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Matthew McCandless, Henry David Venema, Stephan Barg and Bryan Oborne

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International Institute for Sustainable Development
161 Portage Avenue East, 6th Floor
Winnipeg, Manitoba
Canada R3B 0Y4
Tel: +1 (204) 958–7700
Fax: +1 (204) 958–7710
E-mail: info@iisd.ca
Web site: http://www.iisd.org/

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# Executive Summary

Agricultural Beneficial Management Practices (BMPs) are science-based on-farm activities that can reduce negative environmental impacts or increase positive environmental impacts. Agricultural BMPs can therefore produce *ecosystem goods and services*, which can increase human well-being and, according to recent international research in environmental economics, have demonstrable public benefits which deserve support through public policy.

The policy implications of EGS production from agriculture are significant; if the public receives significant benefits from particular agricultural BMPs, the rationale for government support for these practices is clear. Estimating public EGS benefits from agricultural BMPs is however methodologically complex in that EGS are produced at multiple scales simultaneously. For example, the global public benefit of reduced greenhouse gas emissions and the local benefit of improved water quality can result from the same BMP.

This study provides an illustrative estimate of the public benefit of agricultural BMPs in a small watershed in southern Manitoba. Three key elements form the core methodology for this study:

- **A linkage to the community's environmental and agricultural issues.** By dealing with the issues that are important to the community, this public benefits analysis is guaranteed to be policy relevant. While there will be variations from place to place across Canada, based on local ecosystem and economic factors, the issues important in a community will include many national and global issues as well. Using community issues as the starting point also ties the analysis closely to the Human Well-being – Ecosystem Service conceptual framework established by the *Millennium Ecosystem Assessment*, which is the globally-accepted framework for understanding how human well-being is affected by ecosystem goods and services.
- **Using the impact pathway approach to link ecosystem services with agricultural BMPs and their impacts on people.** This approach was developed for use in the analysis of the economic externalities relating to energy generation and use, and is the accepted methodology for estimating of site-specific marginal external costs.
- **The use of watersheds as the basic geographic unit of analysis.**

The watershed-based focus has both a scientific and management rationale. First, hydrology is central to many, if not most, agricultural and environmental interactions (Groffman *et al.*, 2007). The analytical framework developed in this report is explicitly designed to be integrated with AAFC watershed science research through the WEBs (Watershed Evaluation of Beneficial Management Practice program). Second, the watershed focus is consistent with principles of Integrated Water Resources Management, which are increasingly being incorporated into provincial and federal policy for achieving local natural resource management objectives. Third, the watershed approach is compatible with non-hydrological EGS such as carbon sequestration, biodiversity habitat provision,

and landscape amenity.

The valuation exercise is conducted for the South Tobacco Creek (STC) watershed in south-central Manitoba. South Tobacco Creek has been carefully monitored for many years, through a local initiative undertaken by the farm community. A portion of the South Tobacco Creek watershed is one of the seven WEBs research sites in Canada. The valuation methodology illustrated in this study is designed for compatibility with a watershed modelling exercise underway as part of WEBs research at South Tobacco Creek, which will provide a more scientifically rigorous impact pathway analysis. Modelling results are not yet available, and we therefore develop BMP implementation and impact examples based on existing international research.

Three example BMPs are analyzed for their public benefit: forage conversion (converting annual crop land to pasture); zero-till (soil is not tilled prior to seeding); and the utilization of small dams which retain water and regulate flow. Public benefit values are also derived from international research on the impacts of watershed-based BMPs. The EGS quantified and valued primarily relate to water quality and water regulation, specifically the public benefit of decreased sedimentation and nutrient loadings on water bodies.

While the key objective of the study is to illustrate a public benefits valuation methodology for agricultural BMPs compatible with ongoing AAFC scientific research, the quantitative results are nonetheless interesting and deserve further refinement. This paper puts the estimated public benefit of the three BMPs at: zero-till – $80/ha/yr; forage conversion – $150/ha/yr; and small dams – $1,667/dam/yr (all 2008, Canadian dollars). The portion of the aggregate public benefit attributable to these three BMPs in the STC watershed is $13.63/ha/yr.

The South Tobacco Creek calculation of public benefits should be regarded as preliminary and illustrative. It only represents a small subset of public benefit endpoints that could be calculated for each BMP and should be seen as conservative. This is due to the paucity of available valuation data. Nonetheless, the estimated magnitude of public benefit is similar to other Canadian studies. Other Canadian EGS valuation studies have estimated total economic benefits at $44.80/ha (Tyrchniewicz, 2007); $86/ha for croplands in the MacKenzie Valley (Anielski, 2007); and $65.67 in the upper Assiniboine Valley (Belcher, 2001 and Olewiler, 2004).

The key implications are three-fold:

- The public benefit estimation will improve (and increase) with more rigorous scientific analysis of multiple impact pathways as WEBs research matures.
- The public benefit valuation accuracy will improve with Canadian-based valuation exercises, as the current analysis necessarily relies on international studies.
- Agricultural BMPs can produce considerable public benefits in Canadian agricultural

watersheds, with significant implications for Canadian agricultural policy. Watershed-based agricultural BMPs could play a key role in advancing AAFC's *Growing Forward* Strategic Plan, primarily as it links productive local investments with a broader societal expectation for water quality improvements through a well-managed agricultural sector. Quantifying and communicating these public benefits is fundamental to policy and program development.

# 1.0 Ecosystem Services: A Need for Public Benefits Analysis

On-farm management of the environmental impacts and benefits of agriculture is a relatively new phenomenon. Producers have generally embraced the notion that their provision of ecosystem goods and services (EGS) to the broader society should be compensated by the government, however governments bear a responsibility to justify such expenditure as truly being in the public interest. Producer enthusiasm for EGS-type programs in Canada is evident in high uptake rates for the National Farm Stewardship Program (NFSP), Greencover Canada and non-governmental organizations (NGO) programs. However, this trend is recent and is still evolving. Research and pilot projects are ongoing to determine the best delivery mechanisms, be it one-time or annual payments for Beneficial Management Practices (BMPs), or market-based approaches such as nutrient trading or auctions. While work is ongoing to determine the best agricultural EGS supply-management methods, work is similarly required to properly assess the public benefit of such programs. This report is the culmination of four years of research examining how best to determine the value of EGS delivered by agriculture.

The approach taken throughout this research is that demand for specific EGS will vary from place to place and from region to region. These locally-relevant priorities should be used as a guide to determine which EGS elements are important, which practices support these elements and what should be evaluated.

IISD has developed a framework for performing this analysis: the **Impact Pathways Framework**. This framework features three components; the first is the "understanding the watershed" component whereby community consultation is carried out to determine the local watershed priorities, and the BMPs supporting them. The first component fits within integrated water resources management (IWRM) principles. The second component deals with the biophysical impact pathways of the BMPs selected for further analysis. The third component is the economic valuation of the specific BMP impacts. This framework allows for the analysis of EGS benefits consistent with local interests on a watershed basis.

This project complements existing biophysical BMP research, such as Agriculture and Agri-Food Canada's (AAFC) Watershed Evaluation of BMPs (WEBs) project, by providing a methodology for determining the public benefits of the BMPs analyzed by WEBs. The WEBs project in Manitoba uses the Soil and Water Assessment Tool (SWAT) to predict the biophysical impacts and benefits of agricultural BMPs. The BMPs analyzed in this report are among the suite being examined by SWAT. The impact pathways framework also allows BMP EGS evaluation to be coupled with SWAT modelling, such as that being carried out by WEBs.

This first chapter of the report provides background and basic information on the concepts supporting IISD's impact pathways framework. The second chapter describes Components I and II of the framework, and how they apply to a small agricultural watershed in south-central Manitoba. The third chapter presents Component III of the framework, applying it to the case-study watershed. The product of Chapter 3 is an estimate of the non-market value of three BMPs that support a locally-relevant watershed goal. Chapter 4 provides conclusions and recommendations arising out of this work.

## 1.1 Public Values and Private Land Ownership

Virtually all agricultural land in Canada is privately held, and in most cases the landowners also retain rights related to its management. Sampson (1992) explains the historical dilemma of attempting to achieve public benefits on private land. A key element is time; conservation practices typically do not immediately provide measurable economic returns. When considered over a longer timeframe (5–10 years), practices such as conservation tillage, shelterbelt planting and maintenance of wetlands may become directly profitable to individual landowners (Johnson, 1993). The problem is that immediate on-farm costs can result in externality benefits both on and off the farm (i.e., to wildlife users, downstream property owners and to society at large), while returns to the farm only come much later, if at all.

Randall (1987) addresses the nature of this market failure whereby the outcomes of free market activity result in an inefficient use of resources. "Non-exclusive" goods and services (i.e., many types of natural resources) are characterized by "attenuated" (weakened) property rights. Largely due to the goods themselves, appropriate pricing does not occur because it is impossible to collect appropriate rents for use of such resources as migratory birds, fish, wildlife, ambient air, soil and water. Without prices attached to their use, these resources cannot be rationed among users (resulting in overexploitation – "Tragedy of the Commons") and thus, adequate revenue cannot be raised to pay for necessary maintenance and conservation.

Over the past 20 years, various natural resources management systems have evolved that recognize the fundamental role played by private landowners (Scarth, 1984). One method concerns the contracted payment to individual landowners in exchange for their provision of management practices which result in off-farm environmental and/or social externality benefits. Direct benefits on the farm are also possible in the longer term. Such has been the case with the North American Waterfowl Management Plan (NAWMP), which has proven to be both effective and efficient. Today, research in this area is becoming increasingly focused on specifying the exact services provided by particular ecosystems while seeking to standardize their valuation (Boyd, 2006; Boyd and Banzhaff, 2006).

The Nature Conservancy of Canada has funded and aggressively promoted comprehensive economic research related to the value of natural landscapes on the Canadian Prairies, with a strong focus on wetlands (NCC, 2007). Meanwhile, Ducks Unlimited Canada has also made the linkage between wetland/upland functions and IWRM (DUC, 2007). These two national conservation organizations jointly funded a major research project, *The Value of Natural Capital in Settled Areas of Canada* (Olewiler, 2004).

Agriculture and Agri-Food Canada has funded several research projects in support of EGS (AAFC, 2007), and some of these had very strong *watershed-based* foci, such as the Lower Souris River Watershed EGS initiative, which was developed after extensive watershed planning, combined with equivalent environmental farm planning (LSRW, 2007). The department also sponsored a major national EGS conference (AAFC, 2006).

While national governments seek to address the EGS provided by agriculture, the lack of consistent economic data (Kemper, 2006) and the lack of research bridging the gap between biophysical impacts and economic valuation (Vaughan, 1986; Nunes and van den Bergh, 2001; Johnston *et al.*, 2005; Thomassin and Johnston, 2008) complicate their consideration of policy responses. To date, most policy geared towards enhancing and maintaining agricultural EGS involves assisting farmers to implement BMPs.

## 1.2 BMPs and Program Payments

A growing focus on the value of EGS has dominated recent debate on how to implement sustainable development planning and programs in Canada. For the agricultural sector, this involves looking at farming as a provider of a suite of services beyond simply producing food, and looking at other services that agriculture can influence, such as providing and purifying water and air. While food production remains the prime focus, BMPs are important at minimizing adverse agri-environmental impacts and heightening the provision of EGS.

In partnership with all provincial agriculture departments, AAFC provides substantial levels of program funding to support the farm-based implementation of BMPs. BMP promotion through the NFSP and Greencover Canada is a key element of the federal *Agricultural Policy Framework*. Payment for BMPs can assist agricultural producers in their quest to improve net farm income, and are also deemed valuable for the provision of important sustainability values to society. The vast majority of BMPs are being applied on a farm-by-farm basis, although the equivalent environmental farm planning option can bring groups of farmers together to cooperate on an industry, regional, or even watershed basis (AAFC, 2006b). While the NFSP enjoys considerable success through high farmer participation, there are little means in place to measure the environmental performance of these initiatives.

Delta Waterfowl Foundation and Keystone Agricultural Producers of Manitoba have initiated a pilot project in that province, with provincial and federal agricultural funding and administrative support.

Efforts are underway to expand the Alternative Land Use Services (ALUS) program to fund more pilot projects in other provinces, notably in Ontario and Saskatchewan (KAP, 2007). Other EGS projects in Canada include conservation easements and nutrient trading schemes in Ontario (South Nation, 2003; D.W. Draper and Associates, 1997).

These efforts in Canada mirror progress occurring in countries such as Australia and within the EU, where the concept of EGS and the associated application of BMPs by individuals and producer groups are becoming accepted as a standard approach toward achieving agricultural sustainability. However this is rapidly changing in Canada as evidenced by the increased funding for research aimed at building a scientific and policy basis for increasing BMP programming.

## 1.3 The Watershed Basis for Agricultural Water Management

Throughout history, shared drainage areas have brought societies together through the provision of water power, irrigation, domestic water supply, fish, wildlife and transportation. Since the dawn of agricultural society, drainage and irrigation have been major forces behind efforts to manage and/or develop the land resources of a watershed region.

Scientists recognized the watershed during the early 1960s as a sensible framework within which to address interrelated problems of public concern relating to environmental degradation. As any investigations aimed at addressing such chronic concerns would be both expensive and long-lasting, the approach of "taking the whole watershed into account" evolved as an efficient and practical means of tackling these issues with the support of science. Groffman *et al.* (2007) assert that hydrology is the main point of interaction between agriculture and the wider environment, therefore agri-environmental research and analysis should take a watershed approach.

Watercourses are the veins of the agricultural landscape, linking upstream and downstream areas, providing habitat, and delivering nutrients and fresh water. With waterways being so central to the landscape, it is inherent that most of the agricultural-environmental interaction is through hydrology (Groffman *et al.* 2007). Water resources are an appropriate focus of research dealing with agri-environmental issues.

The concept of planning on a watershed scale is not new. It has been relatively late in coming to Canada with Ontario's Conservation Agencies leading the way. Planning is generally a responsibility of government, and Canadian government jurisdictions are not laid out according to watershed boundaries. Awareness of the inevitability that water resources will become overused and are under-protected has existed for several decades. In the 1980s the Canadian government undertook a review of federal water policy and recommended more comprehensive management on a watershed basis (Pearse *et al.*, 1985).

Canada's agricultural watersheds are faced with a range of environmental challenges, including over-allocation, climate change, and nutrient pollution. The issues often manifest as inter-sectoral competition for water resources (for example between agriculture and petroleum extraction in Alberta), and complex transboundary nutrient management challenges such as Lake Winnipeg eutrophication and associated declines in its water quality.

Furthermore, the management of headwater streams within watersheds is particularly important for controlling nutrient loads, and particularly vulnerable to episodic extreme precipitation events. Freeman (2007) estimated that headwater streams encompass more than two-thirds of total stream length within most watersheds, directly connecting upland and riparian areas to the rest of the drainage system. Headwater catchments control the recharge of aquifers, movement of water and amount of time that water spends in the system, i.e., the "residence time" of water within a watershed. The associated hydrological processes in these streams also control the type, timing and distances travelled of material (including nutrients) transported to downstream waters. Alexander (2007) observed headwater streams have major influence in shaping downstream water quantity and quality. Approximately 70 per cent of the mean annual water volume and 65 per cent of the nitrogen flux occurs in second-order streams (Alexander, 2007).

Human alterations to natural systems that reduce the residence time within a watershed (such as wetlands removal and drainage channelization) generally amplify flood peaks, and increase nutrient loads by decreasing the time available for in-stream biological processes to remove nutrients, increasing the scour of nutrient-laden stream-bank sediments It is important to note that riverine floodplains and riparian areas are critical locations for the denitrification process, particularly during floods, when increased water depths serve to improve nitrogen contacts with "microbially reactive floodplain sediments" (Alexander, 2007:46). Similarly, wetlands have also been widely recognized for their ability to remove excess nutrients and improve downstream water quality (Newbold, 2005). Environment Canada (2001) reported that aquatic ecosystems and water resources in the Prairie Provinces face a range of threats related to human activities, which will be exacerbated by climate change, including:

- Physical disruptions and associated problems, including: (a) agricultural and forestry land use impacts; (b) urban water withdrawals; (c) sewage effluent and storm water runoff; and (d) impacts of dams and diversions;
- Chemical contamination, including: (a) persistent organic pollutants and mercury: (b) endocrine disrupting substances; (c) nutrients (nitrogen and phosphorus); (d) urban runoff and municipal wastewater effluents; and (e) aquatic acidification;
- Biological contamination, i.e., waterborne pathogens.

Other studies on the Canadian Prairies demonstrate that prolonged droughts associated with climate warming will likely result in soil erosion from agricultural lands and forest fire burned areas. Such erosion creates sedimentation problems and increases eutrophication of local water bodies due to enhanced nutrients in local water systems. It also leads to increased pathogen loading in streams in summer (Hyland *et al.*, 2003; Johnson *et al.*, 2003; Little *et al.*, 2003).

Natural wetlands have been another important on-farm casualty of agricultural development. Wetlands often represent significant unvalued public benefits including: groundwater recharge; climate stabilization; erosion control; improved water quality; waste management; wildlife habitat; food production (e.g., waterfowl, wild rice); species protection; education; aesthetics; and recreation. Since water is the primary means of interaction between agriculture and the wider landscape, BMP and EGS programming is generally focused on mitigating impacts on water resources, such as erosion and nutrient loading.

Watersheds are the prime vector of agricultural environmental interaction (Groffman *et al.,* 2007). This fact, along with the reality that inter-sectoral discord on water management issues occur at the watershed level, indicate that policy aimed at heightening the delivery of agri-environmental EGS should take place at the watershed level.

## 1.4 Watershed Processes and Nutrient Loading

Several natural and anthropogenic processes contribute to the total nutrient load in any given water body. Each contributing drainage system will have different sources of nutrients, depending on the type of landscape features, soil types, land use and human activities within its particular drainage area. Understanding the biophysical interrelationships between these different variables and the various differences between the composite watersheds of a larger system (in addition to any interrelationships between these composites) is fundamental to understanding total nutrient loading within a larger system, such as a river or lake basin.

All healthy ecosystems require nitrogen and phosphorus; they are essential to life. These nutrients are found naturally in the environment and can also naturally exist in excess levels depending on the characteristics of particular ecosystems. Several human activities have the potential to increase nutrient levels found within an ecosystem, and this may also occur through the movement of nutrients between ecosystems. For example, agriculture tends to import nutrients through the use of various types of fertilizer, and some of these nutrients may be introduced into watersheds through different land use practices and land management techniques. BMPs can greatly influence the rate at which nutrients enter watersheds, as well as influence the rate at which nutrients become available for algal growth downstream (Bourne, 2002).

Bourne (2002) has noted that artificial drainage networks (typically to facilitate agricultural development) increase the natural rate at which nutrients are exported from the land to downstream waterways. Similarly, the loss of wetlands also amplifies these nutrient losses. Equally, losses of riparian vegetation cause stream banks to become less stable, less able to retain nutrients, and more prone to erosion of nutrient-rich sediments.

The various nutrient loads supplied by natural background and undefined sources including forests, wildlife and septic fields, along with sources from present day agriculture are interrelated. Together, these *watershed processes* represent substantial contributions to the total nutrient load of a given downstream water body (i.e., 67 per cent of all Manitoba-based phosphorus loading to Lake Winnipeg—the most eutrophic large lake in the world), as noted by Bourne *et al.* (2002).

According to Bourne *et al.* (2002) it is clear that within Manitoba, watershed processes such as run-off of nutrients from diffuse agricultural sources and from natural processes contributed the largest mass of nutrients to both the Assiniboine and Red Rivers. Within the Assiniboine River basin, 71 per cent of total nitrogen (TN) and 76 per cent of total phosphorous (TP) were contributed from watershed processes, while in the Red River basin, 59 per cent of TN and 73 per cent of TP were similarly contributed from watershed processes.

There is a focus on phosphorus loadings in Canada, due to its previous identification as the primary cause of eutrophication of many important water bodies, notably the Lake Erie in eastern Canada and Lake Winnipeg in Manitoba. Phosphorus has been widely recognized as the logical first priority in addressing eutrophication in water bodies downstream from predominantly agricultural land use areas, primarily due to the propensity for its dissolved form to transport easily from the land into water bodies, and the fact that its particulate form readily attaches to sediment (Hively, 2006; Flaten, 2003; and Soranno, 1995). In addition to understanding the eutrophication contributions of phosphorus itself, these facts also reinforce the importance of understanding the interrelated processes of water flow and soil erosion, both of which can be accentuated by agricultural development and associated upland drainage.

As described by Flaten (2003), various factors determine the amount of phosphorus exported from agricultural lands to downstream water bodies via surface runoff and/or groundwater flow:

Water infiltration rates determined by:

- soil texture/structure
- precipitation intensity/duration;
- snowfall volumes and speed of melt;
- crop management types and vegetative cover; and
- slope, proximity to watercourses, and riparian health.

Manitoba's Lake Winnipeg Stewardship Board makes a clear case for addressing phosphorus loading as an initial priority for reducing downstream nutrient loading, primarily due to the prevalence of livestock manure application in agricultural regions of Manitoba, and the fact that:

Currently, manure application rates in Manitoba are regulated based on crop nitrogen inputs alone. However, the ratio of phosphorus to nitrogen removed by crops is lower than the phosphorus to nitrogen ratio in manure. Therefore, when only the nitrogen content of the manure is considered when determining application rates, phosphorus is often applied at rates that exceed agronomic requirements. A build-up of phosphorus in the soil can lead to soil phosphorus saturation and the subsequent release of phosphorus when water travels through, or over, the soil.
[LWSB, 2006:64]

## 1.5 Water Management Research in Agricultural Watersheds

In 2004, AAFC initiated the WEBs program (Watershed Evaluation of Beneficial Management Practices), a four-year study occurring in seven watersheds across Canada. WEBs is working to assess the relative effects of selected BMPs applied on individual farms, with a focus on water quality. WEBs works at the micro-watershed (300 hectares) level, with the goal of estimating the watershed impacts of local BMP application through modelling (AAFC, 2004). WEBs currently operates in seven Canadian watersheds representative of various eco-zones. The Manitoba case is on South Tobacco Creek (STC).

The impacts of a variety of BMPs are being assessed, including land conversion (annual crop to permanent cover), riparian buffer strip enhancement, management of livestock access to water, nutrient management and small multi-purpose dams (AAFC, 2007b)

In establishing WEBs, AAFC recognized the need to look beyond the farm field in studying the beneficial effects of sustainable farm management practices. WEBs is seeking to understand the various "compounding variables" within local watersheds, that small-scale field research cannot ascertain. A number of innovative modelling exercises are currently being conducted through WEBs. These will build on the growing body of literature towards improved understanding of the complex hydrologic and anthropogenic factors that shape agriculture's impact on the environment. The Soil and Water Assessment Tool (SWAT) appears to be the predominant model in use (Gassman, 2007), although others such as Agricultural Policy Environmental Extender (APEX) and Erosion Productivity Impact Calculator (EPIC) are also in use (Arheimer, 2005; Gérard-Marchant, 2006). Recent innovations include those conducted by Bracmort (2006) and Yang (2007). A compilation of examples of such research is included as Table A-1 in the Appendix. The South Nation Conservation Authority also compiled research on BMP effectiveness (South Nation, 2003, 2005).

## 1.6 EGS Within an IWRM Framework

The only effective way to address the interrelated concerns of agriculture and other sectors, environment and society is to view Canada's agricultural producers as individual decision-makers and land managers within a larger natural landscape. Real environmental solutions will also address the economic reality of profitability that producers face with every management decision..

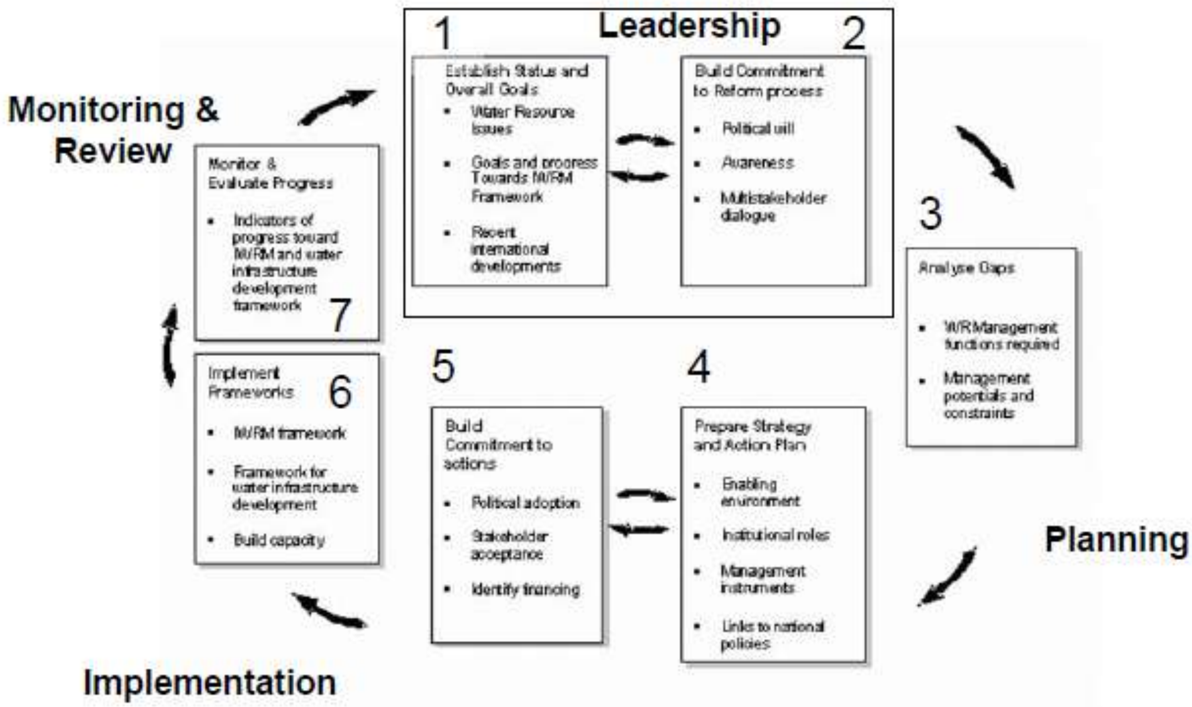
The importance of developing and implementing watershed management activities that assist in achieving the priorities of local stakeholders have been well documented (Borsuk, 2001; Johnson, 2001; Soderqvist, 2003; Jonsson, 2005; Xenarios, 2007). IWRM has been described as having three features which differentiate it from traditional resource-based management.[1] First, it is more "bottom-up" than "top-down" thus emphasizing the building of capacity among local resource users. Second, IWRM encourages cross-sectoral, interdisciplinary management of water resources. Finally, it is focused on comprehensive solutions, encompassing management of other activities (e.g., land use) that affect water resources. IWRM is deemed most effective when implemented as an adaptive process, "evolving dynamically with changing conditions."(Global Development Research Center, 2005)

The Global Water Partnership described integrated management of water resources as a cyclic process consisting of seven steps as illustrated on Figure 1-1: (1) establish status and overall goals; (2) build commitment to reform processes; (3) analyze gaps; (4) prepare strategy and action plan; (5) build commitment to actions; (6) implement frameworks; and (7) monitor and evaluate progress. The cycle then undergoes refinement by returning to the initial steps and other issues can be addressed. As further iterations occur, more challenging issues can be addressed building on the capacity and cooperation built through earlier success.

The Millennium Ecosystem Assessment (MA) is a research program on ecosystems services and changes commissioned in 2001 by then United Nations Secretary-General Kofi Annan. The Millennium Ecosystem Assessment (MA, 2005) provided two critical policy insights related to IWRM and EGS. First, a future scenario consistent with improved EGS provision is one in which, "regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems" (MA 2005). The MA Wetlands and Water Synthesis discussion related to MA Responses 15.5.3 and 15.5.4 suggests that:

[1] From personal communication with Environment Canada Water Policy Branch (2004).

Figure 1-1. The "Integrated Water Resources Management Cycle" as described by the Global Water Partnership (Jonch-Clausen, 2004).




The effective management of inland wetlands and water resources will require improved arrangements for river (or lake or aquifer) basin–scale management and integrated coastal zone management. The effective management of wetlands and water resources requires not only intersectoral coordination but also coordination across different jurisdictions. Actions taken upstream or up-current can have profound impacts on wetland resources downstream or down current. This in turn requires the use of integrated river basin (IRBM) or coastal zone management (ICZM). These integrated regional approaches to water resources management are recognized also as key strategy to contribute to the objectives of poverty alleviation.

To date, however, few efforts at implementing IRBM have actually succeeded in achieving social, economic, and environmental objectives simultaneously. One of the key lessons emerging from ICZM experiences is that more integration per se does not guarantee better outcomes. Adopting an incremental approach—focusing on a few issues initially and then gradually addressing additional ones as capacity increases— is often more feasible and effective. In addition, these approaches can

> only succeed if appropriate institutional and governance arrangements are in place and, in particular, if the authority and resources of the management mechanism are consistent with their responsibilities.
> [MA: Water and Wetlands Synthesis, 2005:58]

The second applicable MA insight centred on the need for increased use of economic instruments based on ecosystem goods and services to mitigate or reverse serious ecosystem degradation, such as: (1) payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are valued by society; and (2) market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way (MA: Water and Wetlands Synthesis, 2005).

The MA strongly advocates the use of EGS payments as a key sustainability strategy for the protection of wetlands and watersheds, suggesting the potential key role which EGS payments could play in terms of IWRM application:

> Payments for services derived from a river basin can support the management of wetlands or protect catchments that provide wetlands with adequate quantities and qualities of water, and hence they act as an incentive to deal with drivers of wetland change such as altered hydrology, pollution, and land use change.
>
> Payment arrangements for these services essentially consist of the negotiation of arrangements among buyers and sellers of these services. They take various forms, depending on the nature of the service, the scale of relevant ecosystem processes that support it, and the socioeconomic and institutional context. These range from informal, community-based initiatives to more-formal contracts between individual parties and complex arrangements among multiple parties facilitated by intermediary organizations.
>
> They may also include a mix of market-based, regulatory, and policy incentives that are more likely to become necessary at larger scales, when threats are beyond the response capacity of individual communities. The effectiveness of payment arrangements will largely depend on stakeholder willingness to pay for them.
> [MA: Water and Wetlands Synthesis, 2005:63]

Many community-based watershed initiatives currently exist and are developing in Canada—through which the shared interests of local residents are being prioritized for action through extensive community consultation and watershed-planning processes (Swanson *et al.,* 2005; Groffman, 2008).

In exploring the public benefits of BMP application within Canada's agricultural watersheds, we contend that if adequate community cohesion exists (and the watershed unit area is appropriate), these common drainage areas will be *meaningful* to the people who live in them and use their resources. They will also be *manageable* in that local governance entities such as local municipalities, conservation districts and other community stakeholders may in fact have significant influence in improving their condition. Given the existence of these conditions, the application of a suite of appropriate BMPs within a particular watershed will subsequently be *measurable*.

The EGS provided through IWRM processes will produce public benefits and address local objectives simultaneously. The challenge for policy is to quantify EGS benefits that come out of the IWRM process, namely for those services identified as priority in the initial stage of the IWRM process (Box 1 on Figure 1-1). This quantification will reveal to policy-makers the public benefits of supporting an IWRM process in a small agricultural watershed. The following chapters will present and demonstrate the impact pathways approach, IISD's framework for carrying out the valuation of the public benefits of IWRM. This approach features three components: a **social** component to determine watershed priorities and the practices that support them; a **biophysical** component to quantify the environmental benefits of changed practices; and an **economic** component that calculates a value of the environmental benefits. Chapter 2 presents the first two components of this approach and relates them to South Tobacco Creek, a small agricultural watershed in south-central Manitoba. Chapter 3 presents the third component of the impact pathways approach and provides demonstration calculations of the process.

# 2.0 The Impact Pathways Approach

This chapter presents the impact pathways approach, a framework for determining, quantifying and evaluating ecosystem services that are of importance within watersheds and adjacent communities. The impact pathways approach is made up of a social component whereby issues of local importance are identified, a biophysical component which links these issues to environmental indicators and an economic component whereby changes in the indicators are expressed as a non-market monetary value.

Component I of the framework involves understanding and prioritizing ecosystem services in the watershed. This involves studying and surveying the local environmental and agricultural landscape, and leads to an understanding of the practices or changes that are required to heighten the delivery of EGS. This first component conforms to IWRM in that the purpose is to understand local water resources issues, set goals and commit to reform. In the case of a small agricultural watershed, priorities will centre on the business of farming and the supporting EGS. The practices that support the increased provision of priority EGS will generally be agricultural BMPs. The MA provides a solid base on which to understand EGS, and sets the course on how to pursue their evaluation.

Once local agricultural and environmental issues have been ascertained and the modes by which they act are understood, it is necessary to understand how to monitor and track them to assess whether conditions are improving or worsening. Component II of the impact pathways approach addresses BMPs and the modes by which they act. This component is synonymous with the type of SWAT modelling presently being carried out by WEBs. The purpose of this component is to link BMPs to quantifiable indicators that can be accurately measured and monitored.

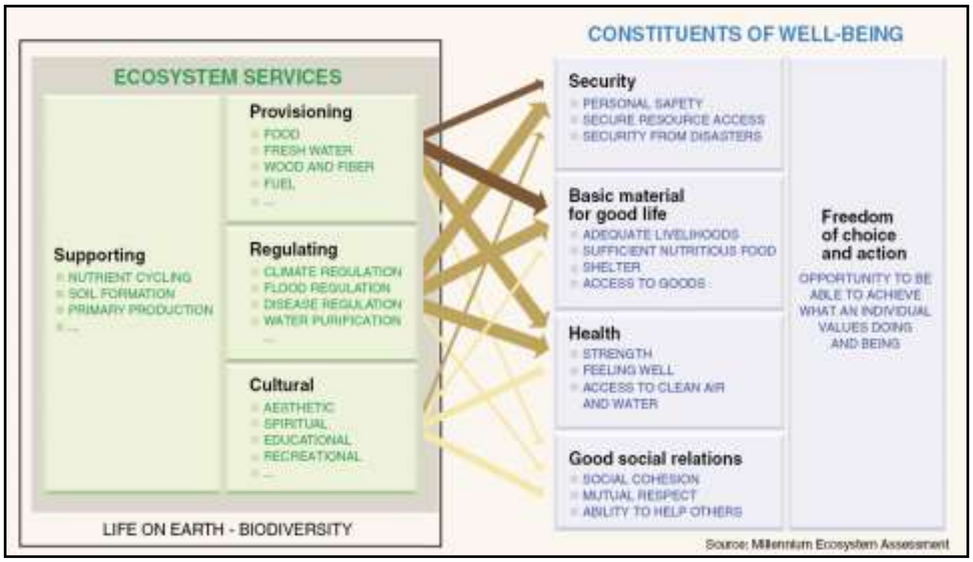
The indicators of interest are what will be evaluated in Component III: valuation, described in Chapter 3. The third component will focus on the calculation of the non-market value. This calculation will be comprised of the sum of all the individual values assigned to marginal changes in the biophysical indicators.

## 2.1 Component I: Understanding the Watershed

There is a large literature on categorizing and evaluating environmental externalities (MA, 2005). The goal of the first component of the impact pathways approach is to define a practical methodology that can lead to a fairly short list of key externalities as they relate to agricultural BMPs. The list can then be used as the basis for valuation research. Of interest here are environmental impacts that are off of the farm; that is the indirect impacts not on the farmer him of herself but on the rest of the population.

The Millennium Ecosystem Assessment (2005) presented a framework for examining EGS and their link to human well-being. EGS are broken down into four types of services: provisioning; regulating; cultural; and supporting. Each of these types is divided into sub-types. For example, the delivery of fresh water would be a provisioning service—while the physical processes that support this delivery would be classified as supporting services. These EGS link to human well-being, which is divided into security, basic material for good life, health, good social relations, and freedom of choice and action. The framework is presented in such a way that freedom of choice and action overlies the other four categories. Figure 2-1 presents the MA EGS framework diagram with links between EGS and elements of human well being.

Figure 2-1: Ecosystem goods and services and human well-being (MA, 2005).




The MA EGS framework fits very closely with IWRM. With one of the main tenets of IWRM being the understanding of local watershed issues (see Box 1 Figure 1-1), the implication is that stakeholders in a local watershed are free to pursue their own interests. These interests are in turn supported by EGS. This implies that the starting point on the MA framework for IWRM should be freedom of choice and action—the premise that watershed stakeholders are free to identify and address their own concerns related to the watershed.

The concerns that a community will have may be social, economic, environmental or political. In an agricultural watershed dependent on natural resources to grow crops and sustain livelihoods, these typically involve the viability of farming, such as farm income, marketing opportunities, transportation costs, rural community depopulation, the availability of local services, etc. Key environmental issues in local agricultural areas typically relate to air or water quality concerns, flooding and drought, soil erosion, pesticide concerns, fish and wildlife habitat loss, etc. Local concerns will be determined largely by local environmental conditions related to soil type, topography, precipitation levels and the locally dominant forms of agriculture (crops, livestock, aquaculture). In order to link this to IWRM, scoping needs to be carried out to determine which EGS most directly address the concerns raised.

Within an agricultural watershed, EGS can be enhanced through BMPs. Since BMPs are the elements responsible for heightening the delivery of EGS in agricultural production, the positive environmental externalities of BMPs are the focus of this valuation exercise. Thus Component I of the impact pathways framework will end with a list of BMPs for which biophysical analysis will be carried out in Component II, and valuation in Component III. A schematic diagram of Component I as it pertains to the South Tobacco Creek watershed is presented as Figure 2-3.

### 2.1.1 South Tobacco Creek Watershed Community Goals

Component I of the impact pathways framework is demonstrated using information from a community consultation of the STC watershed in south-central Manitoba (see Figure 2-2 for location). This consultation was carried out in 2003 and was a scoping exercise looking at community concerns and goals. The goal of water management was then selected, and BMPs that support this goal were selected for valuation.

Figure 2-2: Location of STC in Manitoba (TCMW, 2004).

Through a series of community meetings within the Tobacco Creek Model Watershed, the following priorities were identified:

- improving net farm income and landscape diversity;
- building producer participation and scientific monitoring;
- planning for drought, storage, and water management;
- protecting water quality and riparian areas; and
- addressing drainage and fisheries habitat issues.

As the TCMW Goals were comprehensive and complex (involving at least two interrelated elements within each goal), in some cases it was necessary to split them to their core components. A needs and options analysis ultimately resulted in a set of interrelated watershed planning priorities for South Tobacco Creek that meet the interests of residents in the South Tobacco Creek community. These eight goals are:

- drainage – removing water from cropland in spring prior to seeding;
- water quality – reducing the impact of farming on the quality of local waterways;
- participation – ensuring local producers are given a say on issues affecting them;
- income – ensuring that their farming activities can provide for them and their families;
- fish habitat – ensuring that developments do not impact on aquatic habitat;
- riparian – ensuring that riparian areas are protected from erosion;
- water management – protecting local farmland from flooding and drought and reducing sediment and nutrient loss in runoff; and
- landscape – providing habitat for wildlife.

The community views these goals as simultaneously supporting federal and provincial policy objectives, an important priority given the importance of securing project funding. It was also realized that some of these interrelated priorities could become eligible for external funding, as they assist in fulfilling the biodiversity and conservation-related goals of private funders.

For this valuation project, the eight TCMW integrated goals were considered in light of their potential relationship to the existing suite of AAFC beneficial management practices (BMPs).

It is important to note that TCMW goals exist for which there appear to be no AAFC BMPs. Of course there are aspects of some BMPs (i.e., riparian area management) that are intended to provide multiple benefits, including those related to fish habitat.

For purposes of this report and analysis we selected one watershed goal to identify the linkages with BMPs currently being evaluated. The watershed community goal of water management has historically been an important goal of the STC watershed community. The reasons for this focus date back generations and are due largely to the natural landscape and physiographic features of the region.

### 2.1.2 South Tobacco Creek BMPs that Support Watershed Community Goals

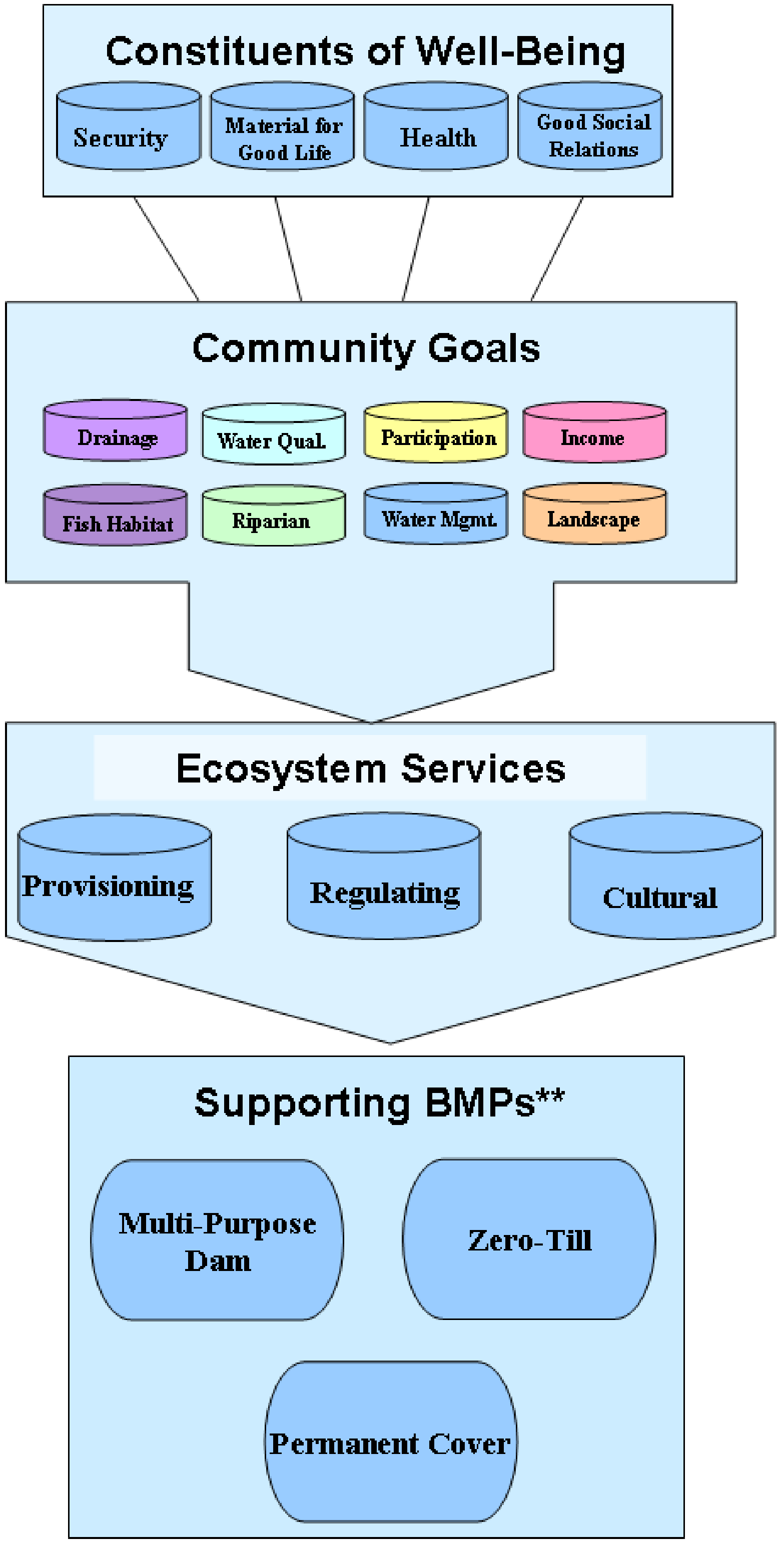
Watershed community goals are supported by specific actions. One type of action is the implementation of a BMP. Understanding the linkage between key environmental issues and current and proposed BMPs is a critical part of making the valuation exercise policy relevant. This is important because the goals provide a framework which makes sense to the watershed community. Local residents already largely agree on these goals, so any related federal or provincial policy objectives will likely be more readily adopted if they can be presented within this existing set of shared goals.

The associated AAFC BMP categories most closely associated with water management in the STC watershed are included as follows:

- #11 (Erosion Control Structures – Riparian);
- #12 (Erosion Control Structures – Non-riparian);
- #13 (Land Management for Soils and Risk); and
- #15 (Cover Crops).

The three BMPs selected for further valuation are multi-purpose dams, zero-till and permanent cover (forage conversion). Zero-till and permanent cover are official BMPs with funding available through the National Farm Stewardship program. Multi-purpose dams are not official national BMPs, but are of significant local importance in the watershed.

Figure 2-3: Flowchart of component I of impact pathways approach, moving from MA constituents of well-being, to STC community goals, to relevant ecosystem services, to supporting BMPs.



## 2.2 Component II: Identifying Impact Pathways

We now consider the second component of the framework. This component involves the biophysical aspect of the analysis. From Component I we have an understanding of the main issues of concern and how they are manifest. The challenge now is to understand the biophysical ecosystem functions that are affected by changing practices, or in the case of a small agricultural watershed, implementing BMP. The purpose of Component II is to identify the specific pathways by which specific BMPs can benefit the environment, and how this change can impact on ecosystem services and human well-being both on and off the farm.

EGS valuation by biophysical modelling such as the SWAT model for STC constructed as part of WEBs can bring increased policy relevance to this type of research. By understanding the key biophysical benefits of BMPs it is possible to assign a value to their incremental benefits. Knowing the value of BMPs can help to set incentives to producers for carrying them out.

The range of BMPs that are applied within a particular watershed community will differ according to the goals it has endorsed. These goals are largely dictated by natural landscape features such as elevation and climate, combined with locally determined management priorities. These priorities are driven by what community residents deem to be important (watershed-related values), historic issues of concern, political realities and the existence of available funding or legislation, which is largely determined by identified federal or provincial policy objectives (e.g., the protection of fish habitat or water quality).

A diagram depicting Component II is included as Figure 2-4.

### 2.2.1 *Impact Modes*

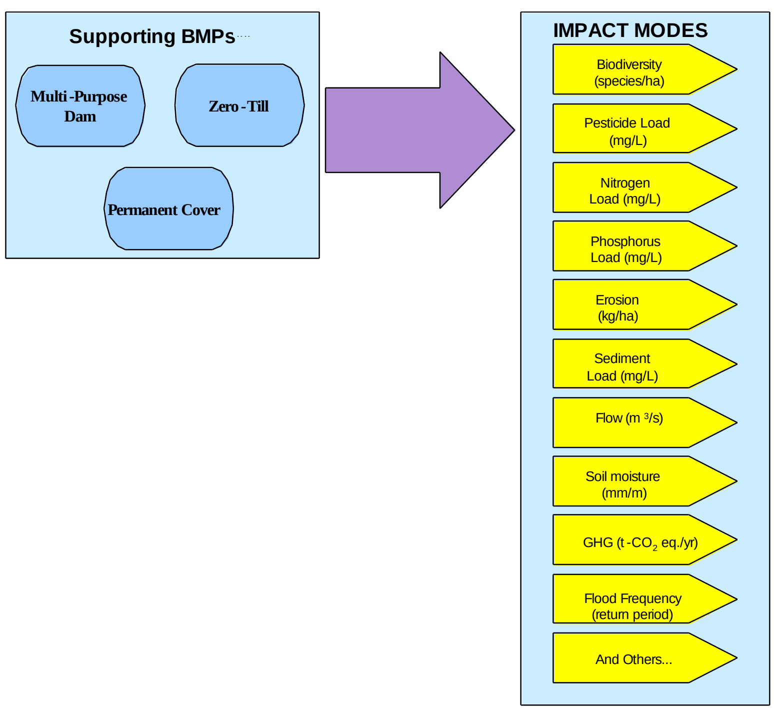
Impact modes are the specific pathways by which a change in agricultural practice can be measured, assessed and monitored. The range of possible impact modes will be numerous for every BMP. The purpose of the second component of the impact pathways approach is to focus the analysis on the impact modes that are of greatest relevance to the local priorities and ecosystem services of interest.

Water erosion results in the loading of soil particles and other constituents into water sources such as creeks, rivers and lakes. These water sources may be either on-farm or off-farm, or both. The state of the environment being impacted therefore includes the on-farm and off-farm quality and quantity of water and also of soil. Water quality is impacted by nitrogen and phosphorus loading, and also by the loading of sediments which are deposited or remain suspended in the water.

This step can be quantitatively complex. For example, in the case of water quality, phosphorus can be transported along with the soil particles via overland runoff to an adjacent creek on the farm. This creek may then transport the phosphorus to a nearby river, which may in turn, deposit the phosphorus in a lake. It is the concentration of the phosphorus at the point where the ecosystem service is provided (e.g., water source, fishing, recreation) which is of interest in the impact pathway analysis. But this requires an understanding, either empirically or by quantitative simulation, of how much of the phosphorus leaving the field via runoff, actually makes it to the point of ecological service benefit is realized.

A literature search was carried out to determine the incremental environmental benefits of BMPs. The purpose of this search of agronomic literature was to determine the effects that BMPs have on water quality through decreased erosion and nutrient leaching. Literature on BMP performance modelled by software such as SWAT and APEX was scanned. The majority of biophysical research on BMP impacts, including WEBs, focuses on specific environmental parameters. The findings of this literature search are presented in Table A-1 in the Appendix. This literature search focused on BMPs that either are implemented in the STC watershed, or are being modelled by WEBs.

Figure 2-4: Component II of impact pathways approach, showing links from supporting BMPs to impact modes.




The impact pathways approach to this point started with a watershed management goal of drought, water storage and water management. The specific practices that support this goal are zero-till, forage conversion and small multi-purpose dams. These BMPs affect multiple environmental indicators. Some of the modes by which the impact of these BMPs can be measured include:

- drainage water volume (commonly measured as a depth in millimetres, or as a volume such as $m^3/s$);

- flood frequency (typically recorded in terms of return period, often in years);
- turbidity loading to water sources (commonly measured as nephelometric turbidity units, or NTUs);
- sediment loading to water sources (typically recorded as tonnes of soil lost per hectare of land, or t/ha);
- sediment load in water bodies (typically measured in terms of milligrams per litre, or mg/l)
- phosphorus loading to water sources (in kilograms per hectare, kg/ha);
- phosphorous concentration in waterways (in mg/l, as dissolved, particulate or total phosphorous);
- nitrogen loading to water sources (typically in kg/ha);
- nitrogen load in waterways (recorded in terms of ammonia, nitrate-nitrite nitrogen or total Kjeldahl nitrogen, in mg/l);
- pesticide loading to water sources (typically as a mass per hectare, the specific mass unit depending on the prevalence of the specific chemical);
- pesticide concentrations in water sources (typically mg/l); or
- biodiversity change (often tracked in terms of area in the case of terrestrial habitat, or volume in the case of aquatic habitat).

Each of these modes is elaborated below.

#### 2.2.1.1 *Water Flow Volume*

*Water flow volume* is a major impact mode within the TCMW. Rapid runoff during the spring and intense summer storms has been the source of historical local concern, particularly due to major associated infrastructure damage to roads, bridges and drainage ditches. Due to major elevation changes (a relatively steep west to east drop in the Western Uplands), water moves swiftly from farm fields into the South (STC) and North (NTC) branches of Tobacco Creek in the western watershed headwaters. If volumes are substantial, downstream flooding can occur in the eastern portions of the TCMW area, typically within the Graham Creek and 4N/Tobacco Creek Drain. Spring runoff provides an important water supply source for downstream irrigators.

#### 2.2.1.2 *Turbidity Load*

*Turbidity load* is less of a local priority, as residents do not rely on Tobacco Creek as a local water supply. Many agricultural producers use water flowing in the TCMW system as a cattle watering supply and for irrigation, although turbidity has not yet been of major concern. However, if considering the cumulative impacts of turbidity loads on a larger scale, such as the Red River Basin or the entire Lake Winnipeg watershed, issues of water clarity and water quality should be of concern in terms of aquatic habitat and perhaps for downstream water supplies. The TCMW is not currently used significantly for recreation, such as fishing. If it were, perhaps turbidity would be more important locally.

#### 2.2.1.3 *Sediment Load*

*Sediment load* is directly related to water flow. Research to date suggests that streambank erosion within the steeply sloped natural headwater channels of the STC and NTC Western Uplands may be just as significant as on-farm soil erosion in this area. Further downstream, sediment deposition occurring via floodwater is problematic for agricultural landowners farming adjacent to waterways in the Central Midlands, who may also have to deal with clogged irrigation pumps. Further east, sediment is largely contained within the drainage system, but it builds up over time and is a costly maintenance issue for municipalities in the Eastern Lowlands.

#### 2.2.1.4 *Soil Transfer*

*Soil transfer* from agricultural fields may be of concern within the Western Upland region of the TCMW. Historically, it was problematic at South Tobacco Creek, although significant improvements in local soil conservation efforts appear to have slowed soil loss considerably. Lighter soils of the North Tobacco Creek are more prone to soil erosion, and local conservation efforts have not been as successful. Further downstream, in the Central Midlands, intensified horticultural and irrigation development on highly productive soils represent a significant soil loss concern, particularly on sloped lands. In the Eastern Lowlands, a relatively open landscape, very flat lands, but generally heavy soils, suggest that soil loss via wind erosion can be a problem. This can be an issue during dry years or when soil conservation practices wane during the production of certain crops which result in more soil disturbance. However, soil gain may also occur through soil deposited via floodwater, as well as wind erosion.

#### 2.2.1.5 *Phosphorus Load*

*Phosphorus load* is associated with both sediment load (natural deposition) and agricultural production (fertilizer and manure runoff). These loads are naturally very high within Prairie escarpmental streams such as the TCMW system, where substantial amounts of natural material moves downstream through natural erosive processes. However, human changes to the landscape (mainly through agricultural development), such as intensified drainage, removal of natural vegetation and road construction all influence water flow, sediment deposition and associated phosphorus loading. Increased phosphorus loading throughout the Lake Winnipeg watershed has been identified as a major source of eutrophication and other quality concerns affecting this important water body.

#### 2.2.1.6 *Nitrogen Load*

*Nitrogen load* is primarily associated with agricultural production, associated with both fertilizer runoff and cattle waste. Both beef and pork production are very significant agricultural activities within the TCMW. As with phosphorus, nitrogen is of significant concern downstream, beyond the TCMW system. The Red River is used for domestic water supply in some communities north and south of Winnipeg, and it is a major recreational feature for the City of Winnipeg. Aquatic habitat within the TCMW itself may be of concern, although local residents do not currently use it as such.

#### 2.2.1.7 *Pesticide Load*

*Pesticide load* has been well documented with the TCMW system and are generally well below Canadian Water Quality Guidelines. However, the cumulative effects of these compounds on local and downstream aquatic ecosystems are not well known. It have been locally noted that pesticide levels could someday create concerns for downstream irrigators within the TCMW system, who require basic quality levels.

#### 2.2.1.8 *Biodiversity Change*

*Biodiversity change* is a major concern and impact of agricultural development across the Canadian Prairies. As some 90 per cent of the Prairie landscape is privately owned and managed, the individual decisions of private landowners are a major factor influencing both terrestrial and aquatic ecosystems. The TCMW landscape has not been well documented in terms of biodiversity change, although the loss of natural vegetation cover and wetlands have been substantial. Some natural areas remain, particularly within the steep ravines of the Western Uplands and some lower riparian areas. This impact mode is not pursued in the analysis.

In order to simplify the valuation calculations, key impact modes have been selected as the one most relevant to the BMPs, and the ones on which the BMPs will have the greatest impact. For zero-till and permanent cover, the impact modes analyzed are phosphorous loss, sediment loss and greenhouse gases. For small multi-purpose dams, the main mode of impact is peak flow reduction.

# 3.0 Component III: Valuation

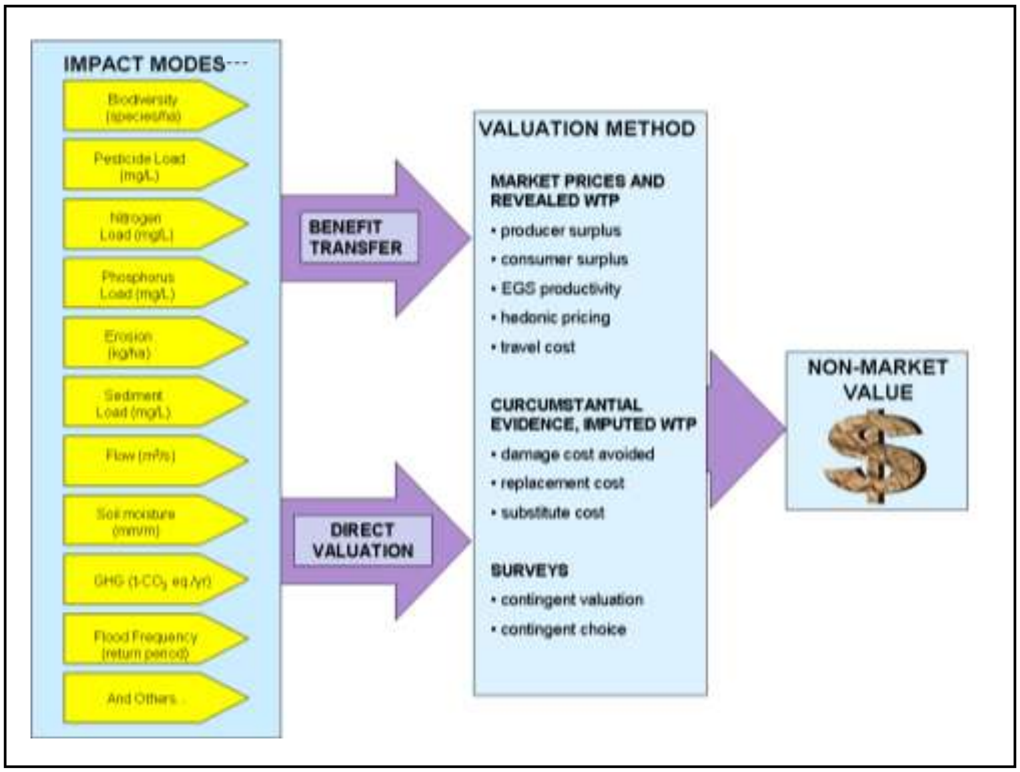
This chapter presents the third component of the impact pathways approach, the determination of the economic value of the changes in impact modes affected by BMPs. This component is demonstrated using the BMPs and impact modes for the STC watershed described in Chapter 2. As discussed above, the history of STC and the larger Tobacco Creek watersheds makes them ideal candidates for valuation tests. Both their community-based information collection and the scientific work carried out as part of WEBs and earlier projects are important inputs to valuation calculations. Few watersheds in the Canadian Prairies have as much background research available.

The chapter begins with a description of the environmental valuation principles underlying Component III. Following this, a demonstration of the valuation methodology is carried out on the impact modes of thee BMPs which fulfil STC's watershed management objective. The watershed priority assessed in Chapter 2 is water management, and the three BMPs analyzed are small dams, zero-till and permanent cover. It is important to note that the environmental performance of the BMPs has been estimated from agronomic literature, but the exact values for this watershed are currently being calculated by the WEBs SWAT model of the STC watershed. These values can be used in this framework once they have been completed.

## 3.1 Valuing Environmental Changes

The third component of the impact pathways framework is the valuation of the changes in EGS measured through impact modes. This component involves determining the value of changes in the impact modes, and assigning values to these changes. A flowchart of this process is included as Figure 3-1.

Figure 3-1: Process diagram for Component III of impact pathways approach.




An important consideration in the scope of the valuation exercise is the type of economic value to include. There is a variety of terms and concepts that are commonly used in discussions of the incremental non-market value of an activity. The most common examples relate to negative environmental externalities—if a factory or a farm pollutes a river, but does not pay any cost as a result, there is an externality. The polluter can sell its product at a price that does not include the cost of the pollution. That cost is borne by those downstream of the polluter, who either put up with dirty water, or pay to clean it up. The costs of this sort of externality can be calculated, if some data and conceptual difficulties can be dealt with (Venema and Barg, 2003).

But there is a broader conceptual framework, into which environmental externalities can be placed. The broad framework or all-encompassing concept can be called "total value," or Total Economic Value" (TEV). TEV can be broken down into the following categories (Pearce, 1993; Bateman *et al.,* 2003):

Use Values:

- Direct use value: The value of the use of the resource, for whatever purpose. Agricultural land can produce crops, but it can also provide biomass for energy generation, perhaps forage for animals, and so on. Some of these values will not be easy to quantify.
- Indirect use value: These correspond to "ecological functions," such as protecting watersheds from siltation, or maintaining biodiversity. Carbon sequestration would be an indirect use value, until there is a market for it in a trading system—at which point sequestration will become a direct value.
- Option values: These are also direct values, even though they do not require that there be any specific use of the item at this time. Option values are those that individuals are willing to pay for maintaining the availability of something for their future use, even though the individual has not and may never see it. Old growth forests in British Columbia might be an example.

Non-use values:

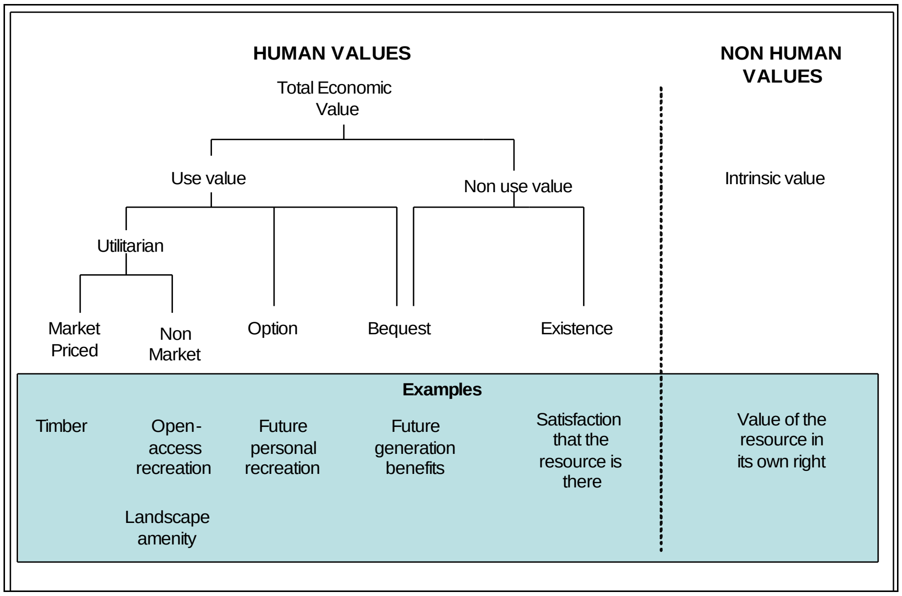
- Existence value: This is an indirect value, in contrast to the categories listed above. It is the result of people's willingness to pay for something with no expectation that they themselves will benefit from it. People contribute to organizations to save the Amazonian rain forest or gorillas in Africa, because they feel that these natural wonders should not be destroyed.

Future-use values:

- Bequest value: an indirect value which accounts for the value of an environmental asset to future generations. Bequest value is made up of the use values and non-use values that future generations can benefit from.

The sum of these categories gives TEV. But these are the "economic" values, which is necessarily an anthropocentric calculation. There is a category of non-economic values as well, often called intrinsic values. These values do not depend on human willingness to pay for them, but are intrinsic to the animal, ecosystem or other part of nature. The diagram in Figure 3-2 below shows the various components of environmental value.

Figure 3-2. Environmental value (Bateman *et al.*, 2003).




There is another feature of the natural world that TEV and the above diagram do not capture, according to Pearce (1993). That is the fact that the above listing of economic values does not include the value of the system as a whole—the whole is greater than the sum of its parts. He calls them "system characteristics." The topic is discussed at length by Bockstael *et al.* (2000), who point out that the calculation of economic values as outlined by Pearce is done by measuring a change in value from one specified state to another, and that both states have to be feasible and comprehensible to individuals for the valuation calculation to have meaning.

There are several methods for environmental valuation that have been developed. These methods have been developed by economists, engineers, and policy-makers. Using the typology of King and Mazotta (2004); Wilson and Carpenter (1999); and Nunes and van den Bergh (2001), the various approaches to valuation that have been used to date are divided into three broad categories.

The first is referred to as ***market prices and revealed willingness to pay***, which include prices directly set in markets, as well as prices that can be inferred from market prices. Methods include:

- ***Direct estimation of producer and consumer surplus*** – can be done for markets where there is a reasonable amount of data and supply and demand curves can be calculated.
- ***Productivity method*** – here, the ecosystem value being calculated is one input to a marketed product, so it is necessary to estimate the value of the input as a portion of the value of the marketed product. For example, an increase in the quality of water in a river will decrease the costs of treatment at a municipal treatment plant, thus contributing to an overall cost savings for drinking water users.
- ***Hedonic pricing method*** – can be used to estimate the values of changes in the characteristics of a good. For example, the value that people derive from a nice view from

their house can be estimated from data on the cost of houses both with and without a view. The same methodology can be used to value (or derive costs for) such things as air pollution or noise.
- ***Travel cost method*** – is best suited to valuing ecosystems or sites that are used for recreation. Basically, the approach uses the costs that people incur in visiting a place as an indicator of its value.

The second category is ***circumstantial evidence and imputed willingness to pay,*** for example the amount that people are willing to pay to avoid floods can suggest the value of wetlands that will perform this service. The specific methods in this category include ***damage cost avoided, replacement cost and substitute cost methods.*** These methods estimate ecosystem costs by estimating the cost of damages due to lost services, the cost of replacing services, or the cost of substituting for such services. For example, the damage that might be caused by flooding after the removal of a wetland can be estimated by looking at the area or property that might be flooded, and the cost of replacing the flood control capacity of the wetland can be estimated from engineering estimates of other sorts of control systems.

The third and final category of valuation methods is ***surveys***, which capture people's statements of their willingness to pay. The types of survey methods include:
- ***Contingent valuation (CV) method*** – the method involves direct surveys of individuals, asking them what they would be willing to pay for certain specific environmental services. The word "contingent" refers to the fact that people are asked how much they would pay for something like an environmental service, contingent on a specific scenario and description of the service. While the methods discussed above try to derive values from market behaviour and engineering cost calculations, CV depends on what people say they would pay for something. The results are controversial, because it is easy to argue that what people say, and what they might actually do, is different. However, such studies are the only way to get some sort of estimates of non-use values.
- ***Contingent choice method*** – in this case, the survey does not ask for specific values, but inquires about the choices or tradeoffs that people might make, and infers value figures from this information. The survey will define two or more outcomes including their costs and benefits, and ask the respondents to rank the outcomes.

***Benefit transfer is*** another valuation concept, involving the transposition of benefits from one study site to another (Brouwer, 2000). Benefit transfer provides a methodology by which valuations obtained in one study can be used elsewhere, in situations shown to be similar enough that such a transfer is reasonable. The depth of analysis required for benefit transfer can take place on three levels (Genty, 2005):
- ***Transfer of statistically-estimated benefits*** – where values that have been determined for one context are directly applied to a similar context.
- ***Transfer of estimated functions*** – where a function that has been determined for one area is used in another. The types of functions that are transferred generally consist of the WTP

per household, or the value per hectare for example.

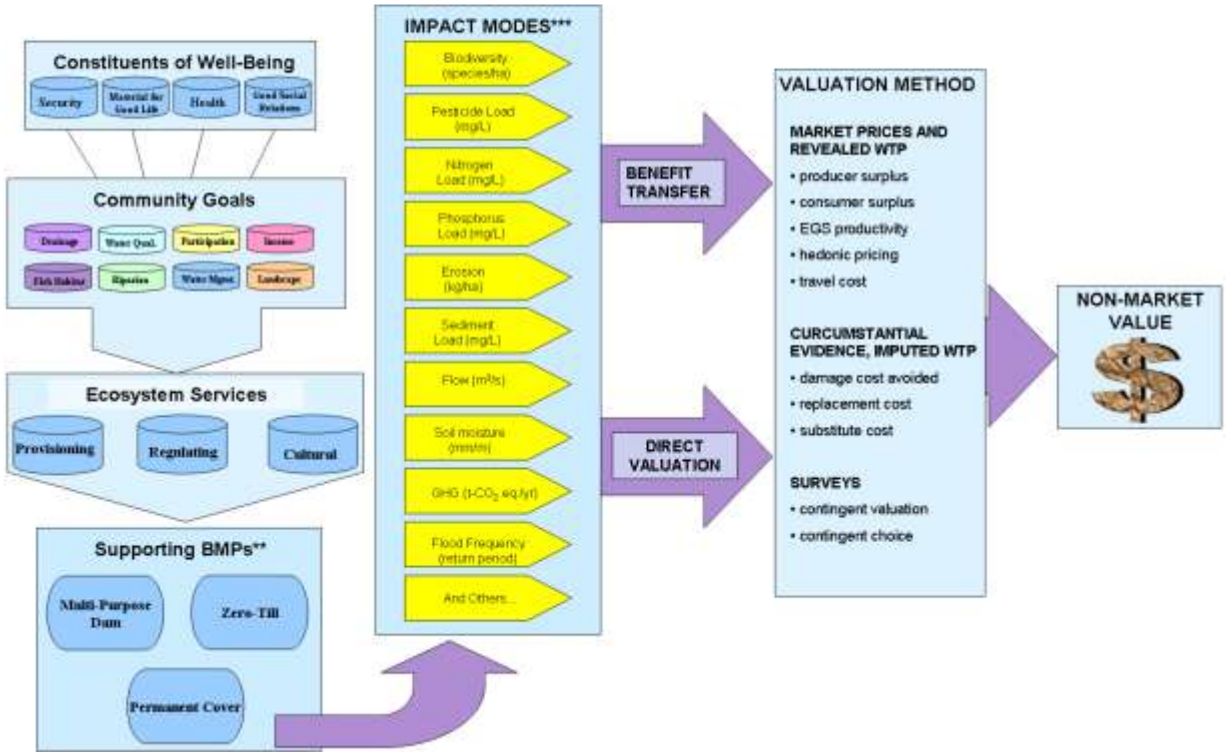
- ***Transfer of meta-models*** – meta-models are models developed for the purpose of benefits transfer. Meta-models are constructed by performing surveys of existing valuation studies to determine factors. Regression analysis is performed to determine the relevance of each factor before constructing a model that can predict values for other areas using the relevant factors.

Transferring values essentially involves directly applying values calculated elsewhere and applying them to specific cases. This method can be effective where the similarity of the locations can be clearly demonstrated. This method becomes less reliable when the values being transferred are vastly different (for example, applying the value of a coastal mangrove wetland to a boreal forest wetland). For this reason the transfer of functions can be a more reliable way of estimating values. If the function of the value of land varies according to the number of species present, then a value of dollars per species can be applied to similar land elsewhere.

Meta-models are a means of systematizing the transfer of functions. At this point in the study of environmental valuation, established values for certain goods and services have yet to be firmly established for all contexts, so meta-models provide a way to develop defensible estimates for valuating ecosystem services when resources do not allow for comprehensive study. Recent efforts in the area of valuation meta-analysis include work by Johnston *et al.* (2005) at determining relevant factors of interest in water quality improvements. This is followed up with work by Thomassin and Johnston (2008) with the development of a methodology for conducting benefit transfer using meta-analysis. Van Houtven *et al.* (2007) similarly conducted a meta-analysis of water quality improvements which can form the basis of a meta-model. Borissova-Kidder (2006) created a methodology to estimate the value of various types of habitat based on several characteristics.

In this project we were able to calculate some of the direct and indirect use values for various BMPs using market prices and revealed WTP values.

Figure 3-3: Detailed systems diagram for BMP impact pathway analysis and valuation.




## 3.2 Trial Public Benefits Calculation

In Chapter 2 the exercise of linking watershed goals to ecosystem services is presented. This work was carried out during a previous consultation in the STC watershed. The community consultation exercise is analogous to Component I of the impact pathways approach. The exercise of linking BMPs to specific impact modes is the focus of Component II of the impact pathways approach. The complete impact pathways framework diagram is included as Figure 3-3.

This valuation is carried out in order to demonstrate a methodology for assessing the non-market value of changed farm practices in the STC watershed, in support of the water management watershed goal. In this valuation exercise, our sample calculations are geared towards three BMPs. The decision of watershed priority and related BMPs is outlined in Section 2.1. The decision to follow this approach is due in large part to the presence of the WEBs program that is studying the effects of certain agricultural BMPs (which support the water management goal) on the water quality of STC. This valuation exercise is centred on the BMPs that WEBs is examining.

### *3.2.1 Methods*

In this exercise, the list of BMPs being evaluated by the WEBs project was evaluated. This list consists of holding ponds from cattle containment areas, permanent cover, zero-till, riparian area management. WEBs research will calculate the environmental benefits of the modelled BMPs. These quantified benefits can then be valued using estimates from literature. This exercise calculates the values gained from three BMPs: zero-till, permanent cover and small dams.

The WEBs integrated model (based on SWAT) will provide pollution equations that can be used to estimate environmental benefits from BMPs, and approximate cost of implementing these BMPs. At the time of this analysis WEBs results for STC were not yet made available. Therefore, a literature search on the environmental benefits of BMPs modelled by software such as SWAT was compiled. Where studies report incremental environmental benefits of specific parameters we were able to hypothetically apply these results to STC, and calculate the value of these practices. In the case of BMPs, valuation was calculated for the present case and for a hypothetical increase in BMP adoption of 50 per cent.

Valuation data was gathered from a search of literature. The challenge in assigning dollar values to changes in environmental variables is that most valuation literature does not relate to specific parameters (i.e., phosphorous concentrations) rather most valuation literature focuses on specific states (i.e., eutrophic). In order to accurately use much of the literature a separate stage of research would be required to link specific parameters to environmental states or conditions, and this research should be as locally-relevant as possible. Through the literature search, it emerged that the most applicable valuation data for this exercise came from avoided cost methods, as generally they relate most closely to specific biophysical parameters.

The parameters valued in this component of the exercise are phosphorous concentration and sediment, as well as the damage cost avoided by changes in erosion and high-flow events. The methodology presented in this component is general, and can be applied to the results generated by the WEBs project. The results generated by this method are for both direct-use and indirect-use human values. Sedimentation of waterways is an issue identified by the local watershed community; therefore decreased sediment concentrations have a direct-use value. None of the water in the STC watershed is used for municipal purposes; therefore the decreased costs of sediment and water removal for treatment are indirect-use human values. Their value would only be realized if the water were being treated for human consumption.

The value of greenhouse gas emissions reduced and the amount of carbon sequestered as a result of implementing the practices was also estimated for zero-till and permanent cover. This impact mode is not being modelled by WEBs, but data on the effectiveness of these BMPs are available from the literature, and the value of one tonne of carbon can be taken from current market prices established by the Chicago Climate Exchange.

The specific steps followed in performing the calculations for zero-till and permanent cover were:

- determine the present adoption rate of the BMP;
- calculate baseline erosion rate;
- establish BMP effectiveness at reducing erosion, phosphorous loading and GHG mitigation;
- determine new erosion, phosphorus and GHG rate;
- compute reduction attributable to BMP; and
- using valuation figures in terms of specific impact modes, calculate the value of reduced sediment erosion, phosphorous leaching and GHG reduction/sequestration.

Direct valuation of benefits achieved by changed practices can be an effective and simple means of performing economic valuation when costs are known. In this case study the simplicity of this method is demonstrated. In the 1990s several small dams were constructed in the STC watershed. These dams had the effect of reducing peak flow, and decreasing sediment load. These changes led to decreased public expenditures for ditch maintenance and flood damage. These avoided costs constitute the direct use values realized by these practices.

### 3.2.2 *Data Collection*

The calculations performed in this case study analysis consisted of an estimate of the biophysical impact of BMPs, and an economic valuation of these changes. In order to perform the biophysical calculations, data on the impacts of BMPs were required to estimate baseline pre-BMP conditions. For the economic valuation calculations, valuation data that could relate to the environmental impacts were required.

The data on the performance of zero-till were taken from the South Nation River nutrient trading scheme (South Nation, 2003, 2005). Erosion rates were taken from Fox and Dickson (1990) and are listed in Table 3.1. Phosphorous loss rates were also taken from Fox and Dickson (1990) and South Nation and are listed in Table 3.2. Considerable research has been taking place on the effectiveness of BMPs at reducing agricultural GHG emissions and sequestering carbon (SSCA, 2005; AAFC 2003). The effectiveness of zero-till and permanent cover at mitigating GHG is tabulated in Table 3.3.

Table 3.1: Erosion rates from conventional till, zero-till and permanent cover:

| Land use | Erosion rate (t/ha/yr) | | | Reduction fraction |
|---|---|---|---|---|
| | low | high | medium | |
| Conventional till | 0.55 | 0.65 | 0.6 | |
| Zero-till | 0.13 | 0.16 | 0.145 | 0.758 |
| Permanent cover | 0 | 0.15 | 0.075 | 0.875 |

(South Nation, 2003, 2005; Fox and Dickson 1990)

Table 3.2: Phosphorous loss rates from conventional till, zero-till and permanent cover

| Land use | P loss rate (t/ha/yr) | | | Reduction fraction |
|---|---|---|---|---|
| | low | high | medium | |
| Conventional till | 0.07 | 1.27 | 0.67 | |
| Permanent cover | 0.02 | 0.38 | 0.2 | 0.64 |
| Zero-till | | | | 0.18 |

(South Nation 2003, 2005, Fox and Dickson 1990)

Table 3.3: GHG mitigation by zero-till and permanent cover

| BMP | GHG mitigation rate (t $CO_2$eq/ha/yr) |
|---|---|
| Zero-till | 0.3 |
| Permanent cover | 1.1 |

(SSCA, 2005; AAFC, 2003)

A scan of the literature on valuation was carried out in order to determine the non-market values of environmental parameters in the STC watershed. This literature search scanned all types of valuation literature, including willingness to pay, direct estimation, etc. The results of the literature search are presented in Table A-2 in the Appendix. Only data that could apply to BMP impact modes were tabulated. Since most valuation data relate to environmental states or conditions rather than specific parameters, the selection of valuation numbers that could be applied in this case study was rather limited.

The value for 1 kg of phosphorous is based on the expenditure that the City of Winnipeg plans to spend on reducing nutrient outflow. Winnipeg plans to spend $670M on facilities that will reduce phosphorous loading to the Red River by 300 t/yr (Shkolny, 2008). Based on a 20-year amortization, this equates to $112 per kg of P per year.

Values for sedimentation are the same as those used by Tyrchniewicz (2007), Olewiler (2004) and Belcher *et al.* (2001). These values were synthesized for Canada by Belcher *et al.* (2001) using benefits values calculated by Ribaudo (1989) on the benefits of the Conservation Reserve Program and Fox and Dickson's (1990) estimate of erosion rates in Canada. Converted to 2008 dollars, the value used for sediment in this analysis is $23.35/ha/yr, which consists of $1.88/ha/yr for avoided costs of sedimentation of conveyance infrastructure, and $21.65 for avoided treatment costs.

The value of GHG reduction/sequestration is taken from the value of GHG credits traded on the Chicago Climate Exchange. As of April 2008 carbon credits were trading for around $6 per tonne. The values used in this analysis are summarized in Table 3.4.

Table 3.4: Values for incremental changes in impact modes.

| Impact Mode | Value ($/t/yr) |
|---|---|
| Water treatment phosphorous | 112,000 |
| Sedimentation of water conveyance | 1.88 |
| Water treatment sediment | 21.65 |
| GHG mitigation | 6 |

(Shkolny, 2008; Tyrchniewicz, 2007; Olewiler, 2004; Belcher *et al.*, 2001; Ribaudo 1989)

Geographic data on the STC watershed were required in order to form the baseline case. These baseline data included watershed area, soil erosion rates, phosphorous loss rates from farmland and BMP adoption rates. These data came from a variety of sources including the local watershed community, the Agriculture Census of Canada (Statistics Canada 2006) and from academic literature. Some of the key geographic data used are summarized in Table 3-5.

Table 3-5: STC watershed geographic information.

| Parameter | Quantity | Unit | Source |
|---|---|---|---|
| Area of land under cultivation in STC watershed | 5,409 | ha | TCMW, 2004 |
| Area of STC watershed (at Miami) | 7,638 | ha | TCMW, 2004 |
| Area of full TC watershed | 112,839 | ha | Manitoba Land Initiative, 2007 |
| Erosion of sediment | 4.34 | t/ha/yr | Fox and Dickson, 1990 |
| Erosion of phosphorous | 0.67 | kg/ha/yr | Fox and Dickson, 1990 |
| Rate of zero-till adoption | 4.79 | % | Interpolated from 2006 Census of Agriculture |
| Area of STC under permanent cover | 134 | ha | TCMW, 2004 |

Agricultural BMPs affect the quality and quantity of water in many ways; some of which are currently being studied by WEBs. While WEBs will offer some insight into the potential of BMPs to affect environmental change, separate analysis is required to determine the actual changes that have occurred as a result of practices already in place. In the case of STC, this involves determining the quality of the water before and after BMPs are implemented. Because there were no water quality samples analyzed for STC before the BMPs were implemented, it was necessary to use neighbouring Lyle's Creek (which has similar geography and hydrography) as a proxy. The water quality for STC and Lyle's Creek were analyzed. The difference in phosphorous loads between the two waterways was attributed to the BMPs implemented in STC, and an assumption was made that the level of BMP implementation in the Lyle's Creek watershed is similar to the level of BMP adoption prior to widespread BMP uptake by the Deerwood Soil and Water Management Association. STC water quality data were found in Glozier's (2006) report on the Water Quality of STC, while water quality for Lyle's Creek is described in the Stephenfield Lake Watershed Management Plan (Manitoba Water Stewardship, 2005). Additional land use data were utilized from AAFC (2002). These data are summarized in Table 3-6. The purpose of this exercise is to verify that changes in water quality can be attributed to the BMPs implemented.

Table 3-6: Water quality comparison between STC at Miami and Lyle's Creek.

| | Area | Area | Average runoff | TP | Total flow | Total P | Watershed P loading |
|---|---|---|---|---|---|---|---|
| | $km^2$ | ha | mm | mg/l | l | kg | kg/ha |
| Lyles Creek | 65 | 6500 | 63.5 | 1.26 | 4.13E+09 | 5200.65 | 0.8001 |
| STC Miami | 76.38 | 7638 | 78 | 0.89 | 5.96E+09 | 5302.3 | 0.6942 |

(Glozier, 2006; Manitoba Water Stewardship, 2005)

### *3.2.3 Calculations*

This section explains the calculations that were performed to determine the values of benefits from BMPs in place in the STC watershed, using biophysical assumptions from modelling studies (similar to WEBs); and using generic values from literature to determine the values of these changes.

Agricultural Census of Canada results for 2006 were analyzed by IISD and interpolated to determine the amount of BMPs applied in the Tobacco Creek watershed (interpolated from the 2006 Agricultural Census of Canada). From the 2006 Census, there are 4,226.8 ha of 112,839.4 ha of farmland under zero-till farming in the Tobacco Creek watershed, for an implementation rate of 4.79 per cent. If we assume that the uptake rated of zero-till is the same in STC, then applying the ratio of 4.79 per cent to STC's 5,409 ha equates to a zero-till area of 202.6 ha. The calculations are performed for the present level of BMP uptake, as well as for a hypothetical increase of zero-till uptake to 8 per cent of cropland, and an increase in permanent cover area to 15 per cent of cropland. This amounts to a total zero-till area of 433 ha, and a total permanent cover area of 811 ha. For the small dams the proposed increase is to a total of 40 dams in the watershed.

Fox and Dickson (1990) estimate that zero-till reduces sediment erosion by 63 per cent, and Gassman *et al.* (2002) estimate P reduction from zero-till to be 18 per cent. Given that the sediment and P loading estimates from conventionally farmed lands are 4.34 t/ha and 0.67 kg/ha respectively (Fox and Dickson, 1990), the estimated sediment and P loading reductions for the entire STC watershed are therefore 561 tonnes for sediment erosion, and 24 kg for P. These biophysical assumptions are summarized in Table 3.7.

Table 3.7: Data of biophysical benefits of zero-till.

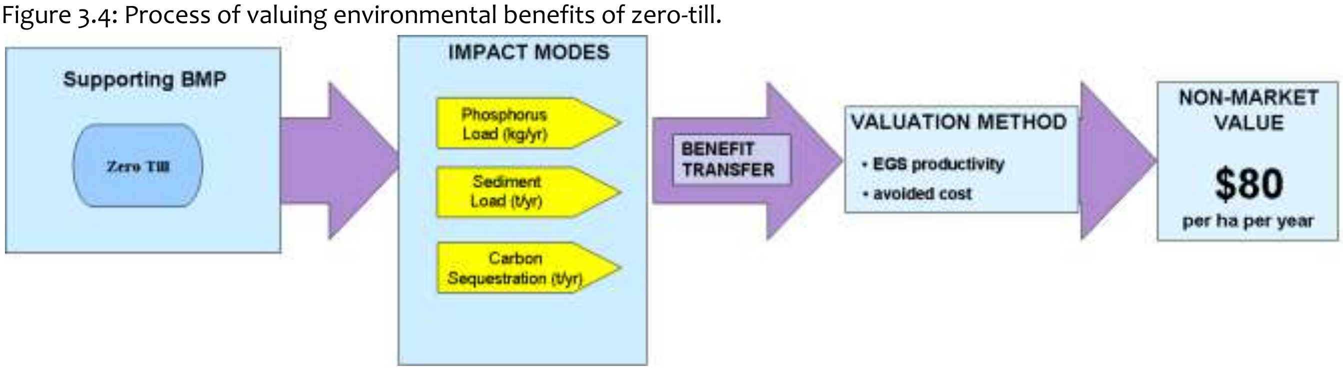
| Zero-Till | Unit | No BMP | Value – present | Value – increase |
|---|---|---|---|---|
| Watershed area | ha | 5,409 | 5,409 | 5,409 |
| BMP Area | ha | 0 | 203.6 | 433 |
| GHG mitigation | t/yr | 0 | 61 | 130 |
| Sediment Erosion | t/yr | 23,502 | 22,940.9 | 22,302 |
| Sediment erosion reduction | t/yr | 0 | 561.3 | 1200 |
| P erosion | kg/yr | 3,624 | 3,062.8 | 2,424 |
| P loss reduction | kg/yr | 0 | 24.4 | 52 |

Applying values to these benefits, we can determine that the public values gained by the implementation of zero-till in the STC watershed contributes a minimum non-market value of over $16,000 per year at present, and over $34,000 per year with an increased uptake rate. This amounts to benefits of over $80 for each ha of land under zero-till farming in the STC watershed. The breakdown of these values is listed in Table 3.8 and shown in Figure 3.4.

Table 3-8: Breakdown of valuation of zero-till in STC watershed in 2008 dollars.

| Impact Mode | Unit | Value of present uptake | Value with increased level of uptake |
|---|---|---|---|
| P – treatment | $/yr | 2,737 | 5,851 |
| Sed – treatment | $/yr | 12,151 | 25,979 |
| Sed – conveyances | $/yr | 1,055 | 2,256 |
| GHG benefits | $/yr | 365 | 780 |
| **Total value of BMP** | **$/yr** | **$16,308** | **$34,866** |
| | | | |
| BMP area | ha | 203 | 433 |
| Value per ha | | **$80** | **$80** |

Figure 3.4: Process of valuing environmental benefits of zero-till.




There are 134 ha of farmland in the STC watershed under permanent cover (TCMW, 2004). Fox and Dickson estimate that permanent cover reduces sediment erosion by 88 per cent and P losses by

70 per cent. Using the estimates for sediment and P loading from conventionally farmed lands of 4.34 t/ha and 0.67 kg/ha respectively, the sediment and P loading reductions from permanent cover in STC watershed are estimated at 515 tonnes for sediment erosion, and 63 kg for P. This data are summarized in Table 3.9.

Table 3.9: Data of biophysical benefits of permanent cover.

| Permanent cover | Unit | No BMP | Value – present | Value – increase |
|---|---|---|---|---|
| Watershed area | ha | 5,409 | 5,409 | 5,409 |
| BMP area | ha | 0 | 134 | 811 |
| GHG mitigation | t/yr | 0 | 147 | 892 |
| Sediment Erosion | t/yr | 23,502 | 22,987 | 20,384 |
| Sediment erosion reduction | t/yr | 0 | 515 | 3,118 |
| P erosion | Kg/yr | 3,624 | 3,109 | 506 |
| P loss reduction | Kg/yr | 0 | 63 | 381 |

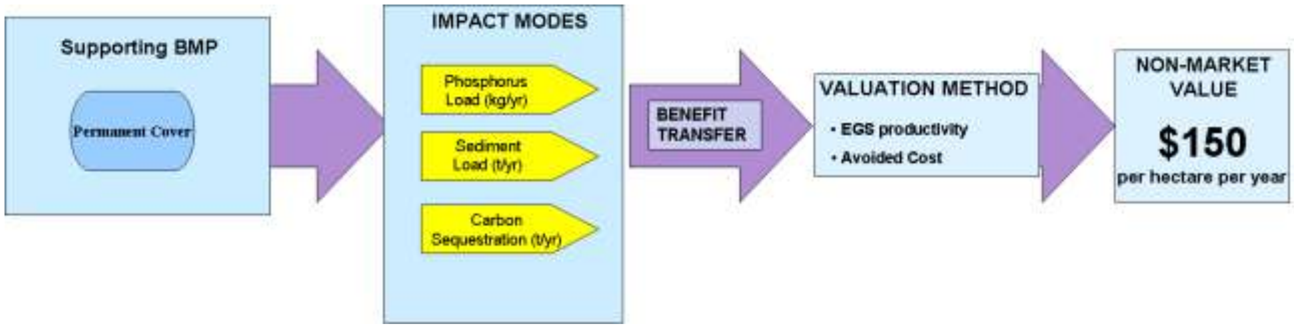
Using the values presented in Table 3-4 determined by Belcher Edwards and Gray (2001) for the Grand River watershed, the value of sediment loading reductions for water treatment from permanent cover in STC are $11,155/year; sediment loading for conveyance infrastructure purposes: $969/year; and the value of P loading reductions by permanent cover for water treatment purposes is $3,650 per year.

The total value of permanent cover conversion in the STC watershed is therefore estimated at $20,000 per year at present, and over $121,000 with an increased level of uptake. These calculations are summarized in Table 3-10. The calculation process is followed in Figure 3-5.

Table 3-10: Breakdown of valuation of permanent cover in STC watershed in 2008 dollars.

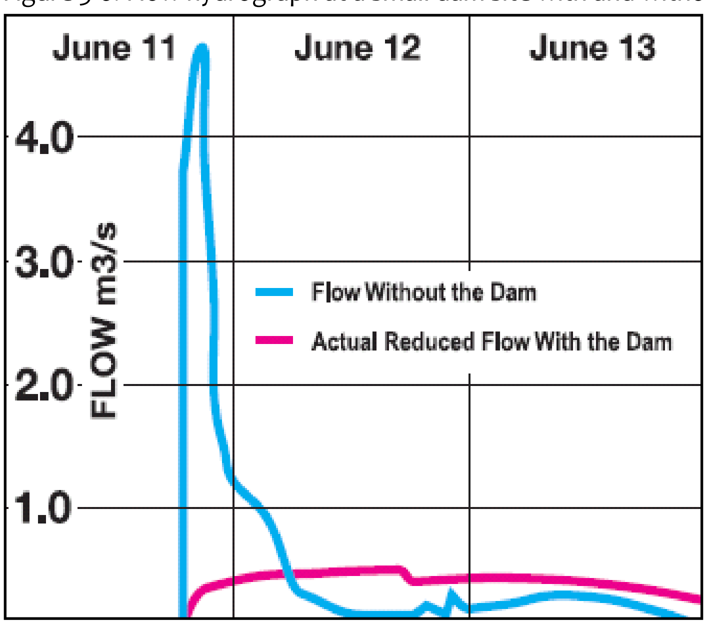
| Impact Mode | Unit | Value – present | Value – increase |
|---|---|---|---|
| P – treatment | $/yr | 7,054 | 42,691 |
| Sed – treatment | $/yr | 11,155 | 67,511 |
| Sed – conveyances | $/yr | 969 | 5,862 |
| GHG benefits | $/yr | 884.4 | 5,887.8222 |
| **Total value of BMP** | **$/yr** | **$20,062** | **$121,952** |
| | | | |
| BMP area | ha | 134 | 811 |
| Value per ha | | $150 | $150 |

Figure 3.5: Flowchart of valuation calculation for STC permanent cover BMP




Twenty six small dams were constructed in the STC watershed in the late 1980s to the mid-1990s, with a total network storage volume of 692 Ml (megalitres). These structures contributed to an improvement in water quality and a reduction in peak flow events (see Figure 3-6 for a graph of flow reduction for a small dam).

Figure 3-6: Flow hydrograph at a small dam site with and without small dam. Source: AAFC, 1995.

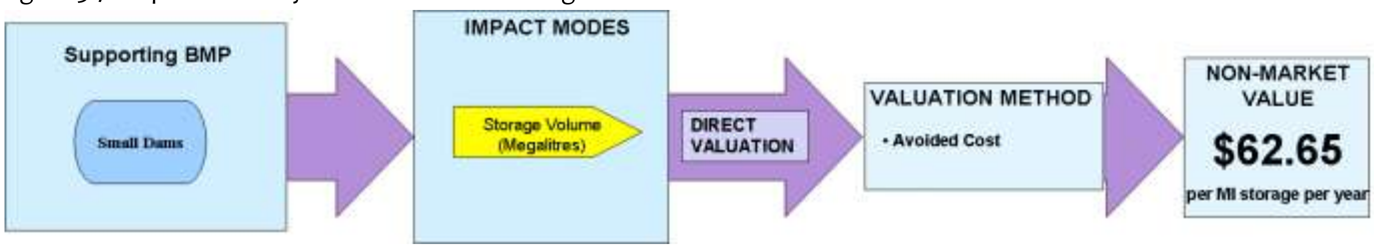



The direct-use benefit to the STC watershed was a decrease in sedimentation of water conveyance structures, and a decrease in flood events. Records from 1986 indicate that this resulted in a savings to municipal governments of $25,000 per year in 1986 dollars (TCMW, 2004). Therefore the direct-use value of the benefits of these structures is $43,354 per year. [updated for inflation] with the present number of 26 dams, and over $66,000 with a hypothetical increase to 40 dams. With a small dam network providing 692 Ml of capacity, this equates to $62.65 per Ml of storage per year. These benefits are summarized in Table 3-11. The calculation process is followed in Figure 3-7.

Table 3-11: Summary of non-market value of small dams.

| Small Dams | Unit | Present case | Increased uptake |
|---|---|---|---|
| Dams | qty. | 26 | 40 |
| Storage capacity | Ml | 692 | 1065 |
| Avoided costs | $/year | 43,354 | 66,696 |
| Avoided costs | $/Ml/yr | 62.65 | 62.65 |

Figure 3.7: Impact Pathways Framework for valuing EGS from small dams




### 3.2.4 *Summary of STC Benefits Valuation*

The total benefits of BMPs in the STC watershed amounts to approximately $80,000 per year. This figure consists of $16,308 of benefits per year from the 202.6 ha of land under zero-till; $20,062 per year from the 134 ha of permanent cover; and $43,354 from 26 small dams. These values are broken down in Table 3-12, and the summary of total value to the watershed is presented in Table 3-13.

Table 3-12: Non-market BMP values in the STC watershed.

| BMP | Impact mode | Valuation | Value type | Value ($/year) |
|---|---|---|---|---|
| Zero-till | Decreased sedimentation of water conveyance infrastructure | Benefit transfer | Direct use | 5.21/ha |
| Zero-till | Decreased sediment load for water treatment | Benefit transfer | Indirect use | 59.97/ha |
| Zero-till | Decrease phosphorous concentrations for water treatment | Benefit transfer | Indirect use | 13.51/ha |
| Zero-till | Mitigation/sequestration of GHG | Benefit transfer | Indirect use | 1.80/ha |
| Permanent cover | Decreased sedimentation of water conveyance infrastructure | Benefit transfer | Direct use | 7.23/ha |
| Permanent cover | Decreased sediment load for water treatment | Benefit transfer | Indirect use | 83.24/ha |
| Permanent cover | Decrease phosphorous concentrations for water treatment | Benefit transfer | Indirect use | 52.64/ha |
| Permanent cover | Mitigation/sequestration of GHG | Benefit transfer | Indirect use | 6.60/ha |

| BMP | Impact mode | Valuation | Value type | Value ($/year) |
|---|---|---|---|---|
| Small dams | Decreased infrastructure maintenance | Direct valuation | Direct use | 62.65/Ml |

Table 3-13: Total BMP values per hectare.

| BMP Values | Increased adoption (total value) | Increased adoption (per unit improvement) |
|---|---|---|
| Zero-till | 34,866 | 80.49 $/yr |
| Permanent cover | 121,952 | 149.71 $/yr |
| Small dams | 66,696 | 62.65 $/Ml |
| Total value | 223,513 | |
| Value spread over all 5,409 ha of cropland | | 41.32 $/ha/yr |

Each hectare of land under zero-till cultivation contributes $80 in non-market value. Each hectare of permanent cover contributes approximately $150 in non-market value. Each of the small dams contributes $1,667 in value to the STC watershed. Aggregated over all the farmland in the STC watershed, the value of the three BMPs is equivalent to $41 per hectare.

### *3.2.5 Limitations of Calculations*

This valuation provides a sample of values that can be calculated for the benefits of implementing BMPs. From this exercise we see that the direct and indirect use benefits of selected BMPs implemented in the STC watershed is approximately $80,000 per year. The reliability of the values calculated depends to a large extent on the assumptions inherent in their calculation. Valuations that rely on literature values require that they are complete and assumed to be locally relevant. While impact modes selected for analysis in this report are the most locally relevant and the most affected by the selected BMPs, they account for only a subset of all the modes of impact of these BMPs. Therefore, the values computed represent only a portion of the complete non-market value of these BMPs. In addition, these BMPs may have co-benefits that may have a value, but cannot be accurately measured.

Therefore, the values calculated in this report constitute a minimum non-market value for the BMPs analyzed. Table 3-14 lists some impact modes that were not valued as part of this analysis, and their potential to increase or decrease the value of the BMPs analyzed.

Figure 3-14: Parameters not valued and their likelihood of increasing or decreasing the non-market value of BMPs.

| Impact mode | Zero-till | Permanent cover | Small dams |
|---|---|---|---|
| Fish habitat ($m^3$) | none | none | increase $ |
| Terrestrial habitat (ha) | increase $ | increase $ | decrease $ |
| Airborne particulate emissions (ppm) | increase $ | increase $ | none |
| Wildfire Risk (% likelihood) | decrease $ | decrease $ | increase $ |
| Average flow (m3/s) | none | increase $ | increase $ |
| Ammonia (mg/l) | increase $ | increase $ | increase $ |
| Total Kjeldahl nitrogen (mg/l) | increase $ | increase $ | increase $ |
| Nitrate/nitrite nitrogen (mg/l) | increase $ | increase $ | increase $ |
| Sodium (mg/l) | none | none | none |
| Magnesium (mg/l) | none | none | none |
| Iron (mg/l) | increase $ | increase $ | none |
| Fecal coliforms (cfm/100 ml) | none | decrease $ | none |
| Pesticide leaching (mg/l) | increase $ | increase $ | none |

### *3.2.6 Benefits in Perspective – BMP Costs*

Understanding the public benefits provided by BMPs can help to determine the feasibility of expanding their implementation. While the benefits of BMPs varies, so too does their cost. Understanding the benefits and costs together can set the stage for determining which BMPs to develop and promote.

Work recently completed by IISD and ÉcoRessources Consultants determined the cost to the producer of implementing a cover crop depends on whether it is an annual or perennial crop (ÉcoRessources, IISD, IRDA, 2008). The cost of establishing a cover crop of fall rye in Manitoba would be $27.80 per hectare (ÉcoRessources, IISD, IRDA, 2008). The cost of maintaining permanent forage cover in Manitoba is estimated at $53/ha (MAFRI, 2007). The benefits of this practice calculated above are $150/ha, not including the private benefits from direct use of the forage. Using the higher figure for cost, this reveals a benefit to cost ratio of 1.23.

The cost of zero-till is often debated as the private benefits to producers may outweigh the costs of implementing the practice since the practice will reduce expenditures and potentially increase yields. Generally the cost of zero-till is limited to the capital expenditure for a chisel, while public costs for technical support may be required in order to educate producers to switch to zero-till. ÉcoRessources and IISD (2008) computed that the total costs (public and private) for implementing zero-till in the Nicolet River watershed would be approximately $469/ha (both public and private costs, not taking into account private benefits). Amortized over 20 years at a rate of 5 per cent this amounts to approximately $65/ha/year. The non-market value of this practice calculated above is

$80/ha/yr, for a benefit to cost ratio of 2.83.

The cost of dams in the STC watershed was $12,500/dam in 2008 dollars (TCMW, 2004). With 26 dams, this equates to a cost of $325,000. Amortized over 20 years at a rate of 5 per cent this amounts to costs of $25,700 per year, or $37 per year per megalitre of storage. The non-market value provided by this storage volume is approximately $63/Ml, for a benefit to cost ratio of 1.7.

The benefits and costs of the three BMPs are tabulated in Table 3-15.

Table. 3-15: Benefit to cost ratio of the three BMPs analyzed for STC.

| BMP | Value $/ha | Cost $/ha | Value/cost /ha |
|---|---|---|---|
| Zero-till | 80 | 65 | 1.23 |
| Permanent cover | 150 | 53 | 2.83 |
| | /Ml | $/Ml | $/Ml |
| Small dams | 63 | 37 | 1.70 |

In the case of STC, the BMPs analyzed have non-market value benefits in excess of their costs. The implication of this is that there is merit in providing public support to BMPs, when there is a net public benefit. To put these costs and benefits into perspective, the average profit margin that farmers receive in a typical Manitoba watershed (the Little Saskatchewan watershed) is $67.95/ha/year (Ecoressources and IISD, 2008).

Programs such as the NFSP have been highly successful at drawing producer interest, however without an understanding of the benefits provided; the case for their continuation rests largely on political will. Proof of a net benefit to the public helps to solidify the case for maintaining producer BMP incentives.

### *3.2.7 Scale up to Full Tobacco Creek*

The previous sections detail the impact pathways approach and how to evaluate BMPs relevant to local priorities. While this is a useful exercise, it is also useful to present a methodology for scaling the benefits up to a larger watershed, in this case the larger Tobacco Creek watershed.

Scale-up can be performed by applying the non-market BMP values calculated above, and applying them to watersheds where the basic geography is known. For the Tobacco Creek watershed, this basic information was taken from the Agricultural Census of Canada, and the pertinent information is listed in Table 3-16. As with the STC analysis, this is performed using the present BMP adoption rates, and for a hypothetical increase of zero-till to 8 per cent of cropland, permanent cover to 15 per cent of cropland and small dams from 50 to 90. The basis for these increases is that they are similar to adoption rates in other watersheds. For small dams the increase is based on the fact that while STC is on the steeper Manitoba Escarpment, much of the rest of the Tobacco Creek watershed is in the Red River Valley where grades are not as steep, hence fewer dams would be required given that flows are regulated by the upstream structures.

Table 3-16: Tobacco Creek watershed cropland.

| Total cropland in STC watershed | Present (ha) | Future - hypothetical uptake (ha) |
|---|---|---|
| Existing amount of cropland (ha) | 112,839 | 112,839 |
| Zero-till (ha) | 4,227 | 9,037 |
| Permanent cover (ha) | 7,062 | 42,738 |
| Small dams storage (Ml) | 1,384 | 2,491 |

Applying the BMP non-market values calculated above of $80/ha/year for zero-till, $150/ha/year for permanent cover and $63/Ml/year for small dams, we calculate that the total values for the three BMPs is $1.4M/yr at present. With the described hypothetical increase in BMP uptake, the total non-market value to the Tobacco Creek watershed is $7.3M/yr. These values are broken down in Table 3-17.

Table 3-17: Non-market BMP values scaled to the full Tobacco Creek watershed.

| Total Value | Present ($/yr) | Increased uptake ($/yr) | Value per unit per year |
|---|---|---|---|
| Zero-till | 340,203 | 727,354 | 80.49/ha |
| Permanent cover | 1,057,218 | 6,426,700 | 150.37/ha |
| Small dams | 83,373 | 150,065 | 62.65/Ml |
| Total value | $1,480,794 | $7,304,120 | |
| **Total Value per hectare over entire Tobacco Creek watershed** | | | **36.39/ha** |

### *3.2.8 Discussion of Valuation*

Economic valuation is an effective means of examining the benefits of BMPs. When non-market BMP benefits are compared to their costs this can provide a means of assessing the business case for programs to assist producers to implement BMPs. A major strength of this approach is that it can help to determine values gained not only by users in the local watershed, but also to society in general.

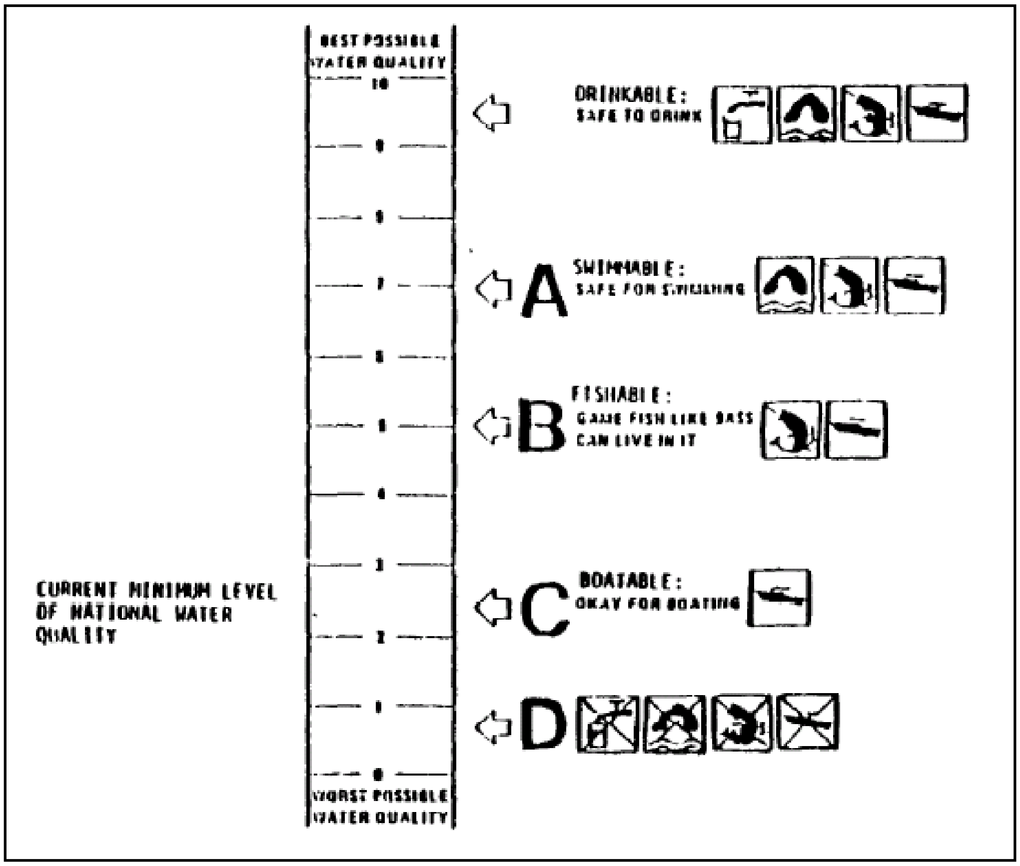
Linking valuation to local priorities can assist with prioritizing the parameters to be valued. Assessing indirect use values helps to determine the impact of practices outside of the local area. In this analysis the value of decreased phosphorous loading was calculated. While this value may have little relevance to the STC watershed, phosphorous loading to Lake Winnipeg is causing eutrophication so a decrease in an upstream catchment will have benefits to the lake. Also indirect use values could become direct use values. For example there is presently no direct use value to farmers in the STC from decreased GHG emissions or increased carbon sequestration, but with the implementation of a domestic cap and trade and offset program for GHGs, this would instantly become a direct use value.

The challenge in conducting this type of valuation work is finding valuation studies that can be applied. A survey of environmental valuation literature revealed that there is no clear linkage between the valuation of water quality, and water quality parameters. The valuation literature most applicable for this type of exercise deals with avoided costs. Contingent valuation and WTP work generally does not relate to specific parameters. Literature from these fields generally asks people about their willingness to pay for better fishing or fewer algal blooms for example. While this is helpful information, it does not relate to the specific parameters that BMPs act upon, such as sediment loads or phosphorous concentrations. This is because it would be inherently difficult to get meaningful results if a survey were conducted asking people their willingness to pay, for example, for a decrease in phosphorous concentrations of 0.14 mg/l.

The most influential attempt to link water quality parameters with WTP and contingent valuation is the Resources for the Future (RFF) Water Quality Ladder (see Figure 3-8) which ranks water quality according to its various human end uses (Vaughan, 1986). These uses are consistent with water quality classification used throughout the world, including the classifications used in Manitoba (Manitoba Conservation, 2002). The water quality ladder has been highly influential for water quality valuation, forming the basis for many valuation meta-analysis studies underlying benefit-transfer methodologies, including those of Johnston *et al.* (2005), Van Houtven *et al.* (2007) and Thomassin and Johnston (2008).

Vaughan (1986, pA-II-1) recognized the inherent difficulty in linking WTP water quality studies to specific parameters while developing the ladder, citing Binkley and Hanemann (1978): "*...people's ratings of water quality levels are likely to exhibit a less-than-perfect degree of association with any one or a combination of the several scientific measures of quality considerations.*" The RFF water quality ladder offers the best clues on how to link the wide body of valuation research with improvements in water quality. The challenge in doing so is to use an index specific enough to value smaller improvements in water quality, ones that may not be perceptible to humans. There are challenges in applying the RFF water quality ladder for this reason.

Figure 3-8: RFF water quality ladder.




The Water Quality Ladder is associated with five parameters (Table 3-18), while water quality guidelines issued by regulatory authorities follow similar categories to the ladder and the official categories list hundreds of parameters. Also presenting a challenge is that the ladder requires that all parameters move in tandem in order for a benefit to be registered. As we see through the impact pathways approach, while the benefits to water quality from BMPs have considerable value, the overall effect of these BMPs may only impact a limited number of parameters, and not the five required to register a change on the ladder, nor the hundreds required to change its category in the Manitoba guidelines.

The third challenge is that the ladder is presented as having ascending levels. In reality the rungs are not additive. For example, the highest rung on the latter is water fit for human consumption. It is unlikely that water fit for human consumption could ever be found in the natural environment (with the exception of water taken at the source of artesian wells or at their glacial source). According to the parameters listed in Table 3-18 drinking water must be free of fecal coliforms. Keeping water free of this bacteria implies that there should be no human or animal contact, therefore to maintain drinking water quality, recreational activities cannot occur and wildlife must be kept away from the water.

The gap between the science and economics of water quality valuation has endured. Recently published research continues to highlight the same issue of the disconnect between water quality valuation and science, 30 years later (Nunes and van den Bergh, 2001; Johnston *et al.,* 2005). Thomassin and Johnson's (2008) fourth recommendation is to link the Water Quality Ladder to specific indicators, and they stress that *"...non-market studies of WTP for water quality improvements should incorporate clear linkages between quantified changes in pollutants of interest (which may or may not be explicitly stated within stated preference survey instruments) and a clearly stated linear, user-based scale"* (Thomassin and Johnson, 2008, p. 20).

The challenge in making a clear linkage between WTP environmental studies such as the Water Quality Ladder is that the biophysical drivers of water quality changes are disparate and highly complex. For example, the Manitoba Water Quality Guidelines mention over 200 chemical compounds, and have guidelines for drinking water, surface water for protection of aquatic life, irrigation, water for livestock, and recreation. There are also two sets of guidelines for aquatic life tissue consumption, depending on whether the tissue is to be eaten by humans or wildlife (Manitoba Conservation, 2002).

Water quality parameters often also have cause and effect relationships. The concentration of one parameter may be influenced by others. For example in Manitoba there are complex temperature- and pH-dependent guidelines for ammonia—due to its toxicity to humans and fish—but ammonia can also attenuate into nitrites and nitrates, for which there are also guidelines. Ammonia, nitrites and nitrates also contribute to biochemical oxygen demand (BOD) which can be used as a measure of the propensity of a water body towards eutrophication. Of course the BOD is not the sole indicator of eutrophication. Aquatic ecosystems can be limited by nitrogenous compounds, they can be limited by phosphorous, or their eutrophication can be limited by the amount of light entering the water (which is affected by the amount of suspended solids in the water). These interrelationships highlight the complexity of associating specific parameters to water quality states, and offer some insight into the amount of work that needs to be done in this area.

It is these complex interrelationships that highlight the difficulty in using WTP studies. In addition, using a combination of revealed willingness to pay for certain aspects and WTP studies for others can introduce issues of double counting, where certain impact modes may partially or totally form part of people's perceptions of a resource.

Table 3-18: RFF water quality ladder rung parameters.

| Water Quality Classification | Measurable Water Quality Characteristics<br>Fecal Coliforms (#/100 ml) | Dissolved Oxygen[a] (mg/l) | 5-day BOD (mg/l) | Turbidity (JTU) | Ph |
|---|---|---|---|---|---|
| Acceptable for drinking water treatment 7.25 | 0 | 7.0 (90) | 0 | 5 | |
| Acceptable for swimming | 200 | 6.5 (83) | 1.5 | 10 | 7.25 |
| Acceptable for game fishing | 1000 | 5.0 (64) | 3.0 | 50 | 7.25 |
| Acceptable for rough fishing | 1000 | 4.0 (51) | 3.0 | 50 | 7.25 |
| Acceptable for boating | 2000 | 3.5 (45) | 4.0 | 100 | 4.25 |

a. Percent saturation at 85° in parentheses.

In order to simplify the process of valuation from agricultural practices, work needs to be carried out on linking the broader valuation literature to specific environmental parameters. While avoided cost literature offers significant insight, the type of values that WTP literature can provide would be a useful complement. Benefit transfer methodologies using this literature have advanced significantly (Borissova-Kidder, 2006; Van Houtven *et al.,* 2007; Johnston *et al.,* 2005; Thommasin and Johnston, 2008). However, in order to use these methodologies when examining specific environmental issues more work needs to be done to link the economics with the science. The RFF water quality ladder can form a basis for this type of linkage, since it is the most influential effort to date, and has formed the basis of a field of benefit-transfer study.

# 4.0 Conclusions

Agricultural beneficial management practices (BMPs) are science-based on-farm activities that can reduce negative environmental impacts or increase positive environmental impacts. Agricultural BMPs can therefore produce *ecosystem goods and services*, which have demonstrable public benefit meriting consideration of public policy support.

This study provides an illustrative estimate of the public benefit of agricultural BMPs in a small watershed in Southern Manitoba – South Tobacco Creek near the town of Miami. South Tobacco Creek is one of seven research sites within AAFC's Watershed Evaluation of Beneficial Management Practice (WEBs) program. Our study objectives were essentially three-fold:

- To provide a defensible, scoping analysis of the public benefit of watershed-based BMPs using an impact pathway approach that could be linked to ongoing WEBs research.
- To identify valuation issues requiring more research in the Canadian context for agricultural policy development.
- To contextualize this research within AAFC's *Growing Forward* Strategic Plan.

The three BMPs analyzed in this study (zero-till, permanent cover and small multi-purpose dams) were consistent with the watershed modelling activities underway through WEBs, and with a previous community-led integrated water resources management (IWRM) exercise (Section 2.1.2). The values of these practices were determined by evaluating their sediment and phosphorous reduction benefits, their GHG mitigation potential, and in the case of small dams the municipal water treatment expenditures avoided (Section 3.2.3).

The non-market values calculated through this process are \$80/ha/year for zero-till, \$150/ha/year for permanent cover, and \$63/Ml/year for small dams (Section 3.2.4). Aggregated over the entire Tobacco Creek watershed, the estimated public benefit is \$36.39/ha/year, which compares well with other research which estimated the non-market public benefits from agricultural lands at between \$40 and \$90 per hectare. The values calculated in this exercise are in all likelihood a conservative lower-bound on the total public benefit, given the large number of known impact pathways that could not be evaluated because of data limitations, such as reduced nitrate and nitrogen, and fecal coliform loads (Section 3.2.6).

The public benefits estimation could be improved through two main approaches:

- More rigorous biophysical modelling – inclusion of more impact pathways and linkages with the type of watershed modelling now underway through the WEBs program. We had hoped to base our impact pathway analysis on SWAT model analysis for South Tobacco Creek, however those research outputs were not available at the time of report preparation.

- Better valuation parameters – a key challenge linking watershed BMPs to public benefits is that contingent valuation and willingness to pay studies generally do not relate directly to specific environmental parameters affected by BMPs, hence our work relied significantly on avoided cost literature. Willingness to pay studies could complement the avoided cost literature significantly if methods are devised to link values to specific parameters. The Resources for the Future Water Quality Ladder is an example of an early attempt to make this link.

A general paucity of relevant valuation data for Canada is evident in this report. The two most influential agri-economic valuation studies to date, those of Tyrchniewicz (2007) and Olewiler (2004) rely on the same valuation data. Tyrchniewicz cites the per hectare values used by Olewiler who for her agricultural analysis directly applies values compiled by Belcher *et al.* (2001). The Belcher *et al.* values for phosphorous are from a report by D.W. Draper and Associates (1997) and values for sediment from Fox and Dickson (1990). The Belcher *et al.* (2001) values for erosion and sediment loss are based on an analysis of the Conservation reserve program in the U.S. by Ribaudo (1989).

The difficulty in relying on values from the U.S. which are nearly 20 years old is that technologies change rapidly and costs vary. Also values from another country may not be applicable in the Canadian context. The scarcity of relevant Canadian valuation data applicable for BMPs highlights the need for more research in this area, and more work at linking existing valuation data to environmental parameters, which will be required to rigorously link valuation exercises to watershed modelling studies.

Despite these analytical challenges, the magnitude of the public benefits involved is noteworthy, and clearly justifies further research effort to refine estimates. The watershed framework for public benefit analysis remains the appropriate analytic framework as it first can capture local management goals expressed through an IWRM exercise and, second, links strongly with the need to address societal goals and expectations for an environmentally sustainable agriculture sectors as expressed in the AAFC *Growing Forward* strategic plan.

Many if not most agricultural-environmental interactions of broad concern to society are fundamentally hydrologic in nature, pertain to water quality and water supply, and therefore should be analyzed from a watershed perspective. By recognizing and quantifying the co-benefits accruing to local communities and the "downstream" public, we begin to identify a new role for agriculture as the sector which conveys ecosystem goods and services from rural to urban Canada, with benefit to both—a role entirely consistent with the expectation for social relevance expressed in the *Growing Forward* strategy.

A vivid illustration of this basic dynamic arises in the South Tobacco analysis herewith reported; our phosphorus reduction benefit is an avoided cost based on the City of Winnipeg's wastewater treatment infrastructure costs for phosphorus removal. South Tobacco Creek is a small sub-watershed within the Lake Winnipeg watershed. Phosphorus removal by the City of Winnipeg is driven by the need to reduce nutrient loads on Lake Winnipeg. Watershed-based agricultural BMPs can in essence provide "soft" infrastructure that could substitute for, or expand the benefits of hard infrastructure.

Communicating the direct and indirect public benefits of watershed-based agricultural BMPs is an important opportunity to advance *Growing Forward* outcomes around water quality and societal demands. A logical next step is to extend the pilot South Tobacco Creek analysis to the larger Lake Winnipeg watershed. Lake Winnipeg is Canada's sixth great lake, and the most eutrophic large lake in the world—its watershed encompasses 90 per cent of the agricultural land on the Prairies. Analyzing the constructive role that watershed-based agricultural BMPs can play in mitigating nutrient loads at a regional ecosystem level would provide a compelling example of agriculture's societal relevance within *Growing Forward*.

# Appendix

Table A-1: Literature search of BMP performance.

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Zero-till (UMRW) | Nutrient reduction | APEX<br>SWAT<br>30 year model | 16,224 | 66% (all cropped fields) | Organic P reduced by 41%;<br>$PO_4$ P reduced by 7%;<br>Total P reduced by 18%;<br>Organic N reduced by 43%;<br>$NO_3$ N increased by 13%;<br>Total N reduced by 9%. | 3,267 kg/yr<br>6,966 kg/yr<br>10,233 kg/yr<br>49,000 kg/yr<br>649,900 kg/yr<br><br>698,900 kg/yr | 1,928 kg/yr<br>6,478 kg/yr<br>8,391 kg/yr<br>27,930 kg/yr<br>734,387 kg/yr<br><br>566,109 kg/yr | | Gassman *et al.*, 2002 |
| Forage conversion | | | | | | | | | |

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Grazing management (LFRW) | Nutrient reduction | APEX SWAT 30-year model with two different rotation types | 127,048 | 71% (all pastures) | Organic P reduced by 63-73%;<br>$PO_4$ P reduced by 3-58%;<br>Total P reduced by 26-64%;<br>Organic N reduced by 63-66%;<br>$NO_3$ N increased by 14-20%;<br>Total N reduced by 7-10%. | 3,267 kg/yr<br>6,966 kg/yr<br>10,233 kg/yr<br>49,000 kg/yr<br>649,900 kg/yr<br><br>698,900 kg/yr | 882-1,209 kg/yr<br>2,926-6,757 kg/yr<br>3,684-7,572 kg/yr<br>16,660-18,130 kg/yr<br>740,886-779,880 kg/yr<br>629,010-649,977 kg/yr | | Gassman *et al.*, 2002 |
| Small dams | Peak flow reduction | | | | 90% flow reduction on-site<br>25% flow reduction over 75 square km | | | | Yarotski, 1995 |

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Constructed wetlands | Nutrient reduction | Observed | N/A: wastewater treatment plant effluent piped into three constructed wetlands, ranging from 52 $m^2$ to 150 $m^2$ | N/A | Ammonia nitrogen ($NH_4$) removal rate of 49-52%;<br>Average $NO_3$ rate of 58% in surface flow wetland design;<br>Total phosphorus (TP) removal rate of 60% in horizontal subsurface flow design;<br>Fecal coliform (FC) removal rate of 94% | 0.34-0.73 mg/L<br>7.13-8.56 mg/L<br>4.23-6.20 mg/L<br>2077-2659 cfu/100 mL | 0.14-0.40 mg/L<br>2.69-5.24 mg/L<br>1.95-3.28 mg/L<br>113-226 cfu/100 mL | | Tunçsiper and Bilal, 2007 |

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Constructed wetlands | Nutrient reduction | Observed | N/A: wastewater treatment plant effluent piped into eight constructed wetlands of various designs and capacities (volumes not provided) | N/A | Biochemical oxygen demand reduced by 17-89%;<br>Suspended solids reduced by 14-77%;<br>Total nitrogen reductions of 18-86%;<br>Ammonia nitrogen reductions of 8-9%;<br>Oxidized nitrogen reductions of 55-98%. | 4-110 mg $1^{-1}$<br><br>2-74 mg $1^{-1}$<br><br>5.9-62 mg $1^{-1}$<br>0.2-50 mg $1^{-1}$<br><br>0-15.8 mg $1^{-1}$ | 8-19 mg $1^{-1}$<br><br>4-76 mg $1^{-1}$<br><br>1.6-18 mg $1^{-1}$<br>0.15-14 mg $1^{-1}$<br><br>0.1-2.9 mg $1^{-1}$ | | Greenway and Woolley, 1999 |

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Reducing fall fertilizer application (UMRW) | Nutrient reduction | APEX SWAT 30-year model | 16,224 | 66% (all cropped fields) | Organic P reduced by 4%; $PO_4$ P reduced by 32%; Total P reduced by 23%; Organic N reduced by 0.4%; $NO_3$ N reduced by 12%; Total N reduced by 11%. | 3,267 kg/yr<br>6,966 kg/yr<br>10,233 kg/yr<br>49,000 kg/yr<br>649,900 kg/yr<br>698,900 kg/yr | 3,136 kg/yr<br>4,737 kg/yr<br>6,856 kg/yr<br>48,804 kg/yr<br>571,912 kg/yr<br>622,021 kg/yr | | Gassman *et al.*, 2002 |
| Manure removal for off-site composting (UNBRW) | Nutrient reduction | APEX SWAT 30-year model | 93,000 | 7% (all manure spreadfields) | Organic P reduced by 69%; $PO_4$ P reduced by 48%; Total P reduced by 57%; Organic N reduced by 65%; $NO_3$ N increased by 20%; Total N reduced by 33%. | 3,267 kg/yr<br>6,966 kg/yr<br>10,233 kg/yr<br>49,000 kg/yr<br>649,900 kg/yr<br>698,900 kg/yr | 1,013 kg/yr<br>3,622 kg/yr<br>4,400 kg/yr<br>17,150 kg/yr<br>779,880 kg/yr<br>468,263 kg/yr | | Gassman *et al.*, 2002 |

| BMPs and watershed name if applicable | Modelled or observed change in env. variable | Model type or observed data | Watershed area (ha) | % of Watershed in BMP | Modelled or observed results | Initial values at outlet | Impact values at outlet | $\frac{\Delta EV}{\Delta BMP}$ | Citation |
|---|---|---|---|---|---|---|---|---|---|
| Optimized phosphorus fertilization | Nutrient reduction | | | | Organic P reduced by 4-17%;<br>$PO_4$ P reduced by 39-54%;<br>Total P reduced by 7-38%;<br>Organic N reduced by 2-10%*;<br>$NO_3$ N decreased by 4-34%*;<br>Total N reduced by 4-33%*. | 3,267 kg/yr<br>6,966 kg/yr<br>10,233 kg/yr<br>49,000 kg/yr<br>649,900 kg/yr<br>698,900 kg/yr | | | Gassman *et al.*, 2002 |
| Holistic application of a suite of several BMPs | Sediment reduction | | | | Total suspended solids reduced by 37-67% | | | | Vaché *et al*, 2002. |
| Holistic application of a suite of several BMPs | Nutrient reduction | | | | Nitrate loads reduced by 54-75% | | | | Vaché, *et al.*, 2002 |

Table A-2: Summary of valuation literature findings.

| Parameter | Value | Valuation method | Location | Author and year | Applicability |
|---|---|---|---|---|---|
| Sedimentation – water conveyance | $0.69/ha/year | Avoided sediment removal costs from ditches | Grand River, Ontario | Belcher, Edwards and Gray, 2001, based on values from Ribaudo, 1989 | Somewhat applicable, although the population density is higher than TCMW |
| Sediment – water treatment | $5.6/ha/year | Avoided sediment removal costs from water treatment | Southern Ontario (applied to Grand River) | Fox and Dickson, 1990, cited in Belcher, Edwards and Gray 2001 | Somewhat applicable, although the population density is higher than TCMW |
| P | $23.5/ha/year | Avoided water treatment costs | Bay of Quinte | D.W. Draper and Associates, 1997 | Somewhat applicable—higher population density than TCMW |
| Sediment – lost topsoil and sedimentation of conveyances | $4.62/ha/year | Avoided sediment removal costs and costs of lost soil | Great Plains (applied to Upper Assiniboine, Manitoba) | Belcher, Edwards and Gray, 2001, based on values from Ribaudo, 1989 | Applicable to TCMW |
| Sediment – sedimentation of conveyances | $1.15/ha/year | Avoided sediment removal costs | Great Plains (applied to Mill River, Prince Edward Island) | Belcher, Edwards and Gray, 2001, based on values from Ribaudo, 1989 | Somewhat applicable—higher population density than TCMW |

| Parameter | Value | Valuation method | Location | Author and year | Applicability |
|---|---|---|---|---|---|
| Phosphorous | GBP75.41 per person for a P reduction sufficient to prevent algae in East Anglian waters | Willingness to pay | East Anglia, U.K. | Bateman *et al.*, 2006 | Not applicable to TCMW—different country, higher population density |
| Phosphorous | $28.71 per person for a 40% reduction | Willingness to pay and stated preference | Minnesota River, Minnesota | Mathews, Homans and Easter, 1999 | Not applicable for BMP research as it relates to eutrophic states, not concentrations |
| Nitrates in drinking water sources | GBP 16M in costs for all U.K. | Direct valuation | U.K. | Pretty *et al.*, 2003 | Not applicable—on a national scale |
| Phosphorous in drinking water sources | GBP 55M for whole of U.K. | Direct valuation | U.K. | Pretty *et al.*, 2003 | Not applicable—on a national scale |
| Pesticide in drinking water sources | GBP 120 M in costs whole of U.K. | Direct valuation | U.K. | Pretty *et al.*, 2003 | Not applicable—on a national scale |

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