Social, Economic and Environmental Evaluation of Beneficial Management Practices, Series 3:

- Treatment Systems for Solid or Liquid Manure (0201)

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Report prepared by:
Amy Kitchen, P.Ag., MRM, Yarrow Environmental Consulting
Patrick Kitchen, MRM, Yarrow Environmental Consulting
Ione Smith, P.Ag., M.Sc., Upland Consulting
Ryan Trenholm, M.Sc., Yarrow Environmental Consulting

Prepared for:
The Sustainable Agriculture Management Branch, BC Ministry of Agriculture (AGRI)

Project Steering Committee:
Mark Raymond, Environmental Agrologist, AGRI
Geoff Hughes-Games, Provincial Soil Specialist, AGRI
Tom Droppo, Industry Specialist, AGRI
Jill Hatfield, Regional Agrologist, AGRI
Gary Telford, Manager, Agriculture and Agri-Food Canada

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Executive Summary

Between July 2013 and March 2014 a project team from Yarrow Environmental Consulting and Upland Consulting was contracted by the British Columbia Ministry of Agriculture (AGRI) to conduct a social, economic and environmental evaluation of the *Treatment Systems for Solid or Liquid Manure* beneficial management practice (BMPs) promoted through the *Canada-British Columbia Environmental Farm Plan Beneficial Management Practices Program* (*BMP Program*). The *BMP Program* cost-shares the implementation of agri-environmental practices and technology on British Columbia farms, promoting agricultural sustainability and contributing to a cleaner, healthier environment. This project was supported by *Growing Forward II,* a federal provincial initiative that supports provincial agricultural programs, such as the *Environmental Farm Plan* and *BMP Programs*.

This project is the third in the series of BMP evaluation projects. The objectives of this project were to:

- Understand and summarize experiences with manure treatment technologies from other jurisdictions;
- Use the established BMP evaluation framework to evaluate the social, economic and environmental outcomes of the *Manure Treatment BMP*; and
- Draw conclusions from the results of the evaluation and make recommendations based on the findings.

A BMP survey was developed for the evaluation. The survey captured information about the financial and environmental outcomes associated with the implementation of the *Manure Treatment BMP* on farms as well as feedback from program participants. Surveys were administered in the fall of 2013 through personal interviews with producers who implemented the *Manure Treatment BMP*. The majority of interviews were conducted on-farm and manure samples were also collected to compare the chemical and biological components of manure prior to and post-treatment at the time of the interview. Additional interviews were conducted with dairy producers who have not adopted the *Manure Treatment BMP* to explore reasons for lack of implementation. *BMP Program* application files submitted by producers were also used for the evaluation. A discounted cash flow (DCF) analysis was conducted to understand the private financial outcomes of BMP implementation at the farm level. In addition, a cost-benefit analysis (CBA) was conducted for the *Manure Treatment BMP* to understand the benefits of BMP implementation to society. Additional calculations were made for dairies that were smaller (<200 milking cows) than the average size of operations captured in this *BMP Program*, (298 milking cows). This is important because the average size of BC dairy operations is 125 milking cows. A SWOT analysis framework was used to highlight the strengths, weaknesses, opportunities and threats associated with the *Manure Treatment BMP* and helped to form the basis for recommendations and conclusions made about the BMP.

Results of the project highlight the outcomes of the *Manure Treatment BMP* to individual farm operations and the effectiveness of BMPs at environmental risk mitigation. The results show that, generally, the BMP results in positive environmental outcomes on-farm and can help producers to manage their environmental risk. Specifically, operators benefit from more targeted application of nutrients and in re-use of solids for bedding material. In most cases the BMP provides a financial benefit to producers; however, the level of benefit is dependent on the type of manure treatment technology implemented and the unique characteristics of the individual farm operation. Smaller dairy operations (<200 milking cows) are less likely to realize financial benefits over the lifetime of the technology. Results of the CBAs show that over the expected life of the BMP a net benefit to society is realized.

Continued support of the *Manure Treatment BMP* is recommended, with an overall category cap that reflects the high level of benefits experienced by those who adopt the BMP and an increased emphasis on pooled projects where average to smaller sized dairy farms may also benefit from the *Manure Treatment BMP* cost-share funding.

The BMP evaluation results presented in this report will aid in:

- Demonstrating the environmental merits of the BMPs to funding agencies;
- Promoting the on-farm benefits of BMPs to producers; and
- Effectively allocating limited program funding in a means that maximizes the net benefits of the BMP Program to the public.

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1.0 Introduction and Background

This project is supported by *Growing Forward II,* a federal-provincial-territorial initiative that supports provincial agricultural programs, such as the *Canada-British Columbia Environmental Farm Plan Program* (*EFP*) and *Beneficial Management Practices Programs* (*BMP Program*). In British Columbia, the *EFP Program*, launched in 2004, was designed to raise awareness and to complement and enhance the current environmental stewardship practices of agriculture producers. Programs were developed based upon a risk assessment of regional issues concerning air, soil, water, and biodiversity and Beneficial Management Practices (BMPs) needed to address the issues. Encouraging the uptake of BMPs such as those reviewed in this report contributes to improved environmental stewardship. Since 2005, the *BMP Program* has encouraged the uptake of environmentally friendly practices on farms and ranches in BC by cost-sharing the implementation of BMP projects with producers.

An essential aspect of *BMP Program* management is to evaluate the process and outcomes of the program. Evaluation and monitoring of a program is a means to discover program strengths, weaknesses, and potential opportunities that could be acted upon as well as threats to the success of the program. Evaluation delivers valuable feedback to *BMP Program* managers to allow the program to be adaptively managed and changed over time to meet the needs of BC farms and the changing environment.

In 2011/12, the BC Ministry of Agriculture commissioned Amy Kitchen, Ryan Trenholm and a team from Simon Fraser University to conduct the first BMP evaluation project. An evaluation framework was developed to assess the social, economic and environmental outcomes of BMPs with four BMPs evaluated for the initial project. A second BMP evaluation project was conducted by Yarrow Environmental Consulting in 2012/13 and three BMPs were evaluated. This project is the third in the series of BMP evaluation projects. The BMP evaluated for this project was:

- Treatment Systems for Solid or Liquid Manure (0201).

The objectives of this project were to:

- Understand and summarize manure treatment experiences from other jurisdictions;
- Use the established BMP evaluation framework to evaluate the social, economic and environmental outcomes of the Manure Treatment BMP; and
- Draw conclusions from the results of the evaluation and make recommendations based on the findings.

The specific research questions addressed in this report are:

- What can be learned from other jurisdictions about on-farm manure treatment?
- What was the uptake of the BMP between 2009 and 2013?
- What were the social, financial and environmental outcomes of the BMP?
- What were the benefits (if any) of the BMP to society?
- Was the BMP effective at mitigating environmental risks?
- Could the BMP be improved in any way?

The BMP evaluation project was conducted by a project team from Yarrow Environmental Consulting and Upland Consulting and directed by a project steering committee from the BC Ministry of Agriculture (AGRI), Agricultural Research and

Development Corporation (ARDCorp), and Agriculture and Agri-Food Canada (AAFC). Yarrow Environmental Consulting is a consulting firm with a mandate of helping to create a resilient local agriculture industry in BC. We specialize in agri-environmental resource management, economic analysis and stakeholder engagement. Upland Consulting specializes in agroecological practices and brings over ten years of experience in crop production, soil nutrition, land use planning, and climate change adaptation and mitigation policy development. Upland is committed to policies and actions that articulate long-term solutions, particularly the enhancement of existing farms and farmland, and the promotion of networks that support local, resilient agricultural systems.

This evaluation project delivers information to *BMP Program* managers regarding how BMPs have been implemented on-farm, their environmental and financial outcomes and the benefits that the BMPs provide to society. The evaluation results presented in this report will aid in:

- Demonstrating the environmental merits of the BMPs to funding agencies;
- Promoting the on-farm benefits of BMPs to producers; and
- Effectively allocating limited program funding in a means that maximizes the net benefits of the *BMP Program* to the public.

The remainder of this report is organized as follows:

- In section 2 the evaluation framework and methodology used to conduct the BMP evaluations is described;
- In section 3 we review the manure treatment technology adopted by BC producers;
- In section 4, the results of the manure treatment technology Jurisdictional Review are presented;
- In section 5 we present the results of the *Manure Treatment BMP* evaluation;
- In section 6 we discuss the results of the evaluation using a Strength, Weaknesses, Opportunities and Threats (SWOT) analysis framework and we present our recommendations and conclusions specific to the Manure Treatment BMP.

1.1 Limitations of the BMP Evaluation Project

The BMP evaluation framework used for this project was developed in response to a desire for more information about the outcomes of BMPs implemented through the *BMP Program.* The methods used for this project were an appropriate means for the evaluation considering time, budget and data constraints associated with the evaluation. Due to the nature and timing of the evaluation and complexities associated with summarizing on-farm outcome data we would like to point out some limitations to the information presented in this report:

- The methods used to determine outcomes are not a true measurement of program impact. To estimate the impact of a program, either baseline data collected prior to BMP implementation or an experimental design procedure where *BMP Program* participants are compared to non-program participants is required.
- The *Manure Treatment BMP* was evaluated as a unique piece of technology; however, it is important to recognize that BMPs are often implemented as a suite of on-farm projects or improvements. As well, each farm implements

environmental improvements within a unique set of operational and environmental circumstances. Thus it is potentially inaccurate to attribute certain environmental and financial outcomes solely to the BMP. It is also possible that a BMP with similar outcomes was funded under a different practice code and this evaluation does not capture the duplication of benefit that may be associated with those implemented BMPs.

- Certain environmental benefits of BMP implementation could not be valued monetarily within the scope of this report. As a result, the net present values of BMP projects determined by the cost-benefit analyses are conservative.
- The conclusions made in this report are not based on statistically significant data.
- The conclusions and recommendations made in this report are based on the results of the BMP evaluations, qualitative information gleaned during the interview process and site visits as well as the authors' opinions and experiences.
- The BMP program is a voluntary program, participants self-select themselves to participate. Often, voluntary environmental programs attract participants who are like-minded. Therefore, their practices, experiences and opinions may not be representative of the industry as a whole.
- The evaluation of the Manure Treatment BMP occurred relatively soon after the majority producers who were included in the evaluation had installed the equipment. Because of this, evaluation results may be skewed as respondents did not have more than a few years of experience with the technology.

2.0 BMP Evaluation Methodology

This project is the third evaluation of BMPs cost-shared through the *Canada-British Columbia Environmental Farm Plan Program*. The methods used for this BMP evaluation project were, in general, similar to the previous BMP evaluation project. The remainder of this section outlines the methodology used to conduct the evaluation. For more detailed step-by-step information about the methodology, please consult the *BMP Evaluation Methodology Guide, 2012* available through AGRI.

Evaluation Framework Overview

To evaluate the environmental outcomes of BMPs on farms, environmental indicators were developed based on the specific environmental risk that the *Manure Treatment BMP* is intended to address. Agri-environmental indicators were used as a proxy for the actual environmental impact of the BMP, as it was beyond the scope of this project to measure impact directly.

To identify on-farm outcomes of BMP uptake, changes that occurred on-farm after the implementation of *Manure Treatment BMP* were assessed by asking respondents to identify their practices prior to BMP adoption, and post BMP adoption.

To determine the financial outcomes of the BMP to the average participant, both private costs and private benefits prior to and post BMP implementation were assessed. A discounted cash flow analysis (DCF) was conducted to portray the on-farm financial outcomes of BMP implementation.[1]

To determine the economic outcomes of the BMP to society, a cost-benefit analysis (CBA) was conducted.[2] Five main steps are followed when conducting a cost-benefit analysis:

1. Identify the issues, risks, and the baseline scenario;
2. Set objectives;
3. Develop alternative regulatory and non-regulatory options;
4. Assess the benefits and costs (using a variety of possible techniques); and
5. Prepare an accounting statement.

To understand the motivational factors for and barriers to BMP uptake, a set of social evaluation questions were developed. Several semi-structured interviews with non-adopters of the BMPs and industry experts were also conducted to better understand the barriers to uptake of the BMP as well as weaknesses of the BMP.

Data Sources and Data Collection Methodology

The data for this project came from five sources:

[1] Discounted cash flow analyses are used by individuals to determine the financial outcomes of a proposed project over its lifetime. The tool tracks cash flows and discounts them based on a set rate to determine the present value of a project.
[2] Cost benefit analyses are used by governments to determine the economic efficiency of alternative policies (i.e. government intervention) for solving a specific problem (e.g. water pollution). Governments at varying levels around the world have adopted this decision tool for assessing new or existing policies.

1. Industry experts and equipment suppliers were interviewed to understand manure treatment equipment and experiences in other jurisdictions.

The purpose of the jurisdictional review was to determine manure treatment system uptake rates and the motivating factors/opportunities and deterring factors/barriers that influence those uptake rates in five jurisdictions; Alberta, Manitoba, Ontario, Idaho, and Washington. Information sources for the jurisdictional review included academic and government publications. We also conducted semi-structured interviews with industry experts (government, industry, and equipment suppliers). A total of eight interviews were completed over the phone. The semi-structured interview focused on three main areas: manure treatment uptake rates in the jurisdiction, motivating factors/opportunities, and deterring factors/barriers.

2. BMP project application files were supplied by the BC Agricultural Research and Development Corporation (ARDCorp).

ARDCorp acts as the delivery agent for both the *Environmental Farm Plan* and *BMP programs* in BC. When a farm applies for BMP project funding, they submit an application form to ARDCorp. The BMP project file data was collected from paper archives by photocopying files and entering relevant data into a database. The data that was obtained from the program files included the contact information for adopters, the total number of adopters (N), the specific city/region where the BMP was implemented, the date the BMP was completed, and the total cost of the infrastructure paid by both the agencies and the producer as well as relevant information on the manure treatment system. The data files collected from ARDCorp included 25 application forms from producers who applied for funding for *Manure Treatment BMPs.*

3. A survey was used to conduct the social, economic and environmental outcome evaluation.

A survey instrument was developed to evaluate the social, economic and environmental outcomes. Questions were designed to capture the outcome indicators as well as based on recommendations made by the project team and AGRI steering committee. Data was collected in two ways:

1. Personal interviews with producers; and
2. Manure sampling at 20 farms.

A target of 20 interviews was set. Interviews were conducted between October and December 2013 and focused on key areas of BMP uptake across the Province including:

- The Fraser Valley;
- Metro Vancouver; and
- Vancouver Island.

Interviews were arranged by telephone and email prior to visiting the farms in-person. Phone interviews were conducted with producers on Vancouver Island. In most cases, interviews corresponded with a site visit and manure sampling. A total of 22 BMP interviews were completed. In addition, five targeted interviews were conducted with industry experts and producers who were not captured by the *BMP Program* to understand the barriers to uptake and current weaknesses of the BMPs.

4. Manure samples were collected to compare chemical and biological parameters of the pre-treatment manure and post-treatment manure streams.

At twenty sites, samples were collected using methods outlined in the *Manure Sampling and Analysis for Nutrient Management* factsheet.[3] At most sites three samples were obtained:

- Liquid manure before entering the separator;
- Solid manure leaving the separator; and
- Liquid manure leaving the separator.

On two occasions the third sample could not be obtained due to physical challenges in collecting the sample (manure in the pit was too deep to reach). At sites with a sand lane a fourth sample (sand) was also collected).[4]

The liquid and solid samples were all analyzed by A & L Canada Laboratories Inc. (subcontracted by Exova Laboratories) for the following parameters:

Table 1. Manure Sampling Methods and Parameters.

Parameter	Unit	Detection Limit	Method Reference
Dry matter	%	0.10	Gravimetric
Total Potassium	%	0.01	Inductively Coupled Plasma (ICP)
Total Phosphorus	%	0.01	Inductively Coupled Plasma (ICP)
Ammonium (NH4-N)	ug/ml or ug/g	0.10	Colourimetric
Total Organic Nitrogen	%	0.10	Combustion
Total Nitrogen	%	0.10	Combustion
pH		N/A	pH meter
Fecal coliform	Most probable number (MPN/ml)	N/A	MFHPB-19 accredited test

The extraction method for Total Phosphorus and Total Potassium is based on EPA Method 3050B as follows:

- The dried, ground sample is weighed into a digestion vessel where hydrochloric and nitric acid are added.
- It is digested for 2 hours at 95 C^{o} then made up to volume with deionized water, shaken and filtered.
- It is submitted for analysis by ICP-OES.

[3] Nutrient Management Factsheet - No. 5 in Series (Revised September 2010, Order Reference No. 631-500-3).
[4] Refer to Appendix II for the detailed manure sampling methods.

5. Data from relevant literature sources were used, particularly to value environmental benefits for the purposes of the CBA.

Some environmental benefits could not be valued monetarily within the scope and timeframe of this project. In order to conduct the cost benefit analysis, values for environmental benefits were gathered from relevant literature sources. This methodology is termed “value transfer” or “benefit transfer”.

Data Analysis

The data collected through personal interviews and phone surveys was combined and analyzed jointly. Average or median values for BMP outcomes are reported to demonstrate both the typical case as well as the aggregate outcomes of BMP implementation.

Financial data supplied by respondents was analyzed using a discounted cash flow (DCF) methodology. A DCF allows private costs and on-farm benefits to be compared over the life of the BMP to determine the net present value (NPV) of the BMP project to the producer.

Data used to conduct the cost-benefit analyses came from both *BMP Program* data and data collected during the evaluation.[5] The net present value (NPV) test was applied as the decision rule to determine whether the project was an overall benefit or cost to society.

SWOT Analysis, Conclusions and Recommendations

To organize the main findings of the evaluation as well as to present some anecdotal findings from interviews, a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was conducted. Finally, conclusions and recommendations, based on the findings of the BMP evaluation were made.

[5] Refer to the first BMP evaluation report for a detailed summary of the CBA methods: http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/AGRI_BMP_Report_FINAL.pdf

3.0 Manure Treatment Technology Overview

In this section we provide a broad overview of the manure treatment technology implemented by producers through the *BMP Program*. The technologies may be generally categorized as solid/liquid separation (dewatering) equipment and bedding recovery units.

3.1 Solid/Liquid Manure Separation Technology Overview

Solid/liquid manure separation, or de-watering, involves the partial removal of solids from liquid manure (slurry). The process converts the initial slurry manure product into two streams: solids and liquids. Solid/liquid manure separation is generally conducted using a gravity system or mechanical separation system. The gravity separation system involves the use of settling basins where solids settle to the bottom and the liquid portion remains at the top and is pumped out to a separate tank for storage or application. The mechanical separation system uses some form of mechanical process to separate liquids from solids. A variety of systems are available on the market such as vibrating screens, roller systems, rotary centrifuges, and screw presses. The appropriate type of mechanical separation system will depend on the specifics of the manure and farm in question. With all types of mechanical separation systems, the solid component is separated from the liquid component and the streams are stored separately.

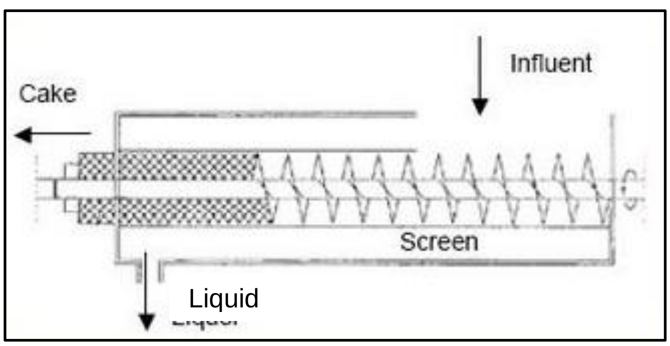

Figure 1. Example of a Screw Press Solid/Liquid Separation System.[6]

Possible Advantages of Solid/Liquid Manure Separation

The possible advantages of Solid/Liquid Separation Equipment include:

- Liquid stream of solid/liquid manure separation is less likely to plug transfer pipes and requires less power to pump;
- Solid component of solid/liquid manure separation is more cost effective to transport due to lower moisture content;
- Liquid component is easier to apply/irrigate due to reduced viscosity;
- Liquid component requires less agitation time relative to untreated slurry;

[6] Source: http://www.extension.org/pages/27470/solids-separation-in-swine-manure-handling-systems#.UpYpTaso7mI.

- The odours associated with separated liquids and solids is reduced compared to unprocessed slurry; and
- N:P ratios of the solid and liquid components are different (solid component has higher P while liquid component has higher N). Thus, the separation allows for more accurate application of nutrients based on the needs of each field.

Possible Disadvantages of Solid/Liquid Manure Separation

The possible disadvantages of Solid/Liquid Separation equipment include:

- High initial cost associated with implementation;
- Ongoing maintenance costs;
- The system results in two waste streams and farms may not be set up to manage two streams of manure;
- Solid/liquid manure separation adds an additional step to the manure management system, which requires attention; and
- The system may require modification to existing facilities such as the construction of new buildings to house the equipment or new electrical systems.

Possible Uses of the Solid/Liquid Output

The solid component can have a variety of uses:

- Land application;
- Green bedding (i.e. not-composted bedding)[7];
- Soil amendments; or
- Solids can be composted for use or sale.

Alternative uses for the liquid component include:

- Use in in-barn flushing systems; or
- A source of irrigation water.

3.2 Bedding Recovery Technology Overview

Bedding Recovery Systems take the manure from a dairy operation and convert a portion of it into bedding material for cows through a composting process. A bedding recovery system is a two-step process:

Step 1. Liquid/slurry manure is separated into solid and liquid streams using a solid/liquid manure separator, such as a screw press (Figure 1). The purpose is to reduce the separated solid component to approximately 65% to 68% moisture content. Solids can be separated from manure as well as anaerobic digestate.

Step 2. The separated solids are fed into a drum that rotates and draws in fresh air to feed the aerobic bacteria creating ideal conditions for composting. The composting solids can reach temperatures of 65 to 70 degrees Celsius, which kills most pathogens

[7] Note that use of green bedding may increase bedding pathogens resulting in consequences to animal health.

in the manure. The solid material will remain in the drum for between one and three days.
When the composting process is complete, the solids are ready to be used as livestock bedding. It is recommended that the bedding is to be used fresh. If the bedding is stored for two or three days, it may begin to compost again.

Possible Advantages of Bedding Recovery Systems

The possible advantages of Bedding Recovery Systems include:

- Producers may realize savings related to reduced bedding expenses;
- Bedding recovery systems ensure producers have a reliable source of bedding;
- Producers can realize additional revenue;
    - Producers may process other dairy farms' manure for bedding either for a fee or for use on their farm;
    - Producers may sell excess bedding to other farms; or
    - Producers may sell composted materials as soil amendments or fertilizer;
- Some aspects of animal health, such as hock sores, abrasions and mastitis, may improve with the use of manure bedding.

Possible Disadvantages of Bedding Recovery Systems

The possible disadvantages of Bedding Recovery Systems include but are not limited to:

- Bedding can reheat if stored for too long prior to use, leading to new bacterial growth which in turn could increase environmental mastitis, therefore bedding should be used when fresh;
- Potential for higher disease incidence when used for calves, in sick pens or maternity pens; and
- Initial investment costs and ongoing operating costs.

Figure 2. An example of a Bedding Recovery System installed on-farm.[8]

Figure 3. The solid output of a Bedding Recovery System.

[8] Source: http://www.daritech.com/categories/manure/beddingmaster/

4.0 Jurisdictional Review Summary

We reviewed five jurisdictions including Washington, Idaho, Alberta, Manitoba, and Ontario with the purpose of understanding manure treatment system uptake and the experiences of producers in other jurisdictions. For each jurisdiction, we investigated the level of uptake of Solid/Liquid Separation and Bedding Recovery Systems, the unique factors leading the uptake of the technologies and the primary motivations and barriers for the adoption of each technology. For the full summary on each jurisdiction, please see Appendix III.

4.1 Uptake of Manure Treatment Technology

Uptake of solid/liquid separation was highest in Washington and Idaho and relatively low in Alberta, Manitoba, and Ontario. Uptake of bedding recovery systems has been relatively high in Washington and Idaho and relatively low in the Canadian jurisdictions of Alberta, Manitoba and Ontario (Table 2).

Table 2. Uptake of Manure Treatment Systems Across Jurisdictions.

Jurisdiction	Uptake of Solid/Liquid Separation	Uptake of Bedding Recovery Systems	Notes
Western Washington	30% of cows, 30% of dairies	33% in Whatcom County, 10%-20% elsewhere in Western Washington	Western Washington has approximately 350 dairies and 100,000 milking cows (average herd size of 285). Therefore, dairies are considerably smaller than those in Eastern Washington
Eastern Washington	90% of cows, 50% of dairies	<5%	There are approximately 75 dairies in Eastern Washington and they are concentrated in the Yakima Valley. 70% milk over 700 animals. Dairies are larger in Eastern Washington compared to Western Washington. Manure is generally row composed due to limited precipitation
Idaho	50% of dairies	20% of dairies	Mainly screen separators which require less maintenance compared to compress and screw press separators. Approximately all in-barn dairies (100) have bedding recovery systems. The rest are open lot dairy farms.
Ontario	<5% of dairies	1.5% of dairies	~60 bedding recovery systems (30 in-vessel/drum composters, 20 dairy anaerobic digesters with separation component, 10 Solid/Liquid Separation systems being used to produce green bedding)
Alberta	<5% of dairies	1% of dairies	Alberta has ~600 dairy farms
Manitoba	<5% of dairies	<1% of dairies	

4.2 Factors Leading to Uptake of Solid/Liquid Separation Technology

Across jurisdictions, producers were motivated to adopt solid/liquid manure separation to better manage nutrients on farm, earn additional revenue from selling separated solids, and to better manage manure volumes (Table 3). Additionally, adoption is more common at larger dairies. Common barriers across jurisdictions include the financial cost of the system and the additional time, attention, and maintenance required by the system. solid/liquid manure separation is also less common on small dairies with lower revenues (Table 4).

Table 3. Motivating Factors and Opportunities Leading to Uptake of Solid/Liquid Technology Across Jurisdictions.

	Western Washington	Eastern Washington	Idaho	Ontario	Alberta	Manitoba
Increased Manure Storage Capacity	✓	✓				✓
Additional Tool for Manure Management	✓	✓		✓	✓	
Systems are more affordable for larger dairy farms	✓	✓				
Cost-share programs	✓	✓		✓		
Manage nutrients in a way that reduces environmental risk		✓				
Opportunity for sales of manure by-products		✓			✓	
Intention to install a Bedding Recovery System in future				✓		
Increased interest due to an increase in use of Bedding Recovery Systems					✓	
Proximity to urban areas					✓	
To reduce solids in manure lagoons			✓			

Table 4. Barriers and Deterrents to Uptake of Solid/Liquid Separation Technology Across Jurisdictions.

	Western Washington	Eastern Washington	Idaho	Ontario	Alberta	Manitoba
The financial cost of the technology	✓	✓	✓	✓	✓	✓
Additional time and maintenance	✓	✓	✓		✓	
Hesitation to change current system			✓	✓	✓	
Less perceived need for treatment due to external factors (i.e. land base and weather)				✓	✓	✓
The financial cost of transporting solid manure				✓		✓
Availability of affordable bedding materials						✓
Lack of incentive programs			✓			
Not appropriate for the style of dairy farm (open lot)			✓			

4.3 Factors Leading to Uptake of Bedding Recovery Systems

Across jurisdictions, the primary motivations for uptake of Bedding Recovery Systems include a desire to decrease bedding costs (Table 5). Common barriers include financial cost, limited applicability of systems to specific farm operations, additional maintenance and time associated with the system, and access to inexpensive bedding alternatives (Table 6).

Table 5. Motivating Factors and Opportunities Leading to Uptake of Bedding Recovery Systems Across Jurisdictions.

	Western Washington	Eastern Washington	Ontario	Alberta	Manitoba	Idaho
Bedding cost savings	✓	✓	✓	✓	✓	
Access to a reliable source of bedding			✓			
Opportunity for sales of manure by-products	✓			✓		
Opportunity to process other farm's manure	✓					
Additional tool for manure management			✓			
Cost-share programs			✓			
Increased manure storage capacity					✓	
The technology makes financial sense on larger dairy farms						✓
Many farms have Solid/Liquid Separator equipment already						✓

Table 6. Barriers and Deterrents to Uptake of Bedding Recovery Systems Across Jurisdictions.

	Western Washington	Eastern Washington	Ontario	Alberta	Manitoba	Idaho
The financial cost of the technology	✓	✓	✓	✓	✓	✓
Additional time and maintenance	✓	✓	✓	✓		
Solids row composted outside already		✓				✓
Availability of affordable bedding materials			✓		✓	
Lack of incentive programs			✓			✓
Animal health concerns			✓			
Style of dairy farms not conducive to technology			✓			✓

5.0 Results of the Social, Economic and Environmental Evaluation of the Manure Treatment BMP

This section will report the findings of the social, economic and environmental evaluation of the *Treatment Systems for Solid or Liquid Manure BMP* that was conducted between August 2013 and March 2014. The BMP uptake statistics, environmental and financial outcomes, social factors of BMP uptake as well as the results of the cost-benefit analysis are reported below in section 5.

5.1 Introduction to the Treatment Systems for Solid or Liquid Manure BMP

The *Treatment Systems for Solid or Liquid Manure Beneficial Management Practice* (herein referred to as the *Manure Treatment BMP*) is intended to address environmental risks associated with the storage, handling and application of un-treated manure produced, handled and stored on farms. Some of the environmental risks associated with untreated manure include: [9]

- Excess manure volume relative to on-farm storage capacity resulting in application of manure in less than ideal conditions; and
- Excess nutrient application on cropland due to an inability to viably export untreated manure.

The *BMP Program* has cost-shared the implementation of solid-liquid separation equipment, bedding recovery units and nutrient recovery technology since the 2009/10 program year. Pathogen and vector attraction reduction treatment systems have been cost-shared through the *BMP Program* since the 2013/14 program year. Pathogen and vector attraction reduction systems were not included in this project as there were no completed projects at the time of the evaluation.

Treatment of manure may reduce the risk of odour or pathogen release, or greenhouse gas emissions associated with livestock manure. In addition, treatment of manure may increase the efficiency of manure management and allow farms to use manure as nutrients more effectively as manure application may occur at more appropriate times. Additionally, separated manure may allow for nutrient application to be better targeted to areas of the farm that are deficient in certain nutrients and away from areas where nutrients are in excess. Manure that has been separated into liquid and solid streams may be easier to handle during manure application because the liquid stream is less likely to clog pipes than untreated slurry.

Solid/liquid separation of manure as well as bedding recovery units can allow producers to reuse the solid portion of manure as bedding. Manure by-products such as bedding and soil amendments may be sold off-farm as a result of implementing a manure treatment system as solids and excess nutrients may be viably transported off-farm.

[9] National Farm Stewardship Program. (2006). *Beneficial management practices descriptions.* Ottawa, ON: Agriculture and Agri-Food Canada.

5.2 Evaluation Survey Response

A total of 22 interviews and 20 site visits were conducted with adopters of manure treatment technology through the BMP Program, which equates to an 96% response rate for the survey overall. An additional interview was conducted with a producer who had implemented bedding recovery units (not cost-shared through the *BMP Program*). Four interviews were conducted with producers who had not adopted any manure treatment technologies, but were considered to be potential candidates.

5.3 Cost-Share Structure and BMP Implementation Costs

Funding for the *Manure Treatment BMP* has been available since the 2009/10 and up to and including the time that this evaluation was conducted (in the 2013/14 program year). Cost-share funding has been available for dewatering systems for liquid manure (i.e. manure separators) and bedding recovery systems for solid and liquid manure since 2009/10.

The cost-share level and cap for the *Manure Treatment BMP* (0201) has changed throughout the years that it has been available. The cost-share and category cap levels have been as follows:

- 2009/2010 – 30% up to $30,000
- 2010/2011 – 30% up to $30,000
- 2011/2012 – 30% up to $30,000
- 2012/2013 – 30% up to $70,000
- 2013/2014 – 30% up to $50,000

The average implementation cost of a *Manure Treatment BMP* project taking into account only the eligible costs was $175,000.[10] The *BMP Program* provided an average of $35,000 in cost-share dollars to producers per BMP project. The average net implementation cost of a *Manure Treatment BMP* project for producers, taking into account only the eligible costs was $140,000. Between 2009/2010 and 2012/2013, producers contributed $3,863,000 and the *BMP Program* contributed $769,000 towards *Manure Treatment BMPs.*[11]

5.4 Manure Treatment BMP Uptake Statistics

This section reports the *Manure Treatment BMP* implementation and distribution statistics for the period between 2009/2010 and 2012/2013.

[10] The average total cost of implementing a Bedding Recovery Unit was $205,000 and the average total cost of implementing a Solid/Liquid Separator was $112,000.
[11] Project costs were determined using the ARDCorp BMP programs data.

BMP Uptake and Regional Distribution of BMPs

A total of 23 *Manure Treatment BMP* projects occurred across BC between 2009/2010 and 2012/2013.[12] [13] One of the projects involved one dairy producer and two poultry producers who applied for a Bedding Recovery Unit as a pooled project; therefore, 25 producer applications were approved in total. Figure 4 and Table 7 and display the regional distribution of implementation for the BMP. To date Manure Treatment BMP projects have been concentrated in the Fraser Valley. It is not clear why there has been no uptake in the Okanagan region; however, the lack of uptake may be due to factors such as:

- The drier climate in the Okanagan resulting in less rain accumulation in manure storages;
- Better access to reliable and cheap sources of bedding (i.e. straw or shavings); and/or
- Limited awareness/exposure to the technology.

[12] A BMP 'project' was defined as a single BMP approved and cost-shared by the BMP programs. Using this definition, an individual farm operation may have implemented one or more distinct BMP projects on one or multiple farm properties.

[13] At the time of this project there were 517 active dairy farms in BC. This information was supplied by the BC Dairy Association.

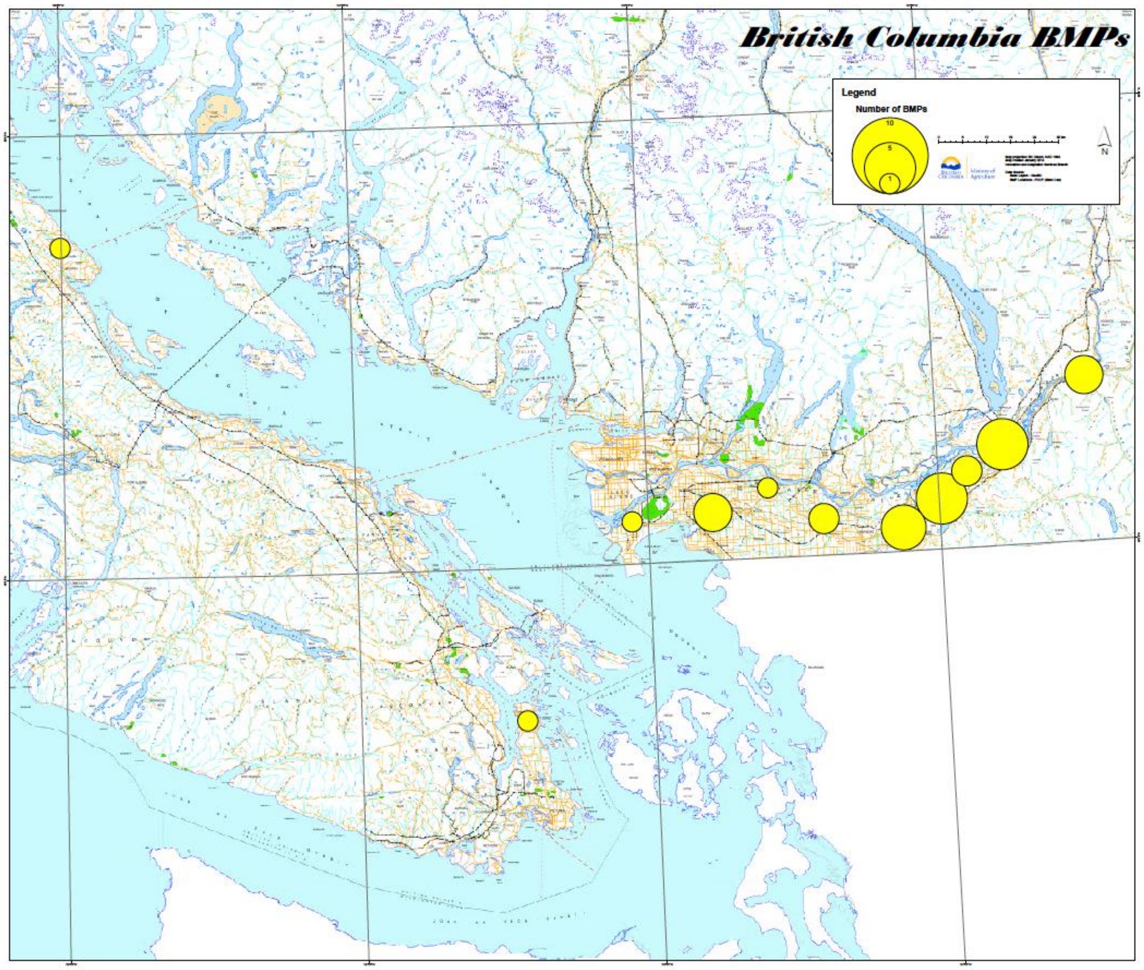

Figure 4. Map of Manure Treatment BMP uptake between the 09/10 and 12/13 program years.

Table 7. Manure Treatment BMPs implemented by Regional District.[14]

Regional District	Number of BMP Projects
Comox Valley	1
Capital	1
Fraser Valley	16
Metro Vancouver	5

Uptake by Commodity

All producers who have implemented manure treatment technologies on their farm through the *BMP Program* were dairy producers. Three producers applied for a pooled project, two of which were poultry producers; however the manure treatment equipment

[14] The regional distribution of BMP uptake was determined using the ARDCorp BMP Program data.

was installed on the dairy farm and is used to treat manure from all three farms.[15] Approximately 5% of the current total dairy farms in the province have adopted the technology through the *BMP Program*.

Uptake Over Time

The *Manure Treatment BMP* has been cost-shared through the *BMP Program* since 2009. It is likely too early to determine if there is a trend in uptake, however uptake of the BMP appears to be increasing, with the majority of producers (52%) implementing their *Manure Treatment BMP* in 2012 (Figure 5). The increase in BMP uptake corresponds with the increase of the BMP cap from $30,000 to $70,000 in the 2012/13 program year although this may not necessarily be the only reason for increased uptake. Other factors contributing to increase in uptake since the initial program year include an increase in awareness of the technology and the benefits that manure treatment offers.

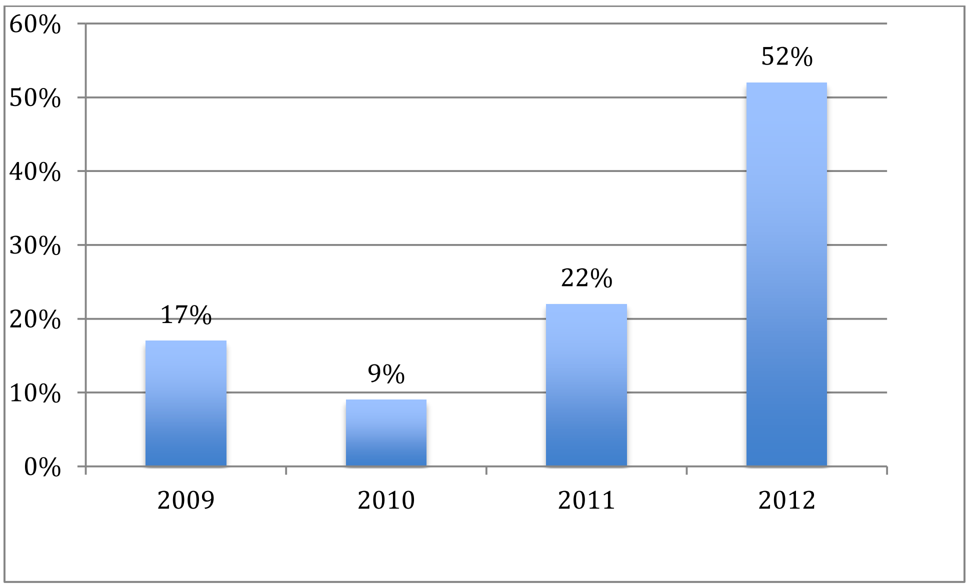

Figure 5. Uptake of the Manure Treatment BMP by year.

5.5 Characteristics of Farms Implementing the Manure Treatment BMP

The average area of land farmed by producers who implemented the *Manure Treatment BMP* was 128 hectares (110 hectares was the median area).[16] The average size of the

[15] Through the *BMP Program*, producers are able to apply for a joint or pooled BMP project whereby the applicants may combine the cost-share funding available to them in order to facilitate the development or larger more effective and economically viable projects. Projects must meet all regulatory requirements with regards to the storage, manure and use of manure produced off-farm. It is important to note that with the transport of manure between farms, there is an increased risk of disease transfer between farm operations. Producers who implement pooled *Manure Treatment BMPs* should have a biosecurity plan in place to mitigate this risk. For more information on pooled projects visit www.bcefp.ca.

[16] The calculations for average and median area of land is based on owned land and do not include other land that producers may lease.

milking herd was 298 cows, which is more than double the province's current average milking herd size of 125 cows (Table 8). Herd sizes, of farms that implemented a *Manure Treatment BMP,* ranged from 80 milking cows 600 milking cows.

The survey indicated that there was almost no change in the average dairy herd size or the land base farmed between the time that the application was submitted and the time of the survey. Two producers indicated that they did not keep their young stock at the farm where the *Manure Treatment BMP* was implemented. All respondents indicated that the farm operators privately owned the land where the BMP was implemented.

Table 8. Average Number of Livestock on Farms that Implemented Manure Treatment BMPs. [17]

	Average Number of Livestock	Median Number of Livestock
Total Herd Size	510	478
Milking Herd Size	298	290
Young Stock	196	200

Farming Experience and Age of Respondents
The average number of years that producers who implemented the *Manure Treatment BMP* have farmed is 28 years. The average number of years that the property, where the BMP was implemented has been farmed was 51 years.[18]

Those who participated in the survey were asked to indicate their age category (Table 9). The majority of producers fell into the 35-54 age category (72.7% of respondents). Thus, the majority of producers who implemented the *Manure Treatment BMP* are younger than the average age of BC farmers (55.7 years).[19]

Table 9. Age of Producers who Implemented the Manure Treatment BMP.

Age	Percentage
18-34	4.5%
35-44	40.9%
45-54	31.8%
55-64	18.2%
65+	4.5%

5.6 The Manure Treatment BMP in Practice

[17] Farm characteristics were determined from the ARDCorp BMP program files and the BMP evaluation survey.
[18] Farming experience was determined from the BMP evaluation survey.
[19] Average age of BC farmers was determined by Statistics Canada, 2011 Census of Agriculture: http://www29.statcan.gc.ca/ceag-web/eng/community-agriculture-profile-profil-agricole?geoId=590000000&selectedVarIds=357%2C359%2C358%2C360%2C

This section gives an overview of the how the *Manure Treatment BMP* has, in general, been implemented on farms. The *BMP Program* funding may have been allocated towards the purchase of:

- Solid/liquid separation equipment; such as:
    - Screw presses;
    - Screen presses;
    - Roller presses; and
- Bedding recovery systems.

Manure Treatment Practices Prior to BMP Implementation

In general, producers had not been treating their manure prior to implementing the *Manure Treatment BMP*. Two producers (10% of respondents) indicated that they already had one separator installed prior to implementing the *Manure Treatment BMP*. Of the producers who had manure treatment equipment prior to installing their *Manure Treatment BMP,* one producer implemented a Bedding Recovery System and one producer installed a second Solid/Liquid Separator.

Type of BMP Implemented

The types of BMPs funded through the *Manure Treatment BMP* may be separated into two general categories:

- Solid/Liquid Separators; and
- Bedding Recovery Systems.[20]

Of the 23 *Manure Treatment BMPs* implemented between 2009/10 and 2012/13, approximately one third of producers implemented Solid/Liquid Separation equipment (seven projects total) and two thirds of producers implemented Bedding Recovery System BMPs (16 projects total). There was a range of technologies implemented within these general categories (Table 10).

For Solid/Liquid Separation equipment, screw presses were the most popular followed by roller presses. In some cases, producers implemented more than one Solid/Liquid Separator in order to achieve a more desirable end product (i.e. a lower moisture content). The Bedding Master system manufactured by Daritech was the most popular bedding recovery system among producers (10 projects total) who used sawdust bedding, followed by the Daritech Sand Recovery System for producers who used sand bedding (3 projects total).

Reponses indicated that approximately 89% of the total manure produced on farm was treated by the *Manure Treatment BMP*. On farms that did not treat 100% of their manure, the remaining manure that was untreated was likely from solid pack barns, maternity or calf pens. Producers who use sand bedding often used other types of bedding (i.e. wood shavings or straw) for these purposes. Other than the dairy farm that

[20] See Section 3.0 for a description of these technologies.

treats manure from two other poultry farms (the pooled BMP project), no respondents indicated that they treat other farms' manure with their system.

Table 10. Manure Treatment Technologies Implemented.

Type of Technology Implemented	Solid/Liquid Separators	Bedding Recovery Systems
Screw Press	7	
Roller Press	5	
Sand lane	1	
Sidehill Screen	1	
Daritech Bedding Master		10
Daritech Sand Recovery System		3
Other Bedding Recovery Unit		3
Total	**14**	**16**

Use of Treated Manure

All respondents indicated that they use the liquid fraction of the treated manure as fertilizer on cropland. Two producers indicated that they use a portion of the liquid fraction as flush water.

The majority of respondents (70%) indicated that they use some of or the entire solid fraction of the treated manure for bedding. Producers also used some or all of their solid manure on crops (30% of respondents) and some indicated that they sold or gave away a portion of their solid manure (22% of respondents).

Of those who indicated they use their solid manure for bedding, an average of 86% of the total solid fraction was recycled as bedding. The remaining solid fraction was either spread on cropland or used off-farm in various applications.

5.7 The Environmental Outcomes of the Manure Treatment BMP

The above sections described how the *Manure Treatment BMP* has been implemented in practice, whereas this section provides insight into the environmental impacts that the BMP has had on farms where it has been implemented.[21]

The indicators used to understand the environmental outcomes of the *Manure Treatment BMP* were:

- Change in the nutrient composition of manure that is applied to land;
- Change in the amount of nutrients applied to crop land;
- Change in the timing of manure application; and
- Change in the amount of nutrients exported off-farm.

Change in the Nutrient Composition of Manure that is Applied to Crop Land

[21] Environmental outcomes were determined by the BMP evaluation survey.

All producers indicated that they were applying the liquid portion of the treated manure to cropland and most were using the solid portion as bedding. A small portion of producers indicated that they were applying either all or some of their solid fraction to corn land.

The results of the manure samples indicate that there are some differences in the chemical composition of the manure prior to and post treatment (Tables 11 and 12). Table 13 describes the manure sampling methods and parameters used by the lab. Figures 6 and 7 compare the total NPK percentages of the input and outputs of both Solid/Liquid Separators and Bedding Recovery Systems.

Solid/Liquid Separators

Treatment decreased the DM composition of the post-treatment liquid fraction by 0.8% and the DM content of the solid fraction was on average 25%. The majority of the ammonium N (NH_4) was concentrated in the liquid fraction of the output. The majority of Phosphorus (79%) was concentrated in the liquid fraction, while 21% was concentrated in the solid fraction. No change in fecal coliforms was detected.

Bedding Recovery Units

Treatment decreased the DM composition of the samples from the Bedding Recovery Unit treatment systems an average of 0.6% and the DM content of the solid fraction was on average 32%. Similar to the samples from the Solid/Liquid Separation equipment, the majority ammonium N was concentrated in the liquid sample. The majority of Phosphorus (83%) was concentrated in the liquid fraction, while 17% was concentrated in the solid fraction. No change in fecal coliforms were detected between the slurry and liquid fraction; however, fecal coliforms in the solid fraction of manure showed a decrease from >1000 MPN/g to an average of 478 MPN/g indicating that the composting process reduces the amount of fecal coliforms detected in the solid fraction of treated manure.

Table 11. Average Chemical and Biological Components of Manure Treated by Solid/Liquid Separation Equipment

	Dry Matter (%)	pH	Total N (%)		NH4-H		Total P (%)		Total K (%)		Fecal Coliforms (MPN/g dry)	
			dry	as received	dry (ug/g)	as received (ug/ml)	dry	as received	dry	as received	dry	as received
Slurry (pre-treatment)	3.5	7.1	6.3	0.2	32434.6	800.7	1.18	0.03	7.27	0.17	0	>1000
Liquid (post-treatment)	2.7	7.3	6.9	0.2	31363.1	710.9	0.95	0.03	5.56	0.15	0	>1000
Solid (post-treatment)	25.3	7.9	1.4	0.4	1311.1	324.4	0.51	0.1	0.78	0.2	0	>1000

Table 12. Average Chemical and Biological Components of Manure Treated with Bedding Recovery Systems

	Dry Matter (%)	pH	Total N (%)		NH4-H		Total P (%)		Total K (%)		Fecal Coliforms (MPN/g dry)	
			dry	as received	dry (ug/g)	as received (ug/ml)	dry	as received	dry	as received	dry	as received
Slurry (pre-treatment)	5.4	7.4	5.0	0.2	22355.1	1059.4	0.89	0.04	4.72	0.23	0	>1000
Liquid (post-treatment)	4.8	8.1	5.9	0.2	29860.6	968.7	1.18	0.05	5.82	0.18	0	>1000
Solid (post-treatment)	32.0	7.9	1.5	0.5	1721.1	470.5	0.34	0.11	0.87	0.25	259	478

Figure 6. Comparison of NPK Percentages Between the Input and Outputs of Solid/Liquid Separation Technology.

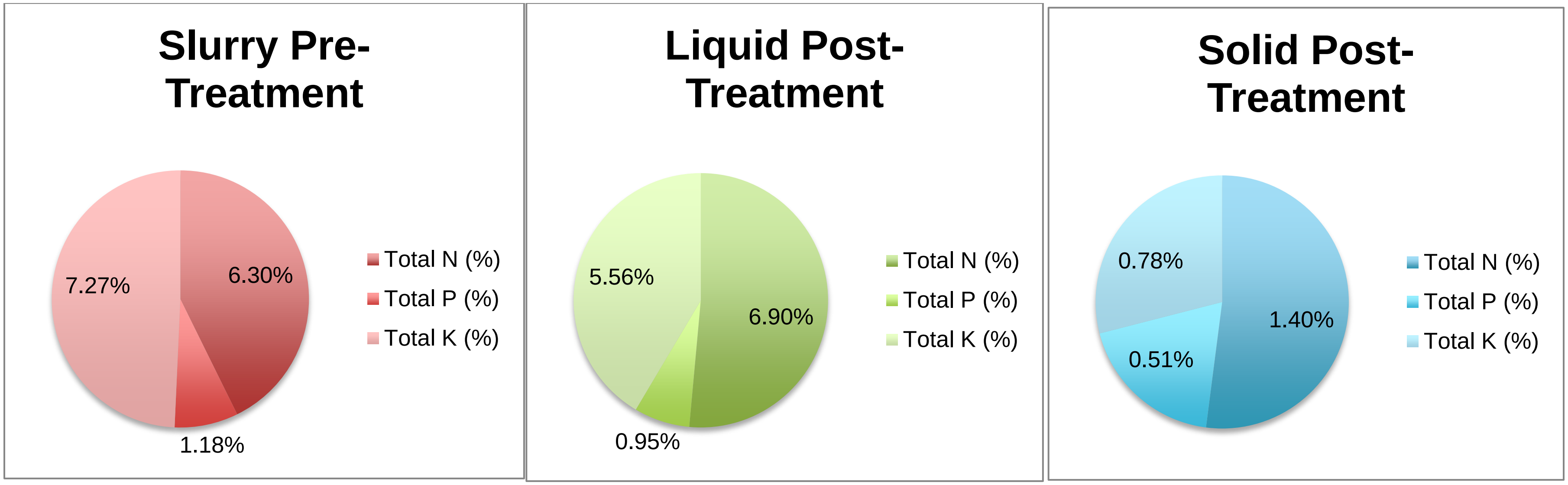

Figure 7. Comparison of NPK Percentages Between the Input and Outputs of Bedding Recovery Systems

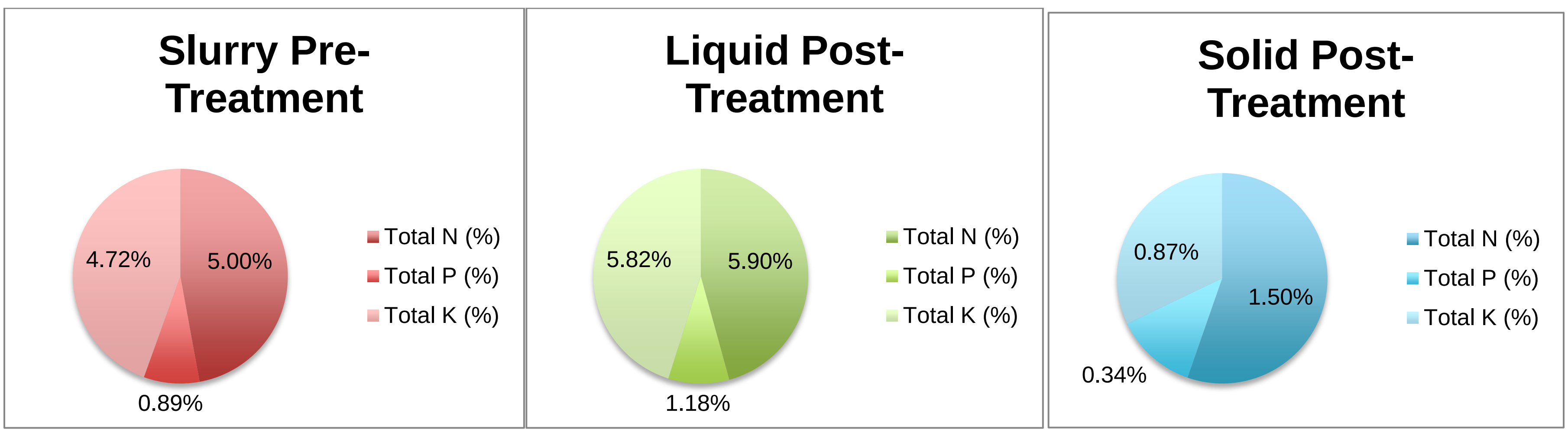

Table 13. Manure Sampling Methods and Parameters

Parameter	Unit	Detection Limit	Method Reference
Dry matter	%	0.10	Gravimetric
Total Potassium	%	0.01	Inductively Coupled Plasma (ICP)
Total Phosphorus	%	0.01	Inductively Coupled Plasma (ICP)
Ammonium (NH4-N)	ug/ml or ug/g	0.10	Colourimetric
Total Organic Nitrogen	%	0.10	Combustion
Total Nitrogen	%	0.10	Combustion
pH		N/A	pH meter
Fecal coliform	Most probable number (MPN/ml)	N/A	MFHPB-19 accredited test

Change in the Amount of Nutrients Applied to Crop Land

The *Manure Treatment BMP* can lead to a decrease in the volume of manure being applied and a change in the nutrient content of the manure if only the liquid fraction of manure is applied on-farm, and the solid portion is used elsewhere.[22] The average farm surveyed produced/applied 2,427,239 gallons of manure per year prior to adopting the *Manure Treatment BMP*. This manure consisted of 19,628 lbs of ammonium Nitrogen, which contained 8215 lbs of Phosphorus (Table 14).

With the installation of a *Manure Treatment BMP*, there was a decrease in manure volume applied and a change in nutrient content of the manure resulting in a net decrease in the amount of nutrients applied annually on the average dairy farm. The average farm applied 2,063,153 gallons of manure per year after implementing the Manure Treatment BMP, consisting of 15,203 lbs/year of ammonium Nitrogen, a 23% decrease, and 7394 lbs of Phosphorus, a 10% decrease.

[22] In this section, we assume that separated solids are not applied.

14. Average Change in the Amount of Nutrients Applied to Crop Land Per Farm that Implements a Manure Treatment BMP.[23][24]

	Pre-Manure Treatment System	Post Manure Treatment System	% Change
Number of milking cows	298	298	0%
Total number of cows	611	611	0%
Number of cow equivalents	445	445	0%
Average annual volume of manure applied (gallons)	2,427,239	2,063,153	-15%
Amount of ammonium N in manure (lbs/1000 gallons)	8.09	7.37	-9%
Amount of Phosphorus in manure (lbs/1000 gallons)	3.38	3.58	6%
Amount of ammonium N applied in manure (lbs/year)	19,628	15,203	-23%
Amount of Phosphorus applied in manure (lbs/year)	8,215	7,394	-10%

Change in Manure Storage Capacity and the Timing of Spreading

The implementation of *Manure Treatment BMPs* increased manure storage capacity by an average of 22 days (a gain of 15%).[25] Anecdotally, producers indicated that the change in their storage capacity ranged anywhere from negligible to a 40% increase in capacity.

Producers were asked to indicate the average amount of days that they spread manure during specific time periods to determine whether the *Manure Treatment BMP* affects the timing of manure application. Although the amount of nutrient loss to the environment is dependent on the weather conditions at the time of spreading as well as other factors, research indicates that generally applying manure to dormant cropland during the winter or “non advised” period increases the risk of nutrient loss. Generally, implementation of the *Manure Treatment BMP* did not affect the timing of manure spreading with the average number of spreading days in each period differing only slightly in any given period (Table 15).

[23] Figures in Table 14 were obtained from the manure samples and survey of producers.
[24] The calculation assumes that the manure samples measured were representative of the real average. If sampling error or variation in the piles were high, there might be a high degree of error in the calculations.
[25] This calculation is based on producers who had not increased the size of their manure storage or installed roofs over their manure pit since implementing their BMP.

Table 15. Change in the timing of manure spreading since BMP implementation.

	Average # of Spreading Days Prior to BMP	Average # of Spreading Days Post BMP Implementation
Sept 1 – Nov 15	5.5	5.3
Nov 16 – Jan 31* not advised	0.36	0.21
Feb 1 – Mar 31	4.6	4.5
April 1 – Aug 31	10.3	9.9
Total Spreading Days	**20.8**	**19.9**

Prior to implementing their BMP, four producers indicated that they experienced times where they needed to spread manure during the 'not advised period'. After implementing the *Manure Treatment BMP*, two producers indicated that still experience times where they need to spread during the 'not advised' period.

Change in the Export of Manure Off-Farm

By separating manure into solid and liquid fractions, transport of solid manure off-farm may be more economical because of the reduced water content. Implementation of manure treatment systems may facilitate the export of nutrients off-farm to farms that are nutrient deficient.

Prior to implementation of the *Manure Treatment BMP*, 14% of respondents (three producers) indicated that they shipped some liquid manure off-farm to neighbouring farms. Of these producers, they shipped between 8% and 60% of their total liquid manure production off-farm (an average of 26% of their total manure slurry production). Similarly, 14% of respondents (three producers) indicated that prior to implementing their *Manure Treatment BMP*, they exported an average of 27% of their solid manure (i.e. from young stock) off-farm.

After implementing their *Manure Treatment BMP* nine percent (two producers) indicated that they ship 5% of the liquid fraction of their manure off-farm. Twenty three percent of respondents (five producers) indicated that they ship between 20% and 70% (an average of 42%) of the solid fraction of their manure off-farm.

Results indicate that there has been a slight increase in the amount of solid manure shipped off-farm since implementation of the *Manure Treatment BMP*.[26] Anecdotally, producers who use the solid fraction as bedding indicated that they did not have enough solid manure to ship off-farm after they satisfy their own bedding needs.

Change in Odour Generated by Manure

Respondents generally indicated that the implementation of their *Manure Treatment BMP* either improved (42%) or did not change (42%) the odour generated by manure on their farm. For those whose manure odour improved it was mostly due to less agitation of their manure pit during storage. Some producers (16%) indicated that manure odour

[26] Sales of manure by-products are discussed in Section 5.8.

had worsened since implementing their manure treatment technology, which was attributed to increased odour when spreading.

5.8 The On-Farm Outcomes of Manure Treatment BMPs

This section will present the on-farm outcomes experienced by farmers and ranchers that implemented *Manure Treatment BMPs* as well as the costs they incurred. The financial and economic outcomes are presented for all BMP projects as well as for solid/liquid separation and bedding recovery systems separately.

To evaluate the private (or on-farm) financial outcomes of the *Manure Treatment BMPs* to the producer, a discounted cash flow (DCF) analysis was conducted. The results of the DCF are presented below in this section. The analysis considers the on-farm situation immediately before BMP uptake compared to directly after BMP uptake and does not consider unrelated changes that may have occurred on the farm after BMP uptake.

On-Farm Benefits and Costs of the Manure Treatment BMP

A series of survey questions aimed at assessing the costs and benefits experienced by farmers due to the adoption of the *Manure Treatment BMP* were asked. The following sections present the results of these survey questions.

Changes in Flexibility and Targeting of Manure Application

The majority of respondents (74%) indicated that they had more flexibility in the timing of manure application since implementing their *Manure Treatment BMP*. Similarly, the majority of producers (70%) indicated that they felt they were better able to target their nutrients to where they were needed. Generally producers indicated that they were able to spread liquid manure on grass between cuts without risk of burning the crop or causing surface crusting. Some producers indicated that they felt that the liquid manure was able to get to the roots of the crop faster than their untreated manure.

Change in Crop Yield and Quality

Approximately half of respondents (52%) indicated that they had noticed an improvement in crop yields. Of these producers, they indicated that their grass yields had increased by 10% and in some cases up to 25%. Producers indicated that where crop yields had improved, it was likely due to the ability to apply liquid manure between cuts in the summer without surface crusting and burning . It is important to note here that for the majority of respondents the 2013 cropping season was their first season since implementing their *Manure Treatment BMP*, and therefore responses are likely skewed to some degree by other factors.

Bedding Expenditures

Respondents were asked if their total bedding costs changed as a result of implementing the BMP. On average, for farms that recycle bedding either by use of a bedding recovery system or solid/liquid separator, $29,500 in annual bedding cost savings were realized, taking into account the cost of bedding for their operation for two to three years prior to implementing their *Manure Treatment BMP*. Farms that installed solid/liquid separation saved an average of $21,800 annually in bedding costs. The average farm that installed a bedding recovery system saved $33,400 in annual bedding costs.

The types of bedding used prior to implementing of the *Manure Treatment BMP* included sand, wood shavings, bedding pellets and straw. Most producers indicated that they still use either sand, shavings or straw to a lesser extent in addition to the composted bedding product.

Bedding/By-product Sales

Respondents were asked if they sold bedding and/or separated solids byproducts associated with the BMP. Eight respondents (35%) indicated that at some point since implementing their *Manure Treatment BMP* they have sold manure byproducts. Six producers indicated that they have sold some solid manure for bedding, and two producers indicated that they have sold some manure as a soil amendment. One producer indicated that they sold some solid manure for a potting mix used by a greenhouse. These producers, on average sold $9,125 in manure by-products annually.

Animal Health Changes

Respondents were asked if they noticed changes in animal health as a result of using treated manure as bedding. Half of respondents (50%) indicated that their animal health had improved. Half of respondents indicated that they did not notice a change in animal health since implementing the *Manure Treatment BMP*. Reasons for health improvement included:

- Fewer hock sores;
- Less mastitis; and
- Fewer abrasions.

Several producers indicated that their cows are more comfortable on manure bedding because they are providing deeper bedding than prior to implementing their *Manure Treatment BMP*. Anecdotally, producers indicated that there was an adjustment period where higher somatic cell counts were experienced when first switching to manure bedding. However, over time and with the appropriate moisture content of recycled bedding, that has improved.

Fertilizer Expenditures

Respondents were asked if their average annual chemical fertilizer expenditures changed as a result of implementing the *Manure Treatment BMP*. Most producers were not able to answer this question because they only had one seasons experience with the BMP on their farm. For respondents who did indicate that their fertilizers costs had changed (5 respondents), on average, these producers realized $2,166.67 per year in fertilizer cost savings. One respondent indicated that the installation of their solid/liquid separation system realized $10,000 per year in cost savings.[27] The average farm that installed a bedding recovery system indicated that they realized $600 per year per farm in fertilizer cost savings since implementing a manure treatment system. Note that the

[27] Average fertilizer savings of $10,000 are based on one respondent and therefore we assume fertilizer savings to be $0 for the DCF and CBA to ensure a conservative estimate.

change in fertilizer expenditures may be attributed to factors other than the *Manure Treatment BMP,* such as changes in the price of fertilizer.

Manure Application Expenditures

Respondents were asked if their manure application costs (if a custom applicator was used) and/or labour changed as a result of implementing the *Manure Treatment BMP*. On average, each BMP resulted in manure application cost savings of $2,600 per farm per year and labour savings of 86.4 hours (a 44% decrease) valued at $1,296 per farm annually.

Farms that installed solid/liquid separation realized $2,500 per year in manure application cost savings, a 14% decrease, as a result of adopting the *Manure Treatment BMP*. Labour savings figures were not available due to insufficient data.

The average farm that installed a bedding recovery system realized a manure application cost savings of $2,667 per year, a 12% decrease. Each farm also experience labour savings of 86.4 hours per year (a 44% decrease) equal to $1,296 per year as a result of implementing the BMP.

Labour Requirements

Respondents were asked if the labour required to maintain their manure treatment system changed as a result of adopting the BMP. On average, each farm experienced an increase of 51.43 hours of labour per year equal to $772 or a 35% increase as a result of adopting the BMP.[28] The increase in labour was attributed to additional maintenance and repairs of manure treatment equipment. Farms that installed solid/liquid separation realized an increase of 179 hours per year, or $2,685. The average farm that installed a bedding recovery system experienced a decrease of 17 hours of labour per year equal to $253 or an 8% decrease as a result of adopting the BMP. It is not clear why there was a difference in the amount of labour required between producers who installed solid/liquid separation equipment and those who implemented bedding recovery systems. For those who realized labour savings, less need to agitate pits and not having to clean out solids at the bottom of pits were cited as the reasons why. It is important to note that these figures may change as producers become more experienced with manure treatment technology on their farms.

Repair and Maintenance Requirements

Respondents were asked if their repair and maintenance costs differed between the previous manure treatment system and the *Manure Treatment BMP* they implemented. On average, each farm realized a $6,871 per year cost increase as a result of adopting the BMP. Each farm that implemented a solid/liquid separation system experienced a $7,423 annual increase in repair and maintenance costs. Each farm that implemented a bedding recovery system experienced a $6,601 annual increase in operational costs. The increase in cost was generally attributed to replacement of screens in the dewatering equipment. It is important to note that these figures may change as producers become more experienced with manure treatment technology on their farms.

[28] A cost of $15/hour was used to calculate the value of labour.

Operational Expenses

Respondents were asked if their operational costs differed between the previous manure treatment system and the *Manure Treatment BMP* they implemented. On average, each farm realized a $4,146 per year cost increase as a result of adopting the BMP. Each farm that implemented a solid/liquid separation system experienced a $3,080 annual increase in operational costs. Each farm that implemented a bedding recovery system experienced a $4,501 annual increase in operational costs. These costs are generally attributed to the additional power (mostly hydro-electricity) needed to operate the systems.

Manure Treatment BMP Discounted Cash Flow Analysis

To understand the financial outcomes of the *Manure Treatment BMP* to the farmer, a discounted cash flow analysis (DCF) was conducted. The DCF is used to present the private costs and benefits associated with the *Manure Treatment BMP* over the life of the BMP to a producer. The breakeven year for each BMP is also presented. [29] The project lifespan of a *Manure Treatment BMP* is assumed to be 15 years.

Values included in the DCF included:

- Producer capital contribution to project;
- Additional capital expenses incurred by producer;
- Repair and maintenance expenditures;
- Operational expenditures;
- Labour expenditures;
- Fertilizer savings;
- Manure application savings;
- Bedding/Byproduct sales;
- Bedding savings; and
- Animal health savings.

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $320,168 to a high of $561,077 while the costs ranged from a low of $282,385 to a high of $358,307 (Table 16). The net present values at all discount rates were positive. They ranged from a low of $37,783 in the case of an 8% discount rate to a high of $202,769 in the case of a 0% discount rate. All NPVs are positive due to the benefits associated with the BMP and the long life span.

Table 16. Private Benefit, Cost, and NPV of the Discounted Cash Flow Analysis for all BMP Projects[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$561,077	$358,307	$202,769	8
3 %	$446,540	$322,211	$124,329	9
8 %	$320,168	$282,385	$37,783	11

[a] Values are in 2013 Canadian dollars.

[29] The breakeven year is the year of the project (Year 0 to 15) where the NPV of the project for s specified discount rate becomes positive.

Depending on the specification of the discount rate aggregate benefits for solid/liquid separation BMP projects ranged from a low of $222,669 to a high of $390,214 while the costs ranged from a low of $241,495 to a high of $326,427 (Table 17). The net present values were positive for 0% and 3% discount rates and negative for the 8% discount rate. They ranged from a low of -$18,827 in the case of an 8% discount rate to a high of $63,787 in the case of a 0% discount rate.

Table 17. Private Benefit, Cost, and NPV of the Discounted Cash Flow Analysis for Solid/Liquid Separation BMP projects[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$390,214	$326,427	$63,787	11
3 %	$310,557	$286,047	$24,509	13
8 %	$222,669	$241,495	-$18,827	-

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate aggregate benefits for Bedding Recovery System BMP projects ranged from a low of $344,004 to a high of $602,847 while the costs ranged from a low of $294,696 to a high of $366,200 (Table 18). The net present values at all discount rates were positive. They ranged from a low of $49,308 in the case of an 8% discount rate to a high of $236,647 in the case of a 0% discount rate.

Table 18. Private Benefit, Cost, and NPV of the Discounted Cash Flow Analysis for Bedding Recovery System BMP projects[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$602,847	$366,200	$236,647	7
3 %	$479,783	$332,204	$147,579	8
8 %	$344,004	$294,696	$49,308	11

[a] Values are in 2013 Canadian dollars.

5.9 Public Benefits of the Manure Treatment BMP

To understand the economic outcomes of BMP adoption, a cost benefit analysis methodology was used. The project lifespan of a *Manure Treatment BMP* is assumed to be 15 years. Appendix III contains a summary of the average costs and benefits used in the *Manure Treatment BMP* CBA.

Values included in the CBA included:

- *BMP Program* cost-share contribution to project;
- Producer capital contribution to project;
- Additional capital expenses incurred by producer;
- Repair and maintenance expenditures;
- Operational expenditures;
- Labour expenditures;
- Fertilizer savings;

- Manure application savings;
- Manure application labour savings;
- Bedding/Byproduct sales;
- Bedding savings; and
- Animal health savings.

CBA Summary

All of the NPV calculated for the *Manure Treatment BMP* to date are negative because the projects were implemented fairly recently. NPV estimates for the BMP over the life of the program all positive with the exception of the NPV of Solid/Liquid separation projects at an 8% discount rate. NPV estimates for adding one farmer to the BMP program at all positive with the exception of the NPV of Solid/Liquid separation projects at a 3% and 8% discount rate. The following sections present the details of the CBA.

Net Present Value of the Program to Date

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $1,645,825 to a high of $1,754,945 while the costs ranged from a low of $5,492,205 to a high of $6,338,225 (Table 19). The net present values at all discount rates were negative. They ranged from a low of -$4,583,281 in the case of an 8% discount rate to a high of -$3,846,380 in the case of a 0% discount rate. All NPVs are negative due to the relatively short time that they have been installed on-farm.

Table 19. Benefit, Cost, and NPV of the Program to Date for all BMP projects[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$1,645,825	$5,492,205	-$3,846,380
3 %	$1,685,710	$5,797,129	-$4,111,419
8 %	$1,754,945	$6,338,225	-$4,583,281

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for solid/liquid separation projects ranged from a low of $390,214 to a high of $422,956, while the costs ranged from a low of $1,283,418 to a high of $1,501,736 (Table 20). The net present values calculated for the program to date were negative. They ranged from a low of -$1,078,779 in the case of an 8% discount rate to a high of -$893,203 in the case of a 0% discount rate.

Table 20. Benefit, Cost, and NPV of the Program to Date for Solid/Liquid Separation projects[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$390,214	$1,283,418	-$893,203
3 %	$402,133	$1,361,380	-$959,247
8 %	$422,956	$1,501,736	-$1,078,779

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for bedding recovery separation BMP projects ranged from a low of $1,165,504 to a high of $1,232,164, while the costs ranged from a low of $4,130,740 to a high of $4,733,013

(Table 21). The net present values calculated for the program to date were negative. They ranged from a low of -$3,500,849 in the case of an 8% discount rate to a high of -$2,965,236 in the case of a 0% discount rate.

Table 21. Benefit, Cost, and NPV of the Program to Date for Bedding Recovery System projects.

Discount Rate	Benefit	Cost	Net Present Value
0 %	$1,165,504	$4,130,740	-$2,965,236
3 %	$1,189,946	$4,348,937	-$3,158,991
8 %	$1,232,164	$4,733,013	-$3,500,849

[a] Values are in 2013 Canadian dollars.

Net Present Value over the Expected Life of the Program

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $8,565,583 to a high of $12,904,763 while the costs ranged from a low of $8,484,598 to a high of $9,040,460 (Table 22). The net present values at all discount rates were positive. They ranged from a low of $80,984 in the case of an 8% discount rate to a high of $3,864,303 in the case of a 0% discount rate. All NPVs are positive due to the benefits associated with the BMP and the long life span.

Table 22. Benefit, Cost, and NPV over the Expected Life of the Program for all BMP projects[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$12,904,763	$9,040,460	$3,864,303
3 %	$10,874,132	$8,692,860	$2,181,271
8 %	$8,565,583	$8,484,598	$80,984

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for solid/liquid separation projects ranged from a low of $1,848,304 to a high of $2,731,500, while the costs ranged from a low of $2,191,329 to a high of $2,470,257 (Table 23). The net present values were positive for 0% and 3% discount rates and negative for the 8% discount rate. They ranged from a low of -$343,025 in the case of an 8% discount rate to a high of $261,243 in the case of a 0% discount rate.

Table 23. Benefit, Cost, and NPV over the Expected Life of the Program for a Solid/Liquid Separation project[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$2,731,500	$2,470,257	$261,243
3 %	$2,317,917	$2,307,283	$10,634
8 %	$1,848,304	$2,191,329	-$343,025

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for bedding recovery separation BMP projects ranged from a low of $6,347,796 to a high of $9,645,554, while the costs ranged from a low of $6,146,191 to a high of $6,473,328 (Table 24). The net present values calculated for the program to date were positive.

They ranged from a low of $201,605 in the case of an 8% discount rate to a high of $3,172,227 in the case of a 0% discount rate.

Table 24. Benefit, Cost, and NPV over the Expected Life of the Program for a Bedding Recovery System[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$9,645,554	$6,473,328	$3,172,227
3 %	$8,102,698	$6,258,564	$1,844,135
8 %	$6,347,796	$6,146,191	$201,605

[a] Values are in 2013 Canadian dollars.

Net Present Value of Adding one Farmer in 2013

This subsection reports on the value of one farm implementing a *Manure Treatment BMP* in 2013. This is the value of the BMP, per BMP project, based on the average aggregate costs and benefits.

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $320,168 to a high of $561,077 while the costs ranged from a low of $317,141 to a high of $393,063 (Table 25). The net present values at all discount rates were positive. They ranged from a low of $3,027 in the case of an 8% discount rate to a high of $168,013 in the case of a 0% discount rate. All NPVs are positive due to the benefits associated with the BMP and the long life span.

Table 25. Benefit, Cost, and NPV of Adding One Farmer with a Manure Treatment BMP project to the Program in 2013[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$561,077	$393,063	$168,013	9
3 %	$446,540	$356,967	$89,573	10
8 %	$320,168	$317,141	$3,027	15

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for solid/liquid separation projects ranged from a low of $222,669 to a high of $390,214, while the costs ranged from a low of $267,962 to a high of $352,894 (Table 26). The net present values were positive for the 0% discount rate and negative for the 3% and 8% discount rates. They ranged from a low of -$45,293 in the case of an 8% discount rate to a high of $37,320 in the case of a 0% discount rate.

Table 26. Benefit, Cost, and NPV of Adding One Farmer with a Solid/Liquid Separation to the Program in 2013[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$390,214	$352,894	$37,320	13
3 %	$310,557	$312,514	-$1,957	-
8 %	$222,669	$267,962	-$45,293	-

[a] Values are in 2013 Canadian dollars.

Depending on the specification of the discount rate, aggregate benefits for bedding recovery separation BMP projects ranged from a low of $344,004 to a high of $602,847, while the costs ranged from a low of $33,078 to a high of $404,583 (Table 27). The net present values calculated for the program to date were positive. They ranged from a low of $10,926 in the case of an 8% discount rate to a high of $198,264 in the case of a 0% discount rate.

Table 27. Benefit, Cost, and NPV of Adding One Farmer with a Bedding Recovery System to the Program in 2013[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$602,847	$404,583	$198,264	9
3 %	$479,783	$370,587	$109,196	10
8 %	$344,004	$333,078	$10,926	14

[a] Values are in 2013 Canadian dollars.

5.9.1 Case Study: Valuing the Environmental Impact of Manure Treatment Systems

This section presents a hypothetical case study of a BC dairy farm that experiences nutrient runoff/leaching. The purpose is to demonstrate the environmental impact and associated abatement cost of nutrient loss and how these impacts change when the farm adopts a *Manure Treatment BMP*, specifically a bedding recovery unit. The environmental impact is discussed in terms of nitrogen and phosphorus loss and the economic cost is discussed in terms of abatement costs. We use the cost of removing ammonium Nitrogen and Phosphorus by sewage treatment to value the environmental impact of nutrient loss from the farm.

When the farm installs a bedding recovery unit, they no longer apply the separated solids (15% of untreated manure), thus the total volume of manure applied is reduced by 15%. In addition, the nutrient content of the manure applied is different. The decrease in the volume of manure as well as the change in the nutrient content of manure applied (Table 28) results in a net decrease in the amount of ammonium N and Phosphorus loss from the farm (Table 28). The associated economic value of this change is a 22% decrease in the abatement cost for ammonium N and 6% decrease in the abatement cost for Phosphorus (Table 29).

Table 28. Characteristics of a Dairy Farm Prior to and After Installing a Bedding Recovery Unit.

	Pre-Manure Treatment System	Post Manure Treatment System	% Change
Number of milking cows	298	298	0%
Total number of cows	611	611	0%
Number of cow equivalents[30]	445	445	0%
Average annual volume of manure applied (gallons)	2,427,239	2,063,153	-15%
Amount of ammonium N applied in manure (lbs/year)	21,460	16,678	-22%
Amount of Phosphorus applied in manure (lbs/year)	8,215	7,714	-6%

Table 29. Nutrient loss Rates and Abatement Costs Associated with the Bedding Recovery Unit.

	Nutrient loss rate	Nutrient loss (lb/year)		Abatement cost of nutrient loss ($/year)[31]		% Change
		Pre	Post	Pre	Post	
Ammonium loss based on nutrient loss rate (lbs/year)	1%	215	167	563	437	-22%
	3%	644	500	1,688	1,312	-22%
	5%	1,073	834	2,814	2,187	-22%
Phosphorus loss based on nutrient loss rate (lbs/year)	1%	82	77	1,551	1,456	-6%
	3%	246	231	4,652	4,368	-6%
	5%	411	386	7,753	7,280	-6%

[30] Formula for calculating cow equivalents can be found at http://www.al.gov.bc.ca/resmgmt/publist/300Series/383100-2.pdf
[31] Abatement cost values are taken from Olewiler et al. 2004. The marginal abatement costs are $2.62/lb N and 18.86/lb P, which are averages based on the range presented for N and P in the Olewiler et al. 2004.

5.10 Manure Treatment BMP Financial and Economic Analyses for Smaller Dairies

To understand the financial and economic outcomes of the *Manure Treatment BMP* to the smaller dairies than the average size of those who have implemented the BMP to date, we conducted a discounted cash flow analysis (DCF) using a subset of BMP adopters. Dairies with fewer than 200 milking cows were selected (n = 5) the average dairy included in the analysis milked 130 cows. All smaller dairies installed Bedding Recovery Systems.

Discounted Cash Flow Analysis for Smaller Dairies

The DCF is used to present the private costs and benefits associated with the *Manure Treatment BMP* over the life of the BMP to a small dairy producer. The project lifespan of a *Manure Treatment BMP* is assumed to be 15 years.

Values included in the DCF included:

- Producer capital contribution to project;
- Additional capital expenses incurred by producer;
- Repair and maintenance expenditures;
- Operational expenditures
- Labour expenditures;
- Fertilizer savings;
- Manure application savings;
- Bedding/Byproduct sales;
- Bedding savings; and
- Animal health savings.

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $301,764 to a high of $528,825 while the costs ranged from a low of $331,170 to a high of $408,124 (Table 30). The net present values for 0% and 3% discount rates were positive and negative for the 8% discount rate. They ranged from a low of -$29,406 in the case of an 8% discount rate to a high of $120,701 in the case of a 0% discount rate.

Table 30. Private Benefit, Cost, and NPV of the Discounted Cash Flow Analysis for BMP projects implemented by smaller dairies (<200 milking cows)

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$528,825	$408,124	$120,701	10
3 %	$420,872	$371,537	$49,335	12
8 %	$301,764	$331,170	-$29,406	-

[a] Values are in 2013 Canadian dollars.

Manure Treatment BMP Cost Benefit Analysis for Smaller Dairies

To understand the economic outcomes of BMP adoption to small dairies, a cost benefit analysis was conducted.[32] The project lifespan of a *Manure Treatment BMP* is assumed to be 15 years.

Values included in the CBA included:

- *BMP Program* cost-share contribution to project;
- Producer capital contribution to project;
- Additional capital expenses incurred by producer;
- Repair and maintenance expenditures;
- Operational expenditures;
- Labour expenditures;
- Fertilizer savings;
- Manure application savings;
- Bedding/Byproduct sales;
- Bedding savings;
- Animal health savings.

Net Present Value of the Program to Date

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $352,550 to a high of $376,034 while the costs ranged from a low of $1,453,976 to a high of $1,689,677 (Table 31). The net present values at all discount rates were negative. They ranged from a low of -$1,313,643 in the case of an 8% discount rate to a high of -$1,101,426 in the case of a 0% discount rate.

Table 31. Benefit, Cost, and NPV of the Program to Date for BMP projects implemented by smaller dairies (<200 milking cows)

Discount Rate	Benefit	Cost	Net Present Value
0 %	$352,550	$1,453,976	-$1,101,426
3 %	$361,139	$1,538,907	-$1,177,768
8 %	$376,034	$1,689,677	-$1,313,643

[a] Values are in 2013 Canadian dollars.

Net Present Value over the Expected Life of the Program

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $1,766,314 to a high of $2,644,125 while the costs were ranged from a low of $2,160,859 to a high of $2,230,618 (Table 32). The net present values for 0% and 3% discount rates were positive and negative for the 8% discount rate. They ranged from a low of -$394,545 in the case of an 8% discount rate to a high of $413,507 in the case of a 0% discount rate.

[32] Refer to the first BMP evaluation report for a detailed summary of the CBA methods: http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/AGRI_BMP_Report_FINAL.pdf

Table 32. Benefit, Cost, and NPV over the Expected Life of the Program for BMP projects implemented by small dairies (<200 milking cows)[a]

Discount Rate	Benefit	Cost	Net Present Value
0 %	$2,644,125	$2,230,618	$413,507
3 %	$2,233,697	$2,173,539	$60,158
8 %	$1,766,314	$2,160,859	-$394,545

[a] Values are in 2013 Canadian dollars.

Net Present Value of Adding one Farmer in 2013

Depending on the specification of the discount rate, aggregate benefits for all BMP projects ranged from a low of $301,764 to a high of $528,825 while the costs ranged from a low of $369,170 to a high of $446,124 (Table 33). The net present values for 0% and 3% discount rates were positive and negative for the 8% discount rate. They ranged from a low of -$67,406 in the case of an 8% discount rate to a high of $82,701 in the case of a 0% discount rate.

Table 33. Benefit, Cost, and NPV of Adding One Small Dairy Farmer with a Manure Treatment BMP project to the Program in 2013[a]

Discount Rate	Benefit	Cost	Net Present Value	Breakeven Year
0 %	$528,825	$446,124	$82,701	12
3 %	$420,872	$409,537	$11,335	15
8 %	$301,764	$369,170	-$67,406	-

[a] Values are in 2013 Canadian dollars.

5.11 Social Factors of Manure Treatment BMP Uptake

This section will present the results of a series of questions about various personal and social aspects of BMP uptake to try to understand the following:

- The motivations for uptake of the *Manure Treatment BMP*; and
- The barriers to uptake of the *Manure Treatment BMP* by other farmers.[33]

Motivations for Uptake of the Manure Treatment Storage BMP

When asked explicitly the main reasons why they decided to implement the *Manure Treatment BMP,* respondents indicated that their main reasons were to:

- Reduce bedding costs (55%);
- Improve crop yields (14%);
- Reduce surface crusting when applying manure to cropland (14%);
- Increase manure storage capacity (14%); and
- Improve cow health (5%).

Respondents were also asked to rate on a scale of 1 to 5 (not important to very important), the reasons why they chose to adopt the *Manure Treatment BMP* from a list of possible motivations (Table 34). Producers indicated that all of the possible motivations listed were at least somewhat important motivating factors when deciding to implement the *Manure Treatment BMP*. Overall "improving the profitability of my operation" was listed as the most important motivating factor (4.6), which is consistent with reducing bedding costs and improving crop yields. Other important factors were improving manure/nutrient management (4.3) and contributing to a positive image for the dairy industry (4.2).

Table 34. Motivating factors for uptake of the Manure Treatment BMP.

Motivation	Average Score
Improving the profitability of my operation	4.6
Improving manure/nutrient management	4.3
Contributing to a positive industry image	4.2
Improving the long-term sustainability of my operation	4.1
Demonstrating stewardship	3.6
Limiting the farm's impact on the environment	3.6
Meeting regulatory requirements	3.3
Facilitating increase in herd size	3.0

Other potential factors that may contribute to uptake of the *Manure Treatment BMP* include the size of the farm and age of the main farm operator. Evaluation results indicate that those who implemented *Manure Treatment BMP*s milk approximately double the average amount of cows for dairy farms in BC. The average evaluation participant was younger than the average age of farmers in BC.

[33] Motivations and barriers were determined from the BMP evaluation survey and interviews. Additional insight into the barriers to BMP uptake was provided by interviews with non-adopters.

Barriers to Uptake of the Manure Treatment BMP

Respondents were asked to indicate what the main barriers to uptake of the *Manure Treatment BMP* are for other producers in their industry. Responses included:

- High costs and other financial barriers (39%);
- Implementation costs are too high for smaller farms (22%);
- Concerns/sigma about using manure bedding (16%);
- The status quo is acceptable for the farm (11%);
- Lack of information/understanding of the technology (6%); and
- Lack of pressure from neighbours to improve practices (6%).

Similar to the motivation question described above, respondents were asked to rate on a scale from 1 to 5 (not a barrier to a large barrier) a set of barriers to *Manure Treatment BMP* uptake. The exact wording of the question was "In your opinion, how significant are the following barriers to the adoption of the *Manure Treatment BMP* for other producers in your industry?" The high cost of BMP implementation was rated as the largest barrier to uptake of the BMP (4.1). The financial situation of the farm and inadequate cost share levels provided through the BMP Program were also considered to be barriers to uptake of the BMP. (Table 35).

Table 35. Barriers to uptake of the Manure Treatment BMP.

Barrier	Average Score
The capital costs of BMP implementation	4.1
The financial situation of the farm	3.6
Inadequate cost-share levels provided through the BMP Program	3.4
No family succession plan for the farm	3.2
A lack of understanding about which BMPs will benefit operations	2.7
Barriers to accessing funding through the BMP Program	2.6
A lack of understanding about how the BMP will benefit operations	2.5
A lack of support from public agencies	2.2
A lack of time or labour	2.1
A lack of industry pressure	2.0
Other environmental priorities take precedent	1.8
Lack of awareness of risks to the environment from farm practices	1.7
A lack of public pressure	1.4

To further understand the barriers to uptake of the *Manure Treatment BMP*, four interviews were conducted with dairy producers in the Fraser Valley who had not implemented a manure treatment technology. The average size of these producers milking herd was 115 cows, which was more consistent with the average size of dairy farms in BC at the time of the evaluation (125 milking cows). All four producers indicated that they had some familiarity with/knowledge of the technology.

These producers indicated that the biggest barrier for them was that the initial infrastructure costs were too high to justify implementation of the technologies on their farm. Beyond the purchase of the treatment technology, farms often need to upgrade their electrical, buildings and other infrastructure at the same time. For larger dairy farm operations, that have higher bedding costs, the payback period is sooner. However, bedding costs for the average dairy farm are already relatively low and therefore they felt it may take between 10 to 15 years for the systems to pay for themselves.

Two producers indicated that their current manure storage facilities were adequate for their farm operation and would consider manure treatment technologies if that were not the case.

One producer indicated that they had concerns with using manure bedding for milking cows as it could lead to an increase in somatic cell counts. They had no concern about using the bedding for the heifer barn. In another case, a producer indicated that sand bedding was considered the industry gold standard and using manure bedding may be considered an inferior practice.

Increased odour was a concern for one producer who believed that there was potential for increased odour during application of the liquid fraction of the manure. Evaluation results indicated that some producers experienced increased manure odours during application depending on their method of application. For example, some producers were spreading a portion of the liquid fraction using an irrigation gun, which resulted in increased odour.

Preferred Sources of Information

Understanding the producers preferred information channels may help to shed light on the barriers to awareness of the *Manure Treatment BMP* as well as provide insight into how the successful promotion of the *Manure Treatment BMP* may be accomplished in the future. The most preferred information source selected by respondents was the producers' peers (95% of respondents). Agricultural supply companies and agricultural magazines were also highly preferred by respondents as sources of information (Table 36).

Two producers indicated that they had been on a tour in the United States to view the manure treatment technology in action. The tour helped them to understand the technology as well as allowed them to see it in action prior to the technology becoming widespread in BC.

Table 36. Information Channels Preferred by Producers who Implemented the Manure Treatment BMP

Information Channel	Percentage of Respondents
Peers	95%
Agricultural supply companies	90%
Agricultural magazines	86%
Newsletters	71%
Farm demonstrations and field trials	67%
Internet/websites	66%
Government publications	57%
Newspapers	48%
Classes/workshops	48%
Books	19%
Mobile media	19%
Television	14%
Social media websites	14%

6.0 Manure Treatment BMP SWOT Analysis, Conclusions and Recommendations

A SWOT Analysis is presented in this section to organize some of the main findings of the BMP evaluation as well as present anecdotal information that may not be presented in the above sections. Note that this section is only the preliminary step in a SWOT analysis and further steps including a detailed analysis and development of an action plan often follows this step in order to direct policy.

6.1 Manure Treatment BMP SWOT Analysis

Strengths

- For those who use the manure byproduct as bedding, bedding costs have been drastically reduced by the BMP.
- The BMP has increased the flexibility of manure spreading timing, allowing producers to avoid spreading during poor conditions.
- The BMP can facilitate targeting of nutrients to areas of specific nutrient deficiency.
- The BMP has allowed farmers to utilize manure more effectively as a fertilizer, particularly during the summer months between cuts of grass.
- Anecdotally, the BMP contributes to improved grass crop yields as manure may be applied as fertilizer during the growing season as there is less risk of build up of organic matter on the soil surface (i.e. surface crusting).
- The BMP may result in operational efficiencies, depending on the manure management practices of the farm previously. Some farmers indicated that they spend much less time agitating, cleaning solids out of pits and fixing blockages while spreading manure.
- The BMP has a positive financial outcome, taking 9 years for producers who have implemented the BMP already to break even (based on an average farm size of 298 milking cows and a discount rate of 3%).
- Implementation of the BMP may lead to other positive changes in the manure management of the farm such as implementation of draglines and injection application equipment.
- The use of composted bedding in general, has a positive impact on animal health, generally reducing hock sores, other issues of lameness and in some cases mastitis.

Weaknesses

- The capital cost of an average *Manure Treatment BMP* appears to be too high for the average BC dairy farm.
- The uptake of the BMP is concentrated in the Lower Mainland area. Few producers have adopted this technology outside this area.
- The uptake of the BMP has mostly been confined to the dairy industry, other technologies specific to the poultry and other livestock industries have not been introduced in the province yet.
- The implementation of the BMP does not appear to effectively increase manure storage capacity for some producers; therefore, in these cases implementation of the BMP may not reduce the need for manure storage expansion.

- According to respondents, the costs of maintaining and operating the *Manure Treatment BMP* are currently higher than expected.
- According to some respondents, the DM content of the treatment manure was not meeting their expectations, resulting in a need for an additional Solid/Liquid Separator. This issue did not appear to be specific to any particular technology.

Opportunities

- Producers appear to respond positively to tours and demos of the technology. There may be an opportunity to increase BMP uptake by highlighting manure treatment technologies on dairy tours.
- Producer awareness of the nutrient benefits of manure is increasing, potentially increasing demand for this BMP in the future.
- Respondents indicated that there may be an opportunity to treat neighbouring farms dairy or poultry manure, reducing the implementation costs of the technology while spreading the benefits amongst other producers. It is important to note that with the transport of manure between farms, there is an increased risk of disease transfer between farm operations. Producers who implement pooled *Manure Treatment BMPs* should have a biosecurity plan in place to mitigate this risk.
- Currently few producers are selling manure by-products; however several indicated that they would consider it in the future if marketing avenues were established.

Threats

- Farms with no plans for family succession lack the incentive to invest in *Manure Treatment BMPs.*
- In the past there has been a stigma around using manure bedding for cows. This view may still prevalent amongst producers.

6.2 Conclusions and Recommendations for the Manure Treatment BMP

This section provides an overview of the main conclusions of the BMP evaluation. Recommendations will also be provided where appropriate. Note that these conclusions and recommendations are based on the authors' opinions and reflect both qualitative and quantitative information collected during the evaluation.

Did the BMP have the outcomes it was designed to have?

To recap, the *Manure Treatment BMP* is designed to have the following environmental outcomes:

- Reduction in stored manure volume resulting in application of manure in more ideal conditions; and
- A reduction in excess manure nutrient application on cropland due to the ability to viably export solid manure off-farm.

The *Manure Treatment BMP* is meeting the targeted outcomes to have to some degree. Note however, that these outcomes are limited in their applicability across BC since the dairy farms adopting these technologies to date are more than double the size of the average dairy farm in BC

On average, uptake of the *Manure Treatment BMP* resulted in a 22-day increase in liquid manure storage capacity (a 15% increase in storage capacity on average). Some producers indicated that they had realized much less increase while others indicated that they had realized up to a 40% increase in storage capacity due to the implementation of their BMP. The timing of manure application did not appear to change drastically due to the implementation of the BM..

The BMP has slightly increased the amount of solid manure that is exported off-farm; however, most producers indicated that they just enough solid manure to meet their own needs. Eight producers indicated that they have sold some manure-byproducts since implementing their manure storage BMP.

Did the BMP meet the expectations of producers?

The BMP is meeting the expectation of producers in most cases. However, is important to note that the majority of producers had only experienced one season with their BMP, therefore the evaluation results may not accurately reflect the long term experiences of producers.

A reduction in bedding costs was the largest benefit experienced by those who implemented the BMP. Most producers who implemented the BMP also experienced an increase in the flexibility of manure application. An improvement in animal health and cow comfort as well as a potential to improve crop yields were benefits experienced by producers.

Some producers indicated that they were dissatisfied with the cost and time associated with maintaining the equipment, for example, replacing screens as well as the operating costs of the equipment. In some cases, producers indicated that they were also dissatisfied with the actual DM content of the solid manure product as well as the increase in manure storage capacity versus what the equipment suppliers had indicated they would experience.

Overall, the DCF analysis indicates that the BMP results in positive financial outcomes for the individual producer.

Is there justification for continued support of the BMP?

Based on the following criteria we recommend continued support of the *Manure Treatment BMP* with an overall category cap that reflects the high level of benefits experienced by those who adopt the BMP and increased emphasis on pooled projects where average to smaller sized dairy farms may also benefit from the *Manure Treatment BMP* cost-share funding.

The criteria used to generate this recommendation was:

Is the BMP effective at mitigating environmental risks?

- Yes, in some cases, the BMP appears to be effective in increasing manure storage capacity as well as facilitating export of nutrients off-farm.

Does the BMP provide the expected outcomes to producers?

- Yes, in general producers indicate that their expectations were met by the BMP despite the high cost of repair and maintenance and increase in operating costs.

Does the BMP provide a benefit to society?

- Our analysis shows that over the lifetime of the BMP (15 years), the BMP has a positive net benefit to society. However it is important to note here that this benefit is based solely on public and private costs and private benefits, as we were not able to value some of the environmental outcomes of BMP implementation within the scope of this report.

Appendices

I. References and Literature Consulted

BC Ministry of Agriculture. (2010). *Nutrient management planning reference guide.* Abbotsford, BC: ARDCorp.

BC Ministry of Agriculture. (2010). *Growing Forward Manure Sampling and Analysis for Nutrient Management* . Nutrient Management Factsheet - No. 5 in Series (Revised September 2010, Order Reference No. 631-500-3).

BC Ministry of Agriculture. (2010). *Reference guide: The Canada -British Columbia environmental farm plan program.* (No. 4). Abbotsford, BC: Agricultural Research and Development Corporation.

BC Ministry of Agriculture and Food. (1990). *Sizing dairy manure storage facilities.* Retrieved from http://www.al.gov.bc.ca/resmgmt/publist/300Series/383100-2.pdf

Hamilton, D. (2010). *Solids separation in manure handling systems.* Retrieved from http://www.extension.org/pages/27470/solids-separation-in-swine-manure-handling-systems#.UpYpTaso7mI

National Farm Stewardship Program. (2006). *Beneficial management practices descriptions*. Ottawa, ON: Agriculture and Agri-Food Canada.

Oleweiler, N., et al. (2004). *The value of natural capital in settled areas of Canada.* Ducks Unlimited & The Nature Conservancy of Canada. Retrieved from http://www.cmnbc.ca/sites/default/files/natural%2520capital_0.pdf

Suess, A., W. Haider, R. Trenholm. (2012). *Socio-Economic and Environmental Assessment of Beneficial Management Practices.* Abbotsford, BC: BC Ministry of Agriculture. Retrieved from: http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/AGRI_BMP_Report_FINAL.pdf

Kitchen, A., P. Kitchen, R. Trenholm. (2013). *Socio-Economic and Environmental Evaluation of Beneficial Management Practices.* Abbotsford, BC: BC Ministry of Agriculture. Retrieved from: http://www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/SocioEconomic_&_Environmental_Review_of_BMPs_2012.pdf

Statistics Canada. (2012). Farm operator data tables. Retrieved, 2012, from http://www29.statcan.gc.ca.proxy.lib.sfu.ca/ceag-web/eng/index-index;jsessionid=E2C5006284CAF869F729BEF1DED5D6E2

Treasury Board of Canada Secretariat. (2007). *Canadian cost-benefit analysis guide*. Ottawa, Ontario:

Treasury Board of Canada Secretariat. (2012). Policy on evaluation. Retrieved from

http://www.tbs-sct.gc.ca.proxy.lib.sfu.ca/pol/doc-eng.aspx?section=text&id=15024

II. Manure Sampling Methods and Results

At twenty sites, samples were collected using methods outlined in the *Manure Sampling and Analysis for Nutrient Management – Nutrient Management Factsheet - No. 5 in Series (Revised September 2010, Order Reference No. . 631-500-3).*
At most sites three samples were obtained:

- Liquid manure before entering the separator;
- Solid manure leaving the separator; and
- Liquid manure leaving the separator.

On two occasions the third sample could not be obtained due to physical challenges in collecting the sample (manure in the pit was too deep to reach). At sites with a sand lane a fourth sample (sand) was also collected. A summary of liquid and solid manure collection is provided below.

Liquid manure collection

- A long PVC pipe fitted with a stopper was lowered into the manure pit.
- Most pits had recently been agitated, however if a crust was visible on the top layer or if the pit had not been agitated then the pipe was used to mix the manure before a sample was obtained.
- The pipe was lifted from the pit and the sample was emptied into a plastic pail. This process was repeated two to three times until about 2 L of sample was collected.
- A funnel was used to pour a subsample of about 750 ml into a 1 L screwtop plastic container.
- The container was labeled and placed on ice in a cooler.

Solid manure collection

- A small shovel (trowel) was used to collect 3 to 4 subsamples of fresh solid manure from the pile of solids created by the separator.
- The surface was scraped away so that dry and weathered material was avoided.
- The material was placed into a plastic pail, mixed, and a subsample of about 750 ml was transferred into a 1 L plastic screwtop container.
- The container was labeled and placed on ice in a cooler.

Shipping to the Lab

- All samples were stored on ice in a cooler for a maximum of 30 hours.
- The date, time, manure type, and farm location was recorded in a sample submission form upon delivery at the laboratory.
- Upon arrival the temperature of the samples was measured to ensure that they had been stored at an appropriate temperature.

Laboratory Analysis

- The liquid and solid samples were all analyzed by A & L Canada Laboratories Inc. (subcontracted by Exova Laboratories) for the following parameters:

Parameter	Unit	Detection Limit	Method Reference
Dry matter	%	0.10	Gravimetric
Total Potassium	%	0.01	Inductively Coupled Plasma (ICP)
Total Phosphorus	%	0.01	Inductively Coupled Plasma (ICP)
Ammonium (NH4-N)	ug/ml	0.10	Colourimetric
Total Organic Nitrogen	%	0.10	Combustion
Total Nitrogen	%	0.10	Combustion
pH		N/A	pH meter
Fecal coliform	Most probable number (MPN/ml)	N/A	MFHPB-19 accredited test

The extraction method for Total Phosphorus and Total Potassium is based on EPA Method 3050B as follows:

- The dried, ground sample is weighed into a digestion vessel where hydrochloric and nitric acid are added.
- It is digested for 2 hours at 95 C^o then made up to volume with deionized water, shaken and filtered.
- It is submitted for analysis by ICP-OES.

Municipality or Local Area	Sample ID	Dry matter %	pH	Total N		NH4-N		Total Organic N		P (total)		K (total)		Fecal coliform	
				%		ug/g		%		%		%		MPN/g dry	
				dry	as received	dry	as received	dry	as received	dry	as received	dry	as received	dry	as received
Rosedale	01A	6.0	7.0	3.83	0.23	13198	791	2.51	0.15	0.89	0.05	4.54	0.27	0	>1000
	01B	33.9	8.4	1.59	0.54	1738	590	1.42	0.48	0.40	0.14	0.73	0.25	0	>1000
	01C	3.6	7.2	6.47	0.23	20526	741	4.42	0.16	1.47	0.05	6.60	0.24	0	>1000
Chilliwack	02A	2.7	7.1	6.56	0.18	25113	671	4.05	0.11	1.25	0.03	5.48	0.15	0	>1000
	02B	4.0	6.9	4.86	0.19	16644	657	3.20	0.13	1.10	0.04	2.61	0.10	0	>1000
	02C	19.5	7.6	1.36	0.26	1709	333	1.19	0.23	0.17	0.03	0.73	0.14	0	>1000
Chilliwack	03A	3.7	7.5	6.09	0.22	28293	1033	3.26	0.12	1.50	0.05	8.47	0.31	0	>1000
	03B	41.2	8.7	1.89	0.78	1716	707	1.72	0.71	0.85	0.35	1.05	0.43	549	226
	03C	9.7	7.4	3.37	0.33	11534	1121	2.22	0.22	1.60	0.16	3.53	0.34	0	>1000
Chilliwack	04A	3.6	7.6	6.81	0.24	36695	1303	3.14	0.11	1.20	0.04	8.68	0.31	0	>1000
	04B	37.5	8.7	1.33	0.50	1036	388	1.23	0.46	0.26	0.10	0.76	0.28	0	<3
Abbotsford	05A	6.7	7.0	4.77	0.32	21709	1463	2.60	0.18	1.05	0.07	3.94	0.27	0	>1000
	05B	37.0	8.6	1.58	0.59	1548	574	1.43	0.53	0.26	0.10	0.62	0.23	0	>1000
Abbotsford	06A	5.5	6.4	4.00	0.22	17255	949	2.27	0.12	0.73	0.04	3.05	0.17	0	>1000
	06B	38.3	7.3	1.38	0.53	577	221	1.38	0.53	0.19	0.07	0.52	0.20	640	245
	06C	0.6	10.1	8.10	BDL	47000	282	3.39	BDL	1.60	BDL	7.71	0.05	0	>1000
Abbotsford	07A	1.7	6.6	6.56	0.11	33235	565	3.24	BDL	1.37	0.02	7.30	0.12	0	>1000
	07B	15.3	8.0	1.59	0.24	1712	262	1.42	0.22	2.29	0.35	0.85	0.13	0	>1000
	07C	92.2	7.9	BDL	BDL	1	1	BDL	BDL	0.07	0.06	0.14	0.13	542	500
	07D	1.9	10.1	5.43	0.10	26368	501	2.79	BDL	1.58	0.03	6.42	0.12	0	>1000
Abbotsford	08A	5.8	8.9	3.73	0.22	16034	930	2.13	0.12	0.89	0.05	3.21	0.19	0	>1000
	08B	34.1	7.8	1.76	0.60	1460	498	1.61	0.55	0.59	0.20	0.68	0.23	2067	705
	08C	3.2	9.5	6.06	0.19	33531	1073	2.71	BDL	1.11	0.04	6.71	0.21	0	>1000

Municipality or Local Area	Sample ID	Dry matter %	pH	Total N		NH4-N		Total Organic N		P (total)		K (total)		Fecal coliform	
				%		ug/g		%		%		%		MPN/g dry	
				dry	as received	dry	as received	dry	as received	dry	as received	dry	as received	dry	as received
Chilliwack	09A	9.7	6.4	3.79	0.37	17227	1671	2.07	0.20	0.54	0.05	3.23	0.31	0	>1000
	09B	5.0	6.4	7.17	0.36	35840	1792	3.59	0.18	1.08	0.05	4.98	0.25	0	>1000
	09C	38.7	8.4	1.47	0.57	406	157	1.43	0.55	0.30	0.12	0.82	0.32	21	8
Chilliwack	10A	4.0	7.1	4.21	0.17	19100	764	2.30	BDL	0.75	0.03	3.25	0.13	0	>1000
	10B	31.7	8.6	1.70	0.54	3	1	1.70	0.54	0.27	0.09	1.04	0.33	0	>1000
	10C	3.4	6.5	6.35	0.22	35029	1191	2.85	BDL	1.16	0.04	5.30	0.18	0	>1000
Langley	11A	5.0	8.4	4.42	0.22	19760	988	2.44	0.12	0.78	0.04	2.97	0.15	0	>1000
	11B	32.2	8.0	1.77	0.57	1823	587	1.59	0.51	0.43	0.14	0.48	0.15	0	<3
	11C	2.3	9.7	7.30	0.17	41000	943	3.20	BDL	1.10	0.03	7.08	0.16	0	>1000
Abbotsford	12A	5.8	8.0	4.91	0.28	24569	1425	2.45	0.14	0.70	0.04	4.63	0.27	0	>1000
	12B	15.2	9.8	1.91	0.29	5125	779	1.40	0.21	0.36	0.05	2.79	0.42	0	>1000
	12C	3.4	8.7	5.19	0.18	26147	889	2.57	BDL	1.07	0.04	6.46	0.22	0	>1000
Deroche	13A	0.8	7.2	7.99	BDL	40875	327	3.90	BDL	1.55	0.01	6.24	0.05	0	>1000
	13B	22.1	7.6	1.21	0.27	570	126	1.15	0.25	0.22	0.05	0.65	0.14	0	>1000
	13C	1.4	7.3	6.19	BDL	28929	405	3.29	BDL	1.35	0.02	6.13	0.09	0	>1000
Deroche	14A	1.6	7.4	7.38	0.12	39063	625	3.47	BDL	1.36	0.02	3.84	0.06	0	>1000
	14B	16.9	6.3	1.47	0.25	2047	346	1.27	0.21	0.20	0.03	0.55	0.09	0	>1000
	14C	2.4	7.5	4.99	0.12	20167	484	2.97	BDL	1.56	0.04	2.44	0.06	0	>1000
Agassiz	15A	6.4	6.9	3.83	0.25	15656	1002	2.26	0.14	0.74	0.05	3.86	0.25	0	>1000
	15B	43.0	8.3	1.35	0.58	407	175	1.31	0.56	0.23	0.10	0.59	0.25	0	<3
	15C	2.7	7.4	6.61	0.18	37815	1021	2.83	BDL	1.14	0.03	8.07	0.22	0	>1000
Agassiz	16A	8.1	7.3	3.62	0.29	16296	1320	1.99	0.16	0.48	0.04	3.73	0.30	0	>1000
	16B	28.3	7.8	1.46	0.41	2541	719	1.21	0.34	0.19	0.05	1.02	0.29	0	>1000
	16C	4.0	7.4	6.59	0.26	35950	1438	2.99	0.12	0.90	0.04	7.71	0.31	0	>1000

Municipality or Local Area	Sample ID	Dry matter %	pH	Total N		NH4-N		Total Organic N		P (total)		K (total)		Fecal coliform	
				%		ug/g		%		%		%		MPN/g dry	
				dry	as received	dry	as received	dry	as received	dry	as received	dry	as received	dry	as received
Rosedale	17A	0.7	7.6	10.43	BDL	70714	495	3.35	BDL	1.82	0.01	20.93	0.15	0	>1000
	17B	23.4	6.9	0.95	0.22	1094	256	0.84	0.20	0.14	0.03	0.54	0.13	0	>1000
	17C	0.8	7.5	10.50	BDL	71625	573	3.33	BDL	1.09	BDL	11.49	0.09	0	>1000
Rosedale	18A	10.1	7.2	3.71	0.37	13624	1376	2.35	0.24	0.60	0.06	3.29	0.33	0	>1000
	18B	32.2	8.1	1.60	0.52	2606	839	1.34	0.43	0.26	0.08	0.70	0.23	90	29
Delta	19A	1.6	7.3	6.89	0.11	26920	431	4.20	BDL	1.03	0.02	7.62	0.12	0	>1000
	19B	16.4	6.7	1.08	0.18	2058	338	0.87	0.14	0.22	0.04	0.95	0.16	0	>1000
	19C	1.3	7.3	8.21	0.11	44721	581	3.74	BDL	1.25	0.02	10.29	0.13	0	>1000
	19D	20.8	8.1	0.86	0.18	2209	1751	0.64	0.13	0.18	0.04	0.88	0.18	0	>1000
Surrey	20A	5.6	6.9	5.06	0.28	22323	1250	2.82	0.16	0.67	0.04	3.99	0.22	0	>1000
	20B	35.8	5.8	0.96	0.34	1375	492	0.82	0.29	0.15	0.05	0.75	0.27	0	>1000
	20C	2.5	7.6	6.84	0.17	37838	946	3.05	BDL	1.02	0.03	5.14	0.13	0	>1000

III. Extended Summary of Jurisdictional Review

We reviewed five jurisdictions including Washington, Idaho, Alberta, Manitoba, and Ontario. In each jurisdiction at least one industry expert was interviewed over the phone. Industry experts included government staff, equipment suppliers as well as industry spokespeople. For each jurisdiction, we looked at uptake of solid/liquid separation and bedding recovery systems and the primary motivations and barriers for the adoption of each technology.

Uptake of solid/liquid separation was highest in Washington and Idaho and lowest in Alberta, Manitoba, and Ontario. Across jurisdictions, producers were motivated to adopt solid/liquid manure separation to better manage nutrients on farm, earn additional revenue from selling separated solids, and to better manage manure volumes. Additionally, adoption is more common at larger dairies. Common barriers across jurisdictions include financial cost of the system and the additional time, attention, and maintenance required by the system. Additionally, solid liquid manure separation is less common on small dairies with lower revenues.

Uptake of bedding recovery systems has been relatively high in Washington and Idaho and relatively low in the Canadian jurisdictions of Alberta, Manitoba and Ontario. Primary motivations for uptake include a desire to increase manure storage capacity, decrease bedding costs, and earn revenue on manure by-products. Common barriers include financial cost, limited applicability of system to specific farm operation, additional maintenance and time associated with the system, and access to inexpensive bedding alternatives.

Washington

The dairy landscape in Washington can be divided into Eastern Washington, which exists in dry, semi-arid climate and Western Washington, which shares a similar climate to the Fraser Valley with high annual precipitation.

Western Washington

System	Uptake	Notes
Solid Liquid Manure Separation	30% of cows 30% of dairies	Western Washington has approximately 350 dairies and 100,000 milking cows. Therefore, dairies are considerably smaller than those in Eastern Washington
Bedding Recovery Systems	33% in Whatcom County 10%-20% elsewhere in Western Washington	

Solid/Liquid Separation

Motivating Factors/Opportunities

- Manure storage capacity;
  - Producers use the separation technology to reduce manure volumes in lagoon effectively increasing liquid storage capacity.
- Additional tool for manure management;
  - Separated solid manure can be higher in Phosphorous and separated liquid manure can be higher in Nitrogen. As a result, producers can more accurately target nutrients. Additionally, the liquid manure stream is easier to pump and apply in a drag line system.
- Systems are more affordable for larger dairies; and,
  - Generally speaking, larger dairies are better able to justify the financial cost of the system.
- Federal cost-share programs.
  - Programs are available which can cover the majority of costs for a separator, pumps, and a storage building.

Deterring Factors/ Barriers

- Financial cost of system;
  - Producers are deterred by the financial cost of the system, especially for smaller dairies common to Western Washington.
- Additional time and maintenance;
  - More maintenance associated with adding the new component to the manure management system on-farm.

Bedding Recovery Systems

Motivating Factors/Opportunities

- Bedding savings;
  - With the production of bedding on-farm, producers reduce bedding costs.
- Opportunity to sell bedding and other composted products off-farm; and,
- Opportunity to process other dairy farms' solid manure.

Deterring Factors

- Financial cost of system;
  - Producers are deterred by the financial cost of the system, especially for smaller dairies common to Western Washington.
- Additional time and maintenance; and,
  - More maintenance associated with adding the new component to the manure management system on-farm.
- Unsuitable bedding material.
  - Existing bedding materials may not be suitable for a bedding recovery system.

Eastern Washington

System	Uptake	Notes
Solid Liquid Manure Separation	90% of cows 50% of dairies	There are approximately 75 dairies in Eastern Washington and they are concentrated in the Yakima Valley. 70% milk over 700 animals. Dairies are larger in Eastern Washington compared to Western Washington
Bedding Recovery Systems	<5%	Manure is generally row composted due to limited precipitation.

Solid/Liquid Separators

Motivating Factors/Opportunities

- Manure storage capacity;
    - Producers use the separation technology to reduce manure volumes in pits/lagoons effectively increasing liquid storage capacity.
- Additional tool for manure management;
    - Separated solid manure can be higher in Phosphorous and separated liquid manure can be higher in Nitrogen. As a result, producers can more accurately target nutrients. Additionally, the liquid manure stream is easier to pump and apply in a drag line system.
- Nutrient concentrations in groundwater;
    - Manure separation has been repurposed as a means of generating a solid component that can be shipped out of the Yakima Valley. Manure separation allows the producer to ship a portion of nutrients off-farm to reduce potential for nutrient concentrations.
- Off-farm sales of separated solids;
    - Producers can sell a composted product or sell the separated solids to compost facility that processes (composts) manure and sells the finished product as a soil amendment.
- Affordability of system for larger dairies; and,
- Federal cost-share programs.
    - Programs are available which can cover majority of separator, pumps, and storage building.

Deterring Factors/Barriers

- Financial cost of system;

    - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Additional time and maintenance; and,
    - More maintenance associated with adding the new component to the manure management system on-farm.

Bedding Recovery Systems

Motivating Factors/Opportunities

- Bedding savings;
    - With the production of bedding on-farm, producers reduce bedding costs.

Deterring Factors/Barriers

- Financial cost of system;
    - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Additional time and maintenance; and,
    - More maintenance associated with adding the new component to the manure management system on-farm.
- Existing bedding materials may not be suitable for a bedding recovery system;
- Separated solids sales; and,
    - Some producers find it more economical to sell solids to compost facility or row compost manure on-farm and sell composted product versus installing an in-vessel composter.
- Row composting.
    - Given the dry climate in Eastern Washington, row composting is an alternative to in-vessel composter.

Ontario

System	Uptake	Notes
Solid Liquid Manure Separation	<5% of dairies	
Bedding Recovery Systems	1.5% of dairies	~60 bedding recovery systems (30 in-vessel/drum composters, 20 dairy anaerobic digesters with separation component, 10 green bedding systems)

Solid Liquid Manure Separation

Motivating Factors/ Opportunities

- Additional tool for manure management;
    - Separated solid manure can be higher in Phosphorous and separated liquid manure can be higher in Nitrogen. As a result, producers can more accurately target nutrients. Additionally, the liquid manure stream is easier to pump and apply in a drag line system.
- Intention to install bedding recovery system;

- In many cases in Ontario, dairy farms install separators because they are planning to implement a bedding recovery system on their farm that requires separation (i.e. composters, anaerobic digesters, green bedding)
- Anaerobic Digester Incentive Program;
    - The program has increased uptake of digesters and producers have installed separators to process digestate for sale or use as bedding.

Deterring Factors/ Barriers

- Additional component to manure management system;
    - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it.
- Different agricultural conditions;
    - Ontario dairies face different conditions, such as more land and less rainfall relative to BC, which may make manure separation less appropriate/necessary. Thus, they do not have the same challenges around manure storage capacity. Some Ontario dairies are also not interested in using manure separation as a component of nutrient management.
- Financial cost of system;
    - Producers are deterred by the financial cost of the system, especially for smaller dairies which are common in Ontario.
- Financial cost of transporting manure;
    - While separated solids are valuable, transporting solids can be expensive which in some cases can outweigh the benefits of selling separated solids as a compost or soil amendment.

Bedding Recovery Systems

Motivating Factors/ Opportunities

- Source of reliable, inorganic bedding;
    - For dairies that do not want to use sand, bedding recovery systems are viewed as a good alternative that provide a renewable source of inorganic bedding.
- Additional tool for manure management;
    - Separated solid manure can be higher in Phosphorous and separated liquid manure can be higher in Nitrogen. As a result, producers can more accurately target nutrients. Additionally, the liquid manure stream is easier to pump and apply in a drag line system.
- Bedding savings;
    - With the production of bedding on-farm, producers reduce bedding costs.
- Anaerobic Digester Incentive Program;
    - The program has increased uptake of digesters and producers have installed separators to process digestate for sale or use as bedding.

Deterring Factors/ Barriers

- Additional component to manure management system;
    - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it.
- Availability of sand as an inexpensive bedding option;
    - Sand is an affordable, readily available source of bedding materials in Ontario and many dairies do not want to switch to a different bedding material. Many larger dairies that could possibly afford the system use sand bedding and are hesitant to switch.
- Financial cost of system;
    - Producers are deterred by the financial cost of the system, especially for smaller dairies which are common in Ontario.
- Additional component to manure management system;
    - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it.
- Dispersion of Ontario dairies;
    - Ontario dairies are relative dispersed and so the option of one dairy processing a number of farms manure, thus making a system more economical for a farm, is limited.
- Existing tie-stall dairies;
    - There are a large number of older, tie-stall dairies with small herds where a bedding recovery system is not economical.
- Incentive programs;
    - The BMP program has had limited uptake most likely due to existing barriers in Ontario, notably cost of installing and operating system on small dairies.
- Animal health concerns;
    - Some producers in Ontario have had mixed experiences with animal health as a result of using bedding from a bedding recovery system.

Alberta

System	Uptake	Notes
Solid Liquid Separation	<5% of dairies	Alberta has ~600 dairies
Bedding Recovery Systems	1% of dairies	

Solid Liquid Manure Separation

Motivating Factors/ Opportunities

- Sand reclamation;
    - A couple of dairies have sand bedding systems and wanted to reclaim sand due to the high cost of sand in Alberta.
- Additional tool for manure management;
    - Separated solid manure can be higher in Phosphorous and separated liquid manure can be higher in Nitrogen. As a result, producers can more

accurately target nutrients. Additionally, the liquid manure stream is easier to pump and apply in a drag line system.

- Off-farm sales of separated solids;
  - Producers can sell a composted product or sell the separated solids to a compost facility that processes (composts) manure and sells the finished product as a soil amendment.
- Emergence of bedding recovery technologies;
  - There has been more interest in manure separation in the past few years due to the emergence of bedding recovery technologies.
- Proximity to urban areas.
  - Producers facing challenges such as close proximity to urban centers have looked at system to reduce nuisance issues (i.e. odour).

Deterring Factors/ Barriers

- Financial cost of system;
  - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Limited perceived need for systems;
  - There is a limited need for manure separation as part of Alberta producers' manure management system. Dairies are less concentrated and there is a large land mass on which to apply manure. Furthermore, manure application technologies (mostly broadcast to date) can handle slurry.
- Additional component to manure management system;
  - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it. Producers are not willing to dedicate time and attention to learn and operate new system.

Bedding Recovery Systems

Motivating Factors/ Opportunities

- Cost effective alternative to bedding;
  - Bedding costs including the cost of transporting bedding materials such as woodchips are high and producers are looking for cost-effective alternatives.
- Off-farm sales of separated solids;
  - Producers can sell a composted product or sell the separated solids to a compost facility that processes (composts) manure and sells the finished product as a soil amendment.

Deterring Factors/ Barriers

- Financial cost of system;
  - Producers are deterred by the financial cost of the system.
- Additional component to manure management system;

    - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it. Producers are not willing to dedicate time and attention to learn and operate new system.

Manitoba

System	Uptake	Notes
Solid Liquid Separation	<5%	
Bedding Recovery Systems	<1%	

Solid Liquid Manure Separation

Motivating Factors/ Opportunities

- Manure storage
    - Producers increased manure storage liquid capacity to comply with winter spreading restriction.

Deterring Factors/ Barriers

- Financial cost of system;
    - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Availability of straw as an inexpensive bedding option;
    - Straw is an affordable, readily available source of bedding materials in Manitoba and many dairies do not want to switch to a different bedding material.
- No land base constraint;
    - There is a large land base to spread on so manure management is not constrained by land base.

Bedding Recovery Systems

Motivating Factors/ Opportunities

- Manure storage capacity;
    - Producers use the separation technology as part of overall manure management system to extend manure storage by increasing liquid capacity to comply with winter spreading restriction.

Deterring Factors/ Barriers

- Financial cost of system;
    - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Availability of straw as an inexpensive bedding option;
    - Straw is an affordable, readily available source of bedding material in Manitoba (~$40/ton currently) and many dairies do not want to switch to a

different bedding material. Thus, bedding recovery systems are less attractive/competitive.

Idaho

System	Uptake	Notes
Solid Liquid Separation	50% of dairies	Mainly screen separators which require less maintenance compared to compress and screw press separators.
Bedding Recovery Systems	20% of dairies	Approximately all 100 in-barn dairies in Idaho. The remaining dairies are open-lot dairies.

Solid Liquid Manure Separation

Motivating Factors/ Opportunities

- Reduce solids in lagoons;
  - Primary reason is to reduce amount of solids in lagoons. Most dairies are irrigated and the lagoon water is pumped through irrigation system. Separated liquids are more easily pumped than slurry.

Deterring Factors/ Barriers

- Financial cost of system;
  - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- Not appropriate for open-lot dairies;
  - Solid/liquid separation equipment is not applicable to open-lot dairies in most cases, which are common in Idaho, due to infrequent manure collection and minimal use of bedding.
- No funding/incentive programs available;
- Additional component to manure management system;
  - Solid/liquid separation adds an additional component to a farm's manure management system and some producers are comfortable with their existing system and are hesitant to change it. Producers are not willing to dedicate time and attention to learn and operate new system.

Bedding Recovery Systems

Motivating Factors/ Opportunities

- Larger dairies can afford systems;

  - Many Idaho dairies are larger (6,000 to 10,000 cows) and the economics of bedding recovery are favorable relative to the cost of bedding (mainly straw).
- Existing separators;
  - Many dairies have separators to avoid loading lagoons with solids and so bedding recovery from solids is a logical next step.

Deterring Factors/ Barriers

- Limited rainfall making row composting possible;
  - Due to limited rainfall (9 inches annually), dairies can row compost solid manure for bedding which is cheaper than in-vessel drum composting.
- Limited need for bedding recovery in open-lot dairies;
  - Open-lot dairies do not use large amounts of bedding and thus a bedding recovery system is not as applicable to open-lot as it is to in-barn dairies.
- Financial cost of system;
  - Producers are deterred by the financial cost of the system, especially for smaller dairies.
- No funding/incentive programs available.

IV. Data Sources for Benefits and Costs Used in the Cost-Benefit Analysis

- All values are per farm (or per farm per year)
- Negative cost indicates a benefit.
- All values are in 2013 Canadian dollars.
- Values were calculated based on the average value per producer who implemented a *Manure Treatment BMP* between 2009 – 2012.

Values and Data Sources for Manure Treatment BMP – All Projects (0201)

BMP	Impact	Amount	Source
Benefits	Reduction in Nutrient Loss (N + P)	N/A	
Costs	Infrastructure:		
	Provided by the EFP	$34,756.04	ARDCorp
	program	$140,822.80	ARDCorp
	Provided by the farmer	$40,661.29	Survey
	Additional infrastructure cost		
	Repair/Maintenance	$6,871.09 per year	Survey
	Operational Costs	$4,145.63 per year	Survey
	Maintenance Labour	$771.51 per year	Survey
	Fertilizer Costs	-$2,166.67 per year	Survey
	Bedding Costs	-$29,538.10 per year	Survey
	Manure application costs	-$2,600 per year	Survey
	Manure application labour	-$1,296 per year	Survey
	costs	-$1,586.96 per year	Survey
	Bedding sales	NA	
	Crop yield changes	-$217.39 per year	Survey
	Animal health costs		

Table Values and Data Sources for Manure Treatment BMP – Solid/Liquid Separation (0201)

BMP	Impact	Amount	Source
Benefits	Reduction in Nutrient Loss (N + P)	N/A	
Costs	Infrastructure:		
	Provided by the EFP program	$26,466.73	ARDCorp
	Provided by the farmer	$86,065.01	ARDCorp
	Additional infrastructure cost	$42,555.56	Survey
	Repair/Maintenance	$7,422.86 per year	Survey
	Operational Costs	$3,080.00 per year	Survey
	Maintenance Labour	$2,684.25 per year	Survey
	Fertilizer Costs	-$10,000 per year	Survey
	Bedding Costs	-$21,800 per year	Survey
	Manure application costs	-$2,500 per year	
	Manure application labour	N/A	
	costs	-$1,714.29 per year	Survey
	Bedding sales	N/A	
	Crop yield changes	N/A	
	Animal health costs		

Values and Data Sources for Manure Treatment – Bedding Recovery Systems (0201)

BMP	Impact	Amount	Source
Benefits	Reduction in Nutrient Loss (N + P)	N/A	
Costs	Infrastructure:		
	Provided by the EFP program	$38,382.62	ARDCorp
	Provided by the farmer	$164,779.333	ARDCorp
	Additional infrastructure cost	$34,886.36	Survey
	Repair/Maintenance	$6,601.48 per year	Survey
	Operational Costs	$4,500.83 per year	Survey
	Maintenance Labour	-$253.33 per year	Survey
	Fertilizer Costs	-$600 per year	Survey
	Bedding Costs	-$33,407.14 per year	Survey
	Manure application costs	-$2,666.67	Survey
	Manure application labour	-$1,296	Survey
	costs	-$1,633.33	Survey
	Bedding sales	NA	
	Crop yield changes	-$333.33	Survey
	Animal health costs		

V. Cost-Benefit Analysis Assumptions and Limitations

Key Assumptions

1. We assumed that the initial infrastructure costs occurred in the first time period and that annual benefits and costs started to occur in the following time period.

2. We assumed that the annual benefits and costs were constant throughout the life of each program. This may not be the case. For example, maintenance and labour costs may increase over the life of a BMP as infrastructure may begin to deteriorate at a faster rate.

3. We assumed that the baseline and BMP scenarios were not impacted by changes in key variables (e.g. population or technological changes). We did not complete a detailed forecast of the baseline or scenario.

4. We assumed that enrolment in the BMP programs would not change from current levels when completing the cost-benefit analysis over the program's lifetime.

5. We assumed that transitional and government regulatory costs were zero. In the case of transitional costs it is likely safe to assume that they are "small and can be ignored"[34]. However, government regulatory costs are likely not zero (e.g. administration costs associated with the EFP Program). However, we did not have any information on these costs.

6. We assumed that the information obtained from the survey and ARDCorp used to determine benefits and costs was representative of the larger population of BMP adopters. For example, average maintenance costs calculated from survey responses were applied to the population of BMP adopters.

Key Limitations

1. We could not quantify all of the benefits or costs. There may be other benefits of this BMP that we're not assessed. For example, a change in nutrient uptake by crops could not be calculated because of inadequate data.

2. We were not able to complete a rigorous analysis of the impacts of the BMP on the environment on or near each farm. This is especially difficult to complete for a program such as the Environmental Farm Plan since agricultural producers are distributed throughout the province. This makes monitoring difficult as information on the change in environmental characteristics such as soil erosion or water quality is difficult and costly to obtain. An additional complication is that it may be difficult to link changes in management practices to any changes observed in the environment. A further issue is that the environmental impacts of management practices on one farm may be negligible, but cumulative impacts of implementing BMPs on many farms may be substantial.

[34] Treasury Board of Canada Secretariat. (2007). Canadian Cost-Benefit Analysis Guide: Regulatory Proposals. Ottawa, ON: Government of Canada. Retrieved on January 22, 2012 from: http://www.tbs-sct.gc.ca/ri-qr/documents/gl-ld/analys/analys00-eng.asp

3. We did not complete a dynamic risk assessment that linked into the CBA.

4. We did not complete a detailed stakeholder impact analysis.