	YES	NO	4 out of 7 sites collected this type of data
Water pathogens	*E. coli*	YES	YES	YES	YES	NO	YES	YES	6 out of 7 sites collected this type of data
Water pathogens	Total coliforms	YES	NO	NO	YES	NO	YES	YES	4 out of 7 sites collected this type of data

inventory and organization, and can help facilitate the exchange and use of data and ideas between participating partners.

3) **Data publication:** Metadata provides an additional means of generalized publication prior to and after the completion of reports and analysis. This reduces the chance of compromise to intellectual property and avoids privacy and data ownership concerns.

4) **Sharing data and experimental processes:** Through internal sharing of metadata, individual WEBs watersheds can quickly observe what types of information are being collected at other sites without the need for referring to reports, documents or data sets. A project-wide metadata summary can allow for comparisons between sites, and the future development of an on-line, Internet-based metadata service for WEBs might allow for searching of specific components related to WEBs data and data collection.

5) **Training for new WEBs watersheds:** New WEBs watersheds could make use of existing metadata from the original sites to see what has been collected at sites similar to theirs, and perhaps even see what was missed in the data collection. Data collection protocols in these new watersheds can thereby build on the experiences of the original seven watersheds.

6) **Data security:** Metadata provides data security and can also help track the use of data. In a situation where a data holder is unable to access needed files, metadata can indicate alternate contact information. Alternatively, in a situation where a data holder may leave their position, the metadata will indicate where unfiled data is to go, whether it is to another person or into data storage. The existing metadata questionnaire encourages researchers to plan for these possibilities.

7) **Collaborative partnerships:** Publishing WEBs metadata will allow other researchers who may be considering doing work in WEBs watersheds to see what data has already been collected, possibly resulting in collaborative partnerships. Relationships between researchers and the watershed population can be enhanced by limiting the number of times that watershed inhabitants are approached for data.

Metadata standards

Reporting of metadata is often set to discipline-specific standards with very specific structure and terminology, allowing for ease of metadata storage, comparison and access. There are three main metadata standards: Dublin Core; USGS FGDC Biological Data Profile; and ISO 19115. Descriptions of these standards are available on the Internet. A large number of data clearinghouses/catalogues are available for the disciplines of geospatial studies and biology, so by maintaining a minimum structure with pre-defined terminology, comparisons between metadata entries can be made. Catalogues are often presented on the Internet with an interface developed for the intended audience. A few examples of web-based metadata catalogues include: NBII metadata clearinghouse (http://mercury.ornl.gov/nbii/), GeoConnections Discovery Portal (http://geodiscover.cgdi.ca/), and RésEau – Building Canadian Water Connections (http://map.ns.ec.gc.ca/reseau/en/). Each of these catalogues allow for public documentation of research—providing an alternative means of ~~a~~advertising" what has been done within a project.

As mentioned above, there are several standards for what to include in a metadata entry in the fields of biology and geospatial studies. While WEBs work covers both of these disciplines, several other aspects to the project are not covered by these standards.

How WEBs Metadata Was Secured

During the WEBs metadata development process, the need to create discipline-specific information and questions that would describe all aspects of the project was considered. Questionnaires were based upon the metadata standards previously mentioned and discipline-specific questions were tailored to the work being done in the project. Sample questionnaires were first circulated to WEBs biophysical scientists, economists and hydrologic and integrated modellers for their input, and for testing of questionnaire clarity and completeness. Very few changes were suggested and very few questions of clarity were raised.

The questionnaires were developed in Microsoft Word, utilizing drop-down menus, for the purposes of maintaining constant terminology while providing blanks for unique information entry. Figure 2 shows

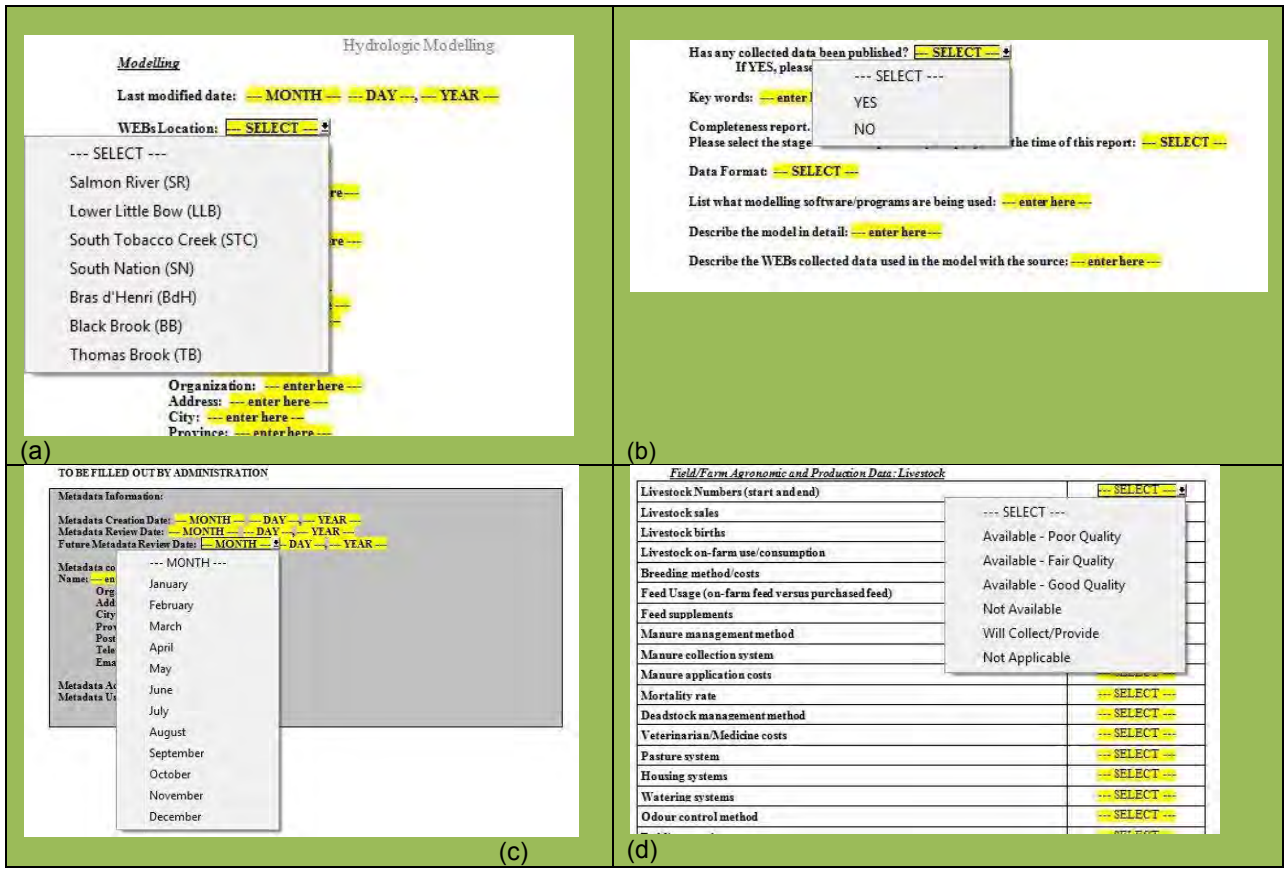

Figure 2: Showing views of the WEBs metadata questionnaire: (a) Location details, including the drop menu for the name of the watershed; (b) Publications to date, along with additional questions related to modelling details; (c) Metadata creation information, including report author; and (d) an example of the agronomic data (livestock) and the relative quality of the data collected in the watershed.

a few examples of the drop-down menus and format of the questionnaire that was circulated in December 2006. For the purpose of showing the content of questionnaires in this report, these are illustrated as a ‗fill-in-the-blank' and ‗check-off-the-best-response format'.

Once the questionnaires were approved, an information package was sent to all WEBs participants, including the questionnaire specific to their discipline. This was done a few months prior to the February 2007 WEBs Technical Workshop with the hopes that the process of filling in the forms might begin. After the workshop participants were given deadlines by which they were to complete their forms. A second circulation of the questionnaire occurred one year later so that those involved would have an opportunity to update their metadata profile.

General information requirements

The general questions asked of all WEBs participants are based upon those typical to most metadata standards and are significant to WEBs and its data management goals. While location is a major component in many metadata standards, in WEBs this particular location component is limited to the name of the watershed reported on in each questionnaire. The geospatial boundaries of the watershed are reported within the Environmental/Hydrologic portion of the questionnaire.

The questionnaires included the dates when data was collected, and when the metadata was created and modified. The data collection dates for each of the watersheds differ somewhat (Table 11). Respondents were also asked to estimate the

frequency of updates,—whether annual, monthly or never (in cases where the research has concluded).

Primary and alternate contact information includes name, organization, address, telephone number and e-mail address. Similar information can be provided for the individuals who maintain the data set if the primary/alternative contacts are not involved in that aspect of the data. Respondents were asked to indicate where data is stored—the address and/or a means of storage such as computer, hard copy or CD/DVD. Respondents were also asked to provide a description of the protocol for data transfer, should any of the contacts or data keepers leave their positions.

Contributor recognition
Acknowledging the contributors to the data set informs metadata users of others who might have information, either on the data or how it was collected or analyzed. Additionally, inclusion of contributors in the metadata gives recognition for work done.

Data sharing, ownership, and confidentiality
The questionnaire asked respondents to describe the ownership of the data set and to estimate the percent that is confidential. If the data is not confidential, what are the access and use restraints placed upon it? Respondents were to include preferred method of data transfer, either through mail service for CDs or DVDs or electronic storage devices or communications such as e-mail or a secure website. The format of the data (e.g. spreadsheet or electronic database) was also requested to allow metadata users to determine if they have the infrastructure (software) to utilize the data. Electronic format is also important in terms of how each site is storing data should a centralized WEBs database be developed.

Source of data
In some cases, WEBs sites used previously-published data and the metadata questionnaire asked respondents to indicate their sources by citing publications and the years of the study covered by those publications. This information tells users that the data are not original observations and credit is given to those who originally collected the data. Additionally, citations for respondents‘ previously-published data and results were included in the questionnaire, to allow metadata users to determine the data‘s level of appropriateness to their work/project.

Data processing, analysis and modification
Respondents were asked to describe the method of data analysis as well as the software used in analysis. There was no specified length or requested detail to the description required. Dates of data processing and the name and contact information of the person processing the information were also requested. Where external data were used, respondents were asked to detail the source(s).

The metadata questionnaire concluded with a request for keywords and a percentage of project completeness. A section dedicated to the metadata/data management administration was also included in each of the metadata questionnaires. This administrative data included: dates of metadata creation, metadata review and proposed/estimated future reviews, metadata administration contact information, and a listing of metadata access of use constraints.

Data availability – grading system
In both the Environmental Conditions questionnaire (which includes climate, geospatial and hydrologic information), and the Economics metadata questionnaire, respondents were asked to describe much of the data collected in their associated watershed in terms of a data grading system:

- Available – Poor quality
- Available – Fair quality
- Available – Good quality
- Not available
- Will collect
- Not applicable

There was no defined protocol for the grading system, so responses were based upon individual opinions.

Specific questionnaires

Environmental conditions
In the Environmental Conditions questionnaire, respondents or site leads were asked to describe each of the WEBs BMPs being studied in their watershed. There were no restrictions on terminology or length of the description. Bounding coordinates and minimum and maximum altitudes were requested. A geographic description of the watershed was also requested; however, specific terminology was not enforced. The questionnaire also requested information on the watershed‘s climate and infrastructure using the ‘data availability‘ grading system described above. Climate-related data included: precipitation, temperature, humidity, solar radiation and wind speed/direction, while the infrastructure section included: building and road locations and soil type. Respondents could enter additional data collections that were not on the list of selections.

As WEBs involves the investigation of water quality and hydrologic data, in 2005 the seven WEBs watershed leads were asked to complete a table (Table 13) with the types of hydrologic, soil and water quality data being collected, including the methods used to collect and analyze the data. This information was intended to assist in confirming appropriate methods for data collection and to ensure consistency of reporting from site to site. As a part of developing the WEBs metadata, these tables were included in the metadata in order to show others what was done at each site and as the easiest way of describing the significant levels of data that were collected. Site leads were asked to describe the type of sampling procedure and lab analysis, whether concentrations or loadings were evaluated, detection limit, frequency of collection and analysis, the lab used for analysis, collection dates and whether the data was obtained through original observations or from an external source - perhaps something published or a collaborative work. The questionnaire included 29 different data variables, with sections for additional site-specific data.

Economics questionnaire

The questions specific to the economics metadata were developed under the ‗data availability' grading system described above. WEBs site economists were asked to rate the data availability for topics such as livestock, land use, agronomics, input prices, machinery costs, and commodity prices. The items in the questionnaire were based upon a survey originally developed as a guide for WEBs economists to help secure appropriate data from producers in each of the watersheds. The current metadata survey was developed to provide economists starting anew in the watershed with examples of the types of data that they might consider collecting from their associated producers, without having to request financial statements.

While the initial survey provided economists with a very general set of potential maximum economic variables to collect, many of the watersheds proceeded on parallel paths, pursuing similar subsets of the potential maximum. Utilizing the original survey to develop the metadata questionnaire ensured that all data already potentially being collected within the WEBs watersheds was included. The metadata questionnaire included space for the economists to record watershed-specific data that were not included in the original WEBs economics survey. While many of the items may seem to have limited economic analysis value, this information can be used in the development of economic models to estimate cost-return functions for agricultural practices in each of the watersheds.

Table 13: Hydrologic and water quality variables for metadata

Water – Chemical	Water – Physical	Water – Pathogens	Soil	Snow	Plant
Total Phosphorus (TP)	Sediment	Fecal Coliforms	Total Nitrogen (TN)	Total Nitrogen (TN)	Surface Residue
Total Dissolved Phosphorus (TDP)	Turbidity	*E. coli*	Total Phosphorus (TP)	Nitrate (NO3-N)	
Total Particulate Phosphorus (TPP)	pH	Total Coliforms	Nitrate (NO3-N)	Ammonia (NH4-N)	
Dissolved Reactive Phosphorus (DRP)	Temperature		Ammonia (NH4-N)	Total Dissolved Nitrogen (TDN)	
Total Nitrogen (TN)	Stream Water Depth		Available Phosphorus		
Total Dissolved Nitrogen (TDN)	EC/Conductivity				
Total Particulate Nitrogen (TPN)	Dissolved Oxygen(DO)				
Nitrate (NO3-N)					
Ammonia (NH4)					

Demographics:
The economics metadata questionnaire also included space for data on the demographics of the watershed. Part of WEBs project objectives is to examine the propensity of producers to adopt BMPs in their daily operations based upon demographic information such as age, gender, education, family, external employment and location of residence. While this part of the project was not assigned to the economists, data collected through surveys of the producers could permit this additional information to be collected.

Hydrologic and integrated modelling questionnaires

The metadata questionnaires for the Hydrologic and Integrated Modelling components were much less complex than the Environmental Conditions and Economics questionnaires. This, because much of the data being used by the modellers would have been described in the Environmental Conditions and Economics questionnaires. WEBs modellers were asked to list any external data, and its source (additional to that collected under WEBs) along with a detailed description of their model. The terminology to be used in the model description was not limited, nor was the length of the description.

The modellers were also asked to list any software that was used in the modelling process. The Integrated Modelling metadata also asked for a listing of the data used from each of the WEBs sites in development of the integrated model—or if data was obtained from an external source, to list the source. For the purpose of publicizing the work of the integrated modelling, the integrated modelling questionnaire also provided space for listing a URL/website.

Possible Methods of Metadata Publication

Two of the many methods of metadata publication are discussed below.

Metadata Database

Many online clearinghouses allow users to search databases for the relevant metadata, which is then linked to a site containing the actual data. This type of clearinghouse system is not possible for the WEBs project for a number of reasons listed previously:

- There are privacy, ownership and confidentiality issues related to many of the WEBs data sets. Development of a database that housed all the metadata but provided only limited access to the data sets was deemed useless.
- The scope of the WEBs project prevented the use of metadata standards that are required by many of these data clearinghouses.
- Many of the clearinghouses are related to a single field of study, whereas the WEBs project covers a number of disciplines.

It may be possible in the future to take some aspects of WEBs data, such as the geospatial data, convert it to a metadata standard, and then place these metadata entries into a clearinghouse. This would allow WEBs data to reach new audiences.

Metadata Website

A WEBs metadata website would be a simple search engine to look into metadata entries and permit a comparison between watersheds. Such a website could be developed, perhaps based upon an Internet site such as Statistics Canada where each selection in the search engine brings up another set of variables for users to consider. For example, users can select one or more or all of the WEBs watersheds, then select a discipline (Environmental Conditions or Economics) from which they might choose a number of variables to examine. Such a website could have links to available data sets or connections to watershed contacts to obtain access to the data sets, assuming that users meet the Use and Access Constraints listed in the metadata. While such a website has not been developed, a means of metadata publication is required to show the work that has been performed in the WEBs project. This report provides that means of publication until an alternative method can be found that will reach a much broader audience.

The Reality of Instituting Metadata for WEBs

Response to the concept and application of WEBs metadata by the WEBs participants varied from the time of conception to the time of completion. Once an approach was found that avoided the need for a centralized database, participants agreed with the use of metadata as a means of data management. This cooperation was perceived to have continued through the review process of the WEBs metadata questionnaires, during the development stages when sites were asked for their opinions on content. No positive or negative comments were received.

In late December 2006, participants were asked to look at their respective questionnaires and voice their concerns and questions at the February 2007 WEBs Technical Workshop. While the content of the questionnaires was not criticized, a number of WEBs participants voiced that they did not have time to complete the questionnaires. While it was not believed that completion of the metadata would take a great deal of time, only one site had completed the survey. This site indicated that completion of the questionnaire had only taken a few hours.

Most of the time required to compile the metadata set was needed for the retrieval of data responses. It was acknowledged by those polled that much of the questionnaire for the Watershed Leads (Environmental Conditions) had already been completed; however, this still did not quell concerns related to the time that would be required. Deadlines were set and many of the sites met these goals. A few sites required additional negotiation to obtain replies—with two of the sites not completing their Environmental and Economics questionnaires until a year later, well past proposed deadlines. The response rate from the WEBs modellers was not as strong, with only three of the possible eight questionnaires being completed and returned by the initial deadline.

Comparison of reported metadata

While much of the metadata was not developed for comparison purposes (e.g. contact information), there are a few aspects of the questionnaires that relate to the state of data and how it is handled and stored.

In the event that the current data holder leaves his/her position, watershed contingency plans for data transfer exist for only three of the seven sites for the Environmental Conditions data set, while five of the seven Economics groups have plans for such an event. For the Environmental Conditions data, these plans consist of transfers to replacement scientists or for storing the data electronically so that it can be accessed using a secure FTP protocol. With the Economics groups, two sites maintain their data on servers that could be accessed in the event of emergency, while the other three have plans to transfer the data by electronic media such as CD/DVD.

For those watersheds which indicate that their collected data can be made available to others, regarding Environmental Conditions data, a protocol is in place to do so. Access restraints range from obtaining approval from a steering committee, to completing a form or writing a letter detailing plans for the use of the data. Though explicitly stated by only one watershed, it is believed that all sites would prefer withholding this data-sharing privilege until all internal data analyses have been completed—likely until after publication of results has occurred. For data sharing regarding Economics, only four of the groups indicated that this would be made available to others. Constraints on data access are site-specific, with agreements and documents for data use being required prior to access. All Environmental and Economics respondents use a spreadsheet data format, except the Salmon River watershed which maintains their Environmental Conditions data in database software.

Table 14 shows the metadata for only one (total nitrogen, TN) of the 29 common hydrologic (water quality) variables reported on. This table illustrates how comparisons might be made within the metadata set but it also illustrates the hazards of doing so. For example, six of the seven sites collected total nitrogen in surface runoff samples through similar methods. Yet of these six sites, all reported nitrogen findings in terms of concentrations but only four reported loadings. Also, the limits of anticipated TN detection capacity varied greatly between sites, from a precision as low as 0.00754 mg/L at the Salmon River watershed to as coarse as 0.3 mg/L at the Black Brook watershed. And frequency of sampling at some sites was run-off or rain-event-related, while other sites performed weekly or bi-weekly sampling.

Data availability and quality

It should be noted that although each site might value their data differently in terms of dataset availability and quality, comparison between sites is possible. For example, in the Economics questionnaire the availability and quality of yield data are rated. While all sites collected yield data, and five of the seven believed their data to be of good quality, two sites rated their data as either of fair or poor quality. As indicated earlier, rating the quality of the data is based upon the judgement of the respondents, given there were no guidelines on rating each variable. As such, comparison between sites should be approached cautiously. Future development and application of WEBs metadata will benefit from additional protocols to clarify data quality.

Where one site might consider yield data to be poor quality, another watershed might consider that data to be of good quality due to the level of data that was available. An example of this would be the yield data for the South Tobacco Creek watershed. Initially it was believed that the yield data, spanning

Table 14: Summary of total nitrogen (TN) water quality data for the seven watersheds

Watershed	Type of field sampling procedure	Name of Lab Analysis Method	Concen-trations	Loadings	Detection Limit	Frequency	Lab Used
Thomas Brook			no	no			
Black Brook	Isco sampler		yes	no	0.3 mg/L	Selected samples from Weir #1 only	Environment and Local Government, NB
Bras d'Henri	Automated and grab samples	Persulfate/Kjeldahl digestion/hydrazine on autoanalyzer	yes	yes	0.1mg/L	4-day composite and rain events	AAFC-AAC
South Nation	autosampler		yes	yes		weekly	City of Ottawa
South Tobacco Creek	automatic sampler or grab samples	Sum of TDN and TPN	yes	yes	0.01 mg/l	runoff based sampling	EC or DFO (depending on sampling site)
Lower Little Bow River	Grab samples	persulfate/Kjeldahl digestion/hydrazine on autoanalyzer	yes	yes	0.01-0.04 mg/L	weekly from spring to fall, monthly in winter (stream), 0-30 min for rainfall simulations	AAFRD (stream), AAFC (rainfall simulations)
Salmon River	grab sample	QuickChem 8000 Automated Ion Analyzer	yes	no	7.54 mg/L	bi-weekly, summer monthly	U of Victoria

more than 15 years on 350 fields, was of good quality. However, after data analysis and consultation with the data collector, it was determined that many farmers were reporting that same yield for all fields under the same crop in the same growing season; hence the reported yields were not field-dependent. This resulted in the South Tobacco Creek economists reporting that the yield data for the watershed was of poor quality while other sites in the WEBs project might consider this type of reporting to be of fair to good quality. The same considerations exist for some of the variables of the Environmental Conditions metadata where an indication of data quality was requested.

Communications requirements

In view of the considerable time required to initiate and populate the WEBs metadata set, additional efforts to communicate the value of the investment are warranted. Although the benefits of the WEBs metadata set were described to participants attending the February 2007 WEBs Technical Workshop, the study's project management, communications and data management teams need to ensure that its value is further demonstrated. This goal might be achieved by publicizing the findings through a means other than this report, which will allow responses to database use to be viewed within a public forum. One option is to employ a searchable on-line webpage, linked to the main WEBs website (www.agr.gc.ca/webs). By such a method, project respondents can better see that their generalized findings have been disseminated, thus placing additional value on their work.

Another possible publication step might be to convert the WEBs geospatial information collected within the Environmental Conditions questionnaire to a standardized metadata format and submit it to a metadata clearinghouse. Once linked to the clearinghouse, the complete WEBs metadata set could be available to other audiences. This option will require additional time investment to convert the WEBs metadata to a standard that utilizes common terminology and specific formats. The time investment required to do so might be spread over all WEBs sub-committees.

Anticipated time commitment

Although all of the Environmental and Economics groups eventually replied to the metadata questionnaires, response time and cooperation could have been better from many sites. When WEBs was initially developed, neither WEBs project management nor its watershed participants were aware of the time that would be required to participate in a metadata program, nor were they fully aware of the benefits that could be provided by metadata at a site and project level. Towards the development of new watershed sites and their associated metadata sets within WEBs, improved cooperation between project management and data/metadata management teams will be essential—including making new sites well aware of metadata expectations well in advance of project start-up. This will be essential to producing quality and timely reports. The value of WEBs metadata might be more obvious to new watersheds if the existing metadata set is circulated early, allowing the watersheds a chance to examine what has been done at other sites and the types of data they might consider collecting.

Conclusions

WEBs data management needs were actively discussed during the first (2005) WEBs Technical Workshop. An approach to data management through the use of metadata was developed to alleviate concerns related to centralizing information that had not yet been published or analyzed, and data privacy issues. Metadata questionnaires were created for each of the major disciplines of the WEBs project: Environmental Conditions (which covered hydrology, water quality and geospatial data), Economics and Modelling. With the exception of the modelling groups, the response rate to filling in the questionnaires was 100%, though deadlines for metadata completion were well exceeded by most sites. These responses have been compiled and summarized into tables towards the development of anticipated metadata publications.

Internal to the WEBs project, the value of the current metadata is three-fold. First, metadata has provided a means of data management and tracking without infringing upon privacy issues or data confidentiality. Second, by making existing study sites aware of the type of work being done elsewhere, all sites are familiar with what others are doing and may choose to adjust their individual approach accordingly. Finally, WEBs metadata questionnaires can be used as a guide for new watersheds entering into the project, to help with their analysis of the effects of BMPs on water quality.

The development of a metadata management strategy for a multi-disciplinary project such as WEBs, can be useful to other groups who are also examining water quality, economics, modelling and associated changing management practices in agricultural watersheds. As with the development of metadata clearinghouses for biological and geospatial sciences, coordination by WEBs with other groups performing similar research could contribute to the creation of a metadata clearinghouse for information collected at a watershed level.

There are still some weaknesses in the WEBs metadata protocol that need to be addressed. These include the need to: incorporate the use of more commonly accepted terminology; clarify definitions surrounding the grading or rating of data quality and availability; and secure the more timely cooperation from watersheds for completion of questionnaires. These weaknesses can be addressed through the development of an enhanced metadata protocol, and through communication with watersheds as to the benefits of metadata to individual sites and the project as a whole.

Notes

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