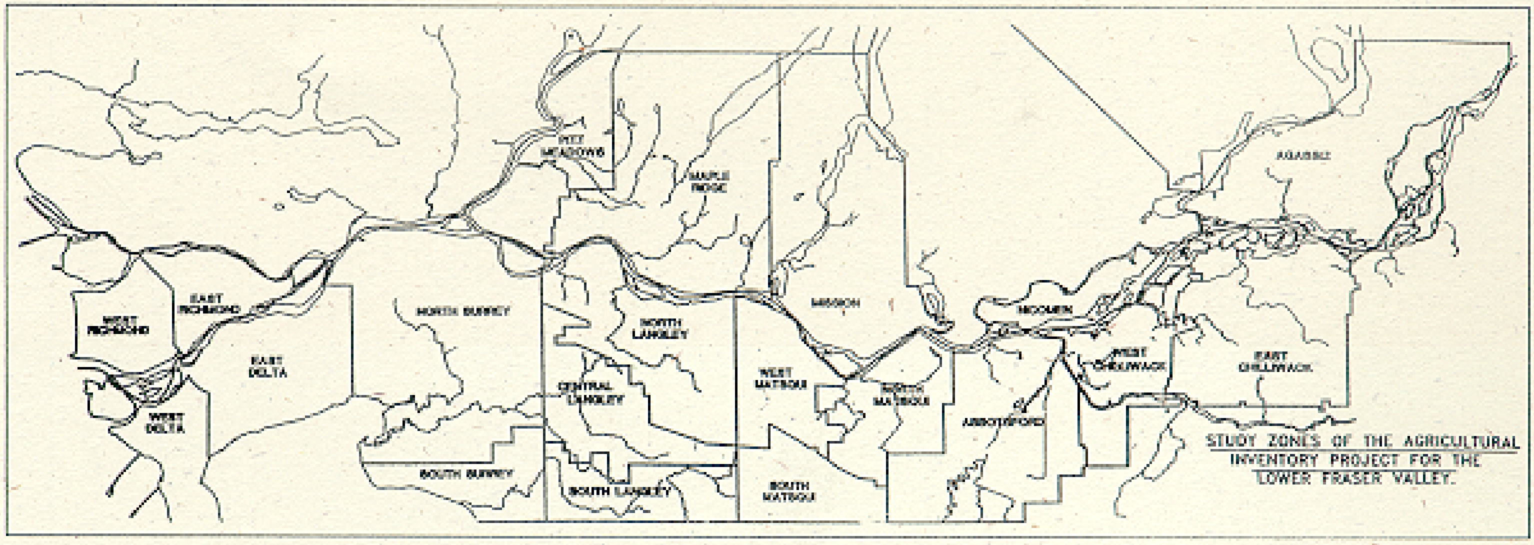
A LITERATURE REVIEW
of the
ECONOMICS OF MANURE MANAGEMENT OPTIONS IN THE LOWER FRASER VALLEY



Component Project
of
Management of Livestock and Poultry Manures in the Lower Fraser Valley

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Ministry of Environment, Lands and Parks

Ministry of Agriculture, Fisheries and Food

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Prepared for:

BC Ministry of Environment, Lands and Parks

Environment Canada
Fraser River Action Plan

BC Ministry of Agriculture, Fisheries and Food

Fisheries and Oceans
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EXECUTIVE SUMMARY

Changes in land use in parts of the Lower Fraser Valley over the last 25 years have contributed to increased environmental problems associated with excess application to land of livestock and poultry manure. The resulting contamination of water, soil, and air is currently being studied under the lead of the Ministry of Environment, Lands & Parks in a project entitled "The Management of Livestock and Poultry Manures in the Lower Fraser Valley." The present report reviews the existing literature regarding the costs and benefits of some alternative management practices.

This report surveyed the literature covering both the private and the social costs of manure-management options. The social costs of manure management options include the costs to society from manure contamination of the environment and comprise the increased health care costs and lost human productivity due to deterioration in human health, threats to the financial viability of commercial and aboriginal fisheries, the loss in value to anglers, recreationalists, and the public due to reduced fish stocks and wildlife, and the eventual losses to farmers from contaminated water and loss in soil productivity. Although the qualitative nature of some of these costs makes them difficult to estimate, the studies cited in this review indicate that the social costs of the status quo are likely substantial. These social costs suggest that although the short-term financial implications of some nutrient management options may not warrant their use on an individual farm basis, if the broader social costs are accounted for, it may be beneficial to society to find effective methods to implement these options. In the long-term, the financial viability of farming in the area may be harmed by continued degradation of the resource base; management options that are friendly to the environment as well as the farmer's financial situation are clearly the most desirable solutions.

The studies of the private costs of manure-management options reviewed here suggest that there is no single "magic-bullet" solution. The financial feasibility of the different options varies not only by farm type, but also by farm size and the availability of crop land. Furthermore, the financial feasibility of various options must be considered in conjunction with the reductions in contamination that result.

There are two basic problems associated with manure management in the Fraser Valley. The first problem is poor manure management at the farm level, e.g., inappropriate manure collection, storage, handling, and application. This problem can be addressed by better management for effective manure nutrient conservation. The second problem concerns the production of manure on farm units in excess of what can be taken up by crops. This results when farm operations import most of their feed, and hence nutrients, and do not have an adequate land base for the absorption of nutrients. Solutions to this problem include management of excess manure. Most of the studies reviewed in this report address the farm-unit excess situation, although some address the nutrient conservation issue as well.

Manure management presents an interesting paradox in that manure can be both a resource (as a source of nutrients for crops and a soil enhancer) and an environmental contaminant (as a contributor to the problems described above) depending on how it is managed. The primary management challenge is to maximize its use as a resource and

minimize its properties as a contaminant. Part of the challenge is to increase the number of farmers and potential end users who appreciate the value of manure as a resource.

Two information gaps can be identified in the literature that would be important to fill before any conclusions can be definitively drawn. First, although there is now a plethora of studies that estimate the social costs of contamination as well as studies that estimate the private costs of various options, only one study cited here (Athwal 1994) weighs the social benefits against the private costs of various options to determine if these benefits outweigh the costs. This must be addressed. Second, none of the studies reviewed here give the least cost method for achieving stated water quality standards or other environmental standards. Since it is becoming well established that the costs of current practices are high, finding cost-effective ways of managing excess manure or reducing the dependence on imported feed should be the next research question addressed in the literature. Innovative management options in which farmers and the environment both benefit must be explored.

RÉSUMÉ

Les changements dans l'utilisation des terres observés dans la vallée du bas Fraser au cours des 25 dernières années ont contribué à accroître les problèmes environnementaux liés à l'épandage en quantité excessive de fumier d'animaux d'élevage et de volaille. La contamination de l'eau, du sol et de l'air ainsi causée fait actuellement l'objet d'une étude réalisée sous la direction du ministère provincial de l'Environnement, des Terres et des Parcs intitulée *The Management of Livestock and Poultry Manures in the Lower Fraser Valley*. Dans le présent rapport, on examine la documentation existante concernant les coûts et les avantages de quelques méthodes de gestion de rechange.

Ce rapport passe en revue la documentation portant tant sur les coûts privés que sociaux des diverses mesures possibles de gestion du fumier. Les coûts sociaux de différentes options en matière de gestion du fumier comprennent les coûts pour la société découlant de la contamination de l'environnement par le fumier et englobent les coûts accrus pour les soins de santé et la diminution de la productivité humaine résultant de la détérioration de la santé chez l'homme, les menaces à la viabilité financière des pêches commerciales et autochtones, la perte de la valeur pour les pêcheurs sportifs, les amateurs de plein air et le public attribuable à la diminution des stocks de poisson et des populations fauniques ainsi que les pertes possibles pour les exploitants agricoles causées par l'eau contaminée et par la diminution de la productivité du sol. Étant donné la nature qualitative de certains de ces coûts, il est difficile d'en évaluer l'ampleur mais, d'après les études mentionnées dans cet examen, les coûts sociaux du *statu quo* sont probablement importants. Ces coûts sociaux laissent supposer que même si les avantages financiers à court terme de certaines mesures possibles de gestion des nutriments pourraient ne pas être suffisants pour justifier leur utilisation à l'échelon individuel dans les exploitations agricoles, si les coûts sociaux sur une échelle élargie sont pris en compte, il pourrait être avantageux pour la société de trouver des méthodes efficaces pour la mise en oeuvre des mesures en question. À long terme, la viabilité financière de l'agriculture dans le secteur

peut souffrir de la dégradation continue de la base de ressources; les méthodes de gestion qui sont respectueuses de l'environnement et qui tiennent compte de la situation financière de l'exploitant agricole constituent de toute évidence les solutions les plus souhaitables.

D'après les études portant sur les coûts privés des options en matière de gestion du fumier examinées dans ce rapport, il semble qu'il n'existe pas de solution «miracle» unique. Sur le plan financier, la faisabilité des différentes options varie non seulement suivant le type d'exploitation agricole mais aussi compte tenu de la superficie de la ferme et de la disponibilité des terres labourables. De plus, il faut examiner la faisabilité des diverses options tout en tenant compte de la diminution de la contamination résultant de leur mise en oeuvre.

Dans la vallée du Fraser, la gestion du fumier est liée à deux problèmes fondamentaux. Premièrement, il y a la mauvaise gestion du funier à la ferme, à savoir la collecte, l'entreposage, la manutention et l'épandage de façon inappropriée du fumier. Il est possible de régler ce problème grâce à une meilleure gestion de manière à assurer une conservation efficace des nutriments du fumier. L'autre problème touche à la production du fumier dans les fermes en quantité supérieure aux besoins des cultures. Ce problème se produit lorsque la majeure partie de l'alimentation animale, et donc les nutriments, provient de l'extérieur et que, de ce fait, l'exploitation agricole ne possède pas les terres nécessaires pour assurer l'absorption des nutriments contenus dans le fumier. Parmi les solutions à ce problème, mentionnons la gestion du fumier excédentaire. La plupart des études examinées dans ce rapport traitent du problème de la production en quantité excédentaire au niveau de l'exploitation agricole tandis que d'autres portent également sur la question de la conservation des nutriments.

La gestion du fumier présente un paradoxe intéressant du fait que le fumier peut être considéré à la fois comme une ressource (c'est-à-dire une source de nutriments pour les cultures et un produit qui enrichit le sol) et comme un contaminant de l'environnement (soit un produit qui contribue aux problèmes décrits ci-dessus), suivant la façon dont il est géré. Le principal défi de la gestion du fumier consiste à utiliser celui-ci le plus possible comme une ressource et à réduire au minimum ses propriétés de contaminant. Une partie du défi consiste à accroître le nombre d'exploitants agricoles et d'utilisateurs finaux possibles pour qui le fumier constitue une ressource valable.

On décèle deux lacunes au niveau de l'information contenue dans la documentation et il est important de combler celles-ci avant de pouvoir tirer des conclusions finales. D'abord, même s'il existe actuellement une foule d'études qui évaluent les coûts sociaux de la contamination et des études qui évaluent les coûts privés de diverses options, seulement une étude citée dans le rapport (Athwal, 1994) met en balance les avantages sociaux et les coûts privés de diverses options dans le but de déterminer si ces avantages dépassent les coûts. Il faut se pencher sur cette question. Deuxièmement, aucune des études examinées dans le rapport n'indique la méthode la moins coûteuse pour assurer le respect des normes établies en matière de qualité de l'eau ou d'autres normes environnementales. Puisque l'on reconnaît actuellement que les coûts des pratiques actuelles sont élevés, la documentation future devrait porter sur la recherche de méthodes rentables de gestion du fumier excédentaire ou de réduction de la dépendance face aux aliments pour animaux provenant de l'extérieur. Il faut explorer des méthodes de gestion innovatrices qui profitent tant aux exploitants agricoles qu'à l'environnement

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1. INTRODUCTION

Changes in land use in the Lower Fraser Valley over the last 25 years have contributed to increased environmental problems associated with the management of animal wastes. The resulting contamination of water, soil, and air is currently being studied under the lead of the Ministry of Environment, Lands & Parks in a project entitled “The Management of Livestock and Poultry Manures in the Lower Fraser Valley.” The present report reviews the existing literature regarding the costs and benefits of some management alternatives. The options discussed include maintaining current practices as well as implementing new management practices.

There are two basic problems associated with manure management in the Fraser Valley. The first problem is poor manure management at the farm level, e.g., inappropriate manure collection, storage, handling, and application. This problem can be addressed by better management for effective manure nutrient conservation. The second problem concerns the production of manure on farm units in excess of what can be taken up by crops. This results when farm operations import most of their feed, and hence nutrients, and do not have an adequate land base for the absorption of nutrients. Solutions to this problem include management of excess manure. Most of the studies reviewed in this report address the farm-unit excess situation, although some address the nutrient conservation issue as well.

This review first discusses some of the environmental problems and economic consequences of excessive manure applications to the land base. It then discusses the current economic environment and agricultural policies in the Lower Fraser Valley. This is followed by a presentation of the issues related to the economics of manure management options and a review of the existing literature on the estimates of the benefits and costs of those options. This includes estimates from other parts of the world that are dealing with the same issues, as well as estimates generated from the Lower Fraser Valley. Conclusions and other considerations are discussed in the final section.

The objective of the report is to gain insights from what has already been learned about the economics of manure management in order to develop a manure management strategy that maintains the financial viability of farms in the study region, while still addressing the issue of air, water, and soil pollution from animal wastes. The report is a preliminary step toward identifying the costs and benefits of the various options presented. It also identifies other potential mechanisms for dealing with this problem and information still needed. The report only addresses agriculture with the full understanding that other industries and practices also contribute to the environmental problems identified and that these other activities must also be dealt with.

2. ENVIRONMENTAL ISSUES

There are several potential human health and environmental problems associated with manure use in excess of the amount where crop nutrient requirements are met and with inappropriate manure management. These include nitrate contamination of drinking water (which has been linked to methaemoglobinaemia, or “blue baby syndrome”), pathogenic bacteria in drinking water, eutrophication of surface waters (which can lead to fish kills and habitat damage that causes long-term population impacts), fish kills due to toxic surface runoff, and high levels of atmospheric ammonia, which contribute to the formation of fine particulates and related respiratory problems. The specific contamination problems that result from current agricultural practices are discussed elsewhere (Brisbin and Runka

1995). The economic consequences of these problems include increased health care costs and lost human productivity due to deterioration in human health, threats to the financial viability of commercial fisheries, the loss in value to anglers, recreationalists, and the public due to reduced fish stocks, and the eventual losses to farmers from contaminated water, losses in soil productivity, and concentrations of nutrients in plants at levels that are toxic to humans. Although it is difficult to quantify the total of these costs, there has been some research done in this area. The results of these studies are reviewed below.

3. CURRENT ECONOMIC ENVIRONMENT AND AGRICULTURAL POLICIES IN THE LOWER FRASER VALLEY

Primary agriculture in British Columbia employs 29,000 people and contributes CAN$1.5 billion to the economy annually (1994 data). Primary fisheries and aquaculture in British Columbia employ 7,600 people and contributes CAN$0.54 billion to the economy annually (1994 data). British Columbians spent approximately $5 billion on food in 1992. This was approximately 14% of total expenditures and was comparable to expenditures on food in other provinces in Canada and most industrialized countries (Statistics Canada 1994, US Department of Commerce, 1995).

At the time of the 1991 Census of Agriculture, there were 3,587 small farms (defined as farms with annual gross farm receipts of less than $40,000) and 1,955 large farms (farms with annual gross farm receipts greater than $40,000) in the Lower Fraser Valley (Brisbin 1994). Furthermore, the Lower Fraser Valley is an important area of agricultural production. The 1991 Census of Agriculture estimates gross farm receipts in excess of $700 million per year and a total capital value of farm assets in excess of $3.5 billion for the area (data cited in Brisbin 1994).

While decisions that affect agricultural production have the potential to influence employment in the agricultural sector and prices that consumers must pay for food, it must also be remembered that practices in the agricultural sector can affect expenses in other sectors of the economy as well. For example, because agriculture affects fish stocks, consumers may pay more for fish than they would if the damage from agriculture were mitigated. Contamination of water and air may result in higher government health care expenditures, and reduced international competitiveness of the agricultural sector.

Dairy, egg, and poultry production in Canada are all currently under supply management; the amount a province may produce is determined by quota, farmers must have a license to produce, and the prices paid to farmers by the marketing boards are determined by industry average per-unit costs of production. The markets for other agricultural commodities are less regulated.

Supply management of dairy, egg, and poultry also controls the importation of competing products through the use of quantitative restrictions, although these restrictions are being converted to tariffs and will eventually be eliminated under the World Trade Organization rules on agriculture market access. Current tariffs and restrictions range from 5-15% for seafood to 180-300% for dairy and poultry products.

Tariffs of other commodities are lower than those under supply management, ranging from no tariffs on non-processed beef and hogs to 10-15% on fruits, vegetables, and processed meats. These tariffs are scheduled to decline to zero over the next decade. The prices for commodities not under supply management are determined by the North American market flows.

Without a general equilibrium model of the full effects of changes in manure management and the new trade rules, it is difficult to predict the consequences for producers and consumers of different manure management alternatives. This report considers only the direct effects to producers and consumers of various options.

The Code of Agricultural Practice for Waste Management in BC (hereafter referred to as "the Code") forbids the spreading of manure on land as a means of disposal. The Code provides an exemption if manure is applied as a fertilizer or soil conditioner and does not cause pollution (Agricultural Waste Control Regulation 1992). To this end, the Manure Management Strategy for the Lower Fraser Valley identifies high-risk periods for fall and winter spreading of manure. The Fisheries Act specifies that no deleterious substance[1] may be deposited in water frequented by fish. Although overall compliance with the Code and the Fisheries Act is desirable, it has not been achieved to date. For the purposes of this report, complete compliance with the Code and the Fisheries Act is considered the desired objective; non-compliance will be considered current practice, although the degree of compliance is improving.

4. ISSUES RELATED TO ECONOMICS

The Lower Fraser Valley has been broken into twenty Agricultural Waste Management zones (Brisbin 1994). An individual farm within a waste management zone may have inadequate nutrient management practices (for both manure and inorganic fertilizers) which result in excess nutrients and other contaminants entering the receiving environment from that farm. However, there may be no excess for the zone as a whole. On the other

[1] A deleterious substance is a substance that if added to water would degrade the quality of the water, or form part of a process of degradation of the water.

hand, there may be a surplus of nutrients in a zone due to high animal densities and the small land base on which to apply manure in that zone. The total amount of nutrients applied in a zone or on each farm, the form or source of nutrients, and how and when nutrients are applied all jointly affect the environmental consequences of manure management.

There are several difficulties that arise when trying to balance the need to reduce contamination of the environment from improper application of animal manure and the need to maintain the financial viability of the farm sector in British Columbia. According to the Waste Management Act, pollution is interpreted to mean the presence in the environment of substances or contaminants that substantially alter or impair the usefulness of the environment (Agricultural Waste Control Regulation 1992). However, substantial alteration or impaired usefulness does not arise until the pollutant reaches a certain threshold. This can be readily demonstrated under certain site-specific situations but is difficult to do on a broader regional basis. Nitrates occur naturally in the water, and become a human health problem only when nitrate levels become excessive. If nitrate levels in part of an aquifer are found to be higher than the established threshold, it may be difficult to identify the culprit farm(s) or other sources of contamination due to the non-point origin of the contamination and long delay before the consequences of groundwater contamination are experienced.

Environmental contamination problems result not only from agriculture, but also from municipal effluents, industrial discharges, septic systems, and urban runoff, and other sources of contamination. Although the extent of the contribution to environmental contamination in the Lower Fraser Valley that comes directly from agriculture is not known with certainty, there is some evidence of the magnitude of the contribution of agriculture to groundwater NO_3 and excess nitrogen (N). Moon et al. (1994) report that sources of N other than agriculture contributed between 17% and 57% of the measured groundwater NO_3 in the Abbotsford aquifer. Schreier (1996) reported that 67% of the excess nitrogen applied over the Salmon River watershed was from agriculture and 33% was from septic systems.

Many management options that lead to compliance with the Code involve concentrated costs (for farmers) but distributed benefits (for society and farmers) (Zimmerman 1996). The short-run private marginal costs of managing manure decrease with the amount of manure [i.e., the more manure spread on the land (and hence the more nutrients reaching the environment), or improperly disposed of, the lower the marginal cost to the farmer of manure management (up to the point where soil is degraded)]. Marginal costs refer to the additional costs incurred per unit of manure handled. These costs are shown by - $MC_{private}$ in Figure 1 to be an inverse function of the amount of nutrients that potentially reach the environment.[2] It would be in a farmer's short-run financial interest to dispose of an amount of manure that results in x nutrients escaping the agricultural system and reaching the environment since this is the point where the marginal cost of management is minimized. Any reduction in this amount will entail additional financial costs to the farmer (assuming everything else is held constant)[3]; amounts above this will eventually lead to reduced soil productivity. On the other hand, there are marginal costs to the public of

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[2] These curves are highly stylized for the purpose of illustration. In reality, environmental thresholds warrant "step-like" curves.

[3] It should be noted that these costs do not include the longer-term costs associated with excessive spreading such as costs due to accumulation of potassium in soils and animal disease resulting from water pollution.

poor manure management. These costs, which include the costs of reduced fish production, reduced human health, and other costs, are represented by MC_{social} and are an increasing function of the amount of manure reaching the environment as a result of management practices.

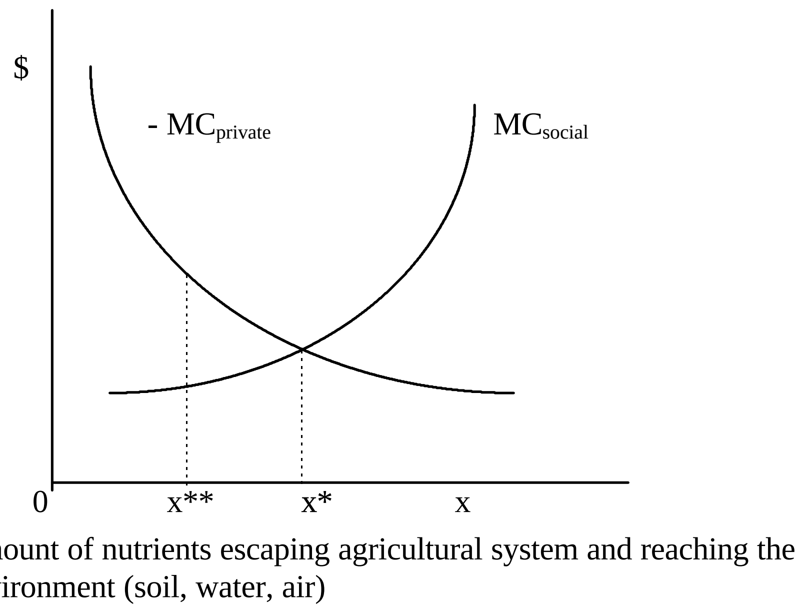

Figure 1: The Marginal Costs and Marginal Benefits of Manure Management

The "economically optimal" amount of nutrients reaching the environment is represented by *x**, an amount lower than *x*. At this point, the private marginal costs of reducing the amount of nutrients escaping the agricultural system and reaching the environment per unit are just equal to the public benefits. From an economic point of view, this is the "acceptable" level of nutrients reaching the environment. This amount is likely to differ from the "optimal" amount of nutrients from an environmental perspective and the "optimal" amount from a private farmer's financial perspective (*x*). The point *x*** represents the "optimal" point for soil productivity (this point may or may not diverge from *x**). The amount of nutrients reaching the environment at *x** balances the costs to the farmer against the benefits to society of reducing the amount of nutrients escaping the agricultural system and reaching the environment.

There are several ways of achieving *x**. The first is by regulating farming practices supported with proper enforcement (e.g., reaching 100% compliance with the Code) so that the total amount of nutrients from an area is this "optimal" level. This level can also be achieved through the use of financial mechanisms such as taxes. Both approaches rely on the "polluter pays" principle in which the farmer is responsible for financing any changes in management practices.[4] Subsidies to farmers who adhere to friendly practices is another option, however, the philosophy behind this approach may be construed as "government/public pays." Another alternative is to introduce practices to farmers that both reduce the burden to society of manure management practices AND reduce the marginal costs to farmers of manure management.

The representation in Figure 1 is largely theoretical since the social costs of contamination are uncertain, as are the application threshold levels required to maintain optimum soil productivity at *x***. It is therefore not possible to determine with certainty whether point *x** and *x*** coincide. However, advances have been made in estimating points along these curves, suggesting that although we do not know exactly where point *x** lies, it is evident that current practices lead to an amount of manure being introduced into the environment that is to the right of *x**. Water quality criteria and objectives, while having no legal basis, do provide benchmarks to identify areas where the amount of nutrients reaching the environment is too far to the right.

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[4] The "polluter pays" principle is used in other sectors of the economy. The GVRD Solid Waste Management Plan, for example, explicitly states that the "polluter must pay."

Developing mechanisms to reduce the amount of manure escaping the agricultural system and reaching the environment would thus likely be in both society's and farmers best interest. The bottom line is that there are both benefits and costs to changing current practices; these need to be weighed against each other before informed decisions can be made.

Manure management presents an interesting paradox in that manure can be both a resource (as a source of nutrients for crops and a soil enhancer) and an environmental contaminant (as a contributor to all of the problems described above) depending on how it is managed. The primary management issue is how to maximize its use as a resource, minimize its effects as a contaminant, and attain compliance with the Agriculture Waste Control Regulation and the Fisheries Act.

5. REVIEW OF LITERATURE REGARDING COSTS AND BENEFITS OF MANAGEMENT OPTIONS

5.1. Costs to Society of Current Practices

From Figure 1 it is clear that reducing nutrient losses in an agronomic system too far towards zero is not desirable from an economic perspective since the costs to farmers (and ultimately to consumers) of achieving this objective would overwhelm the benefits to society of reduced contamination.[5] However, there are clear indications that the "costs" to society of current practices are high. Somewhere in between farmers continuing with current practices, and too much regulation, is the optimal level (x^*) of manure application that regulation should aim for (assuming the use of good management practices). At this point, the benefits of reducing contamination to some level of acceptable risk just equal the costs. An important question to be addressed is the level of nutrient losses associated with perfect compliance with the current Code and how this compares with both x^* and x^{**}. Of course, this will vary on site-by-site basis with differences in soil type, slope of land, etc.

It is important to note from Figure 1 that an "economically optimal" amount of manure reaching the environment may be achieved with the introduction of new management options that both reduce the private marginal cost to the farmer of manure management **and** reduce the amount of nutrients reaching the environment. This would result in a shift to the left of the private marginal cost curve and a reduction in the amount of manure that reaches the environment. These new options include innovative methods of manure management such as marketing composted or pelleted manure product, or composted dairy solid waste, which have proven to be financially viable in some instances (Agriculture and Agri-Food Canada 1995).

Although it is impossible to identify the exact optimal level, which may vary with agricultural zone (as described in Brisbin, 1994), it is useful to be more exact about what the costs to society are. This is a difficult task since clean drinking water, clean air, and improved human and animal health are not commodities bought and sold in the market, although they certainly influence market choices. Economists call these goods "non-market goods." These goods have "value" even if it is difficult to identify the value in monetary terms.

[5] It should be noted that this framework assumes that all measures that result in a reduction in the amount of nutrients reaching the environment will increase farmers' marginal costs. This is likely to be an overly restrictive assumption in this case.

Economists have primarily used three approaches to valuing non-market goods. One approach is to estimate lost revenues that result from the degradation or loss of a particular resource. In the case of contamination of waters from manure, for example, economists might estimate the lost revenues from fishing due to fish-stock depletion, or the infrastructure cost to develop new water supplies or treat current sources when water supplies are contaminated. Additionally, they may estimate the lost human productivity from health problems that result from contaminated drinking water.

Another approach is to argue that people would be willing to pay for amenities such as cleaner water if they had the opportunity to do so; value can be estimated by creating a hypothetical market and surveying members of the population regarding the "purchases" they would make in this created market. Researchers might ask survey respondents how much they would pay to reduce water contamination, for example. They then use this as a rough estimate of the benefits associated with reducing contamination. This approach is called "willingness to pay" (WTP).

The third approach, called "averting expenditures," is to observe how much people spend to avoid exposure to contamination. This gives some indication of how much the amenity is worth to people. For example, the amount people spend on bottled water and water-filtration systems gives an estimate of how much people value clean water.

Several of the studies estimating the value of cleaner drinking water are reviewed here. It should be noted that these estimates are not additive. Theoretically, willingness to pay estimates subsume averting expenditures and lost revenues. They also include "existence" and "option" value - the value that derives from knowing a resource exists or that one might have the opportunity to use it in the future. Willingness to pay estimates provide the most comprehensive estimate of the value of a resource, however, they are also the most empirically tenuous. Having different types of measures provides some ballpark figures on the value of resources.

It should be noted that both willingness to pay estimates and averting expenditures are a function of people's ability to pay, as well of people's perceptions of the quality of drinking water. If people's perceptions diverge widely from the actual quality (as measured by scientists), the value of cleaner water may be over- or under-estimated. Results of a study conducted in the Lower Fraser Valley (Hopington Aquifer) show that people generally overestimate the quality of their drinking water. The survey results showed that 82% of respondents considered the quality of their drinking water to be good or excellent, and 18% considered the quality to be moderate or poor. Well-water samples collected from the same households showed that water quality was moderate to poor (based on nitrate concentrations) in approximately 45% of wells. The quality was good or excellent in the remaining 55% (Schreier, et al. 1996).

The results of two studies using the WTP approach suggest that people place a positive value on improved water quality in the Lower Fraser Valley in British Columbia. Athwal (1994) estimated the amount individuals would be willing to pay to obtain better water quality in the Abbotsford farming areas. The study asked area residents how much they would be willing to pay to obtain a lower amount of nitrate in their drinking water. It also asked survey respondents how much they spent on bottled water and/or filtration systems, and the reasons for these purchases (to avoid contamination is only one of many possible reasons people purchase bottled water or filtration systems). The telephone survey contacted 115 residents who received water from the Abbotsford aquifer. The study estimated that the stated WTP was $0.5 - $0.6 million per year for the affected population of the area on groundwater (6,300 households).[6] The average WTP **per household** was estimated to range between CAN$81 - CAN$97, while actual averting expenditures were estimated to be CAN$143/year per household (see Figure 2).

Hauser, van Kooten, and Cain (1994) asked 343 people in the Central Fraser Valley region how much they would pay for clean water. The study found that the population in that region would pay between CAN$0.5 million and CAN$1.8 million dollars per year (CAN$78 - CAN$284/year per household). The survey also estimated averting expenditures by asking survey respondents how much they spent in one year on bottled water and water-filtration systems. The study estimated that averting expenditures were slightly lower than the WTP at CAN$0.4 million per year (CAN$70/year per household).

A study by Abdalla (1992) estimated averting expenditures to avoid losses from contaminated water in Pennsylvania. The study considered the borough of Perkasie, which has an estimated 2,760 households (population 7,877). The chemical Trichloroethylene (TCE) had been detected in one of the borough's wells at levels that exceeded the Environmental Protection Agency's maximum contaminant level; residents had been advised of the contamination. This study used mail questionnaires to elicit information about the increases in household averting expenditures taken in response to the contamination. The estimates of expenditures for the population of the region for the 88-week period of the study ranged from US$60,000 - US$130,000 (CAN$71,000 - CAN$154,000).[7] Per household, the figures range from approximately US$22 - US$47

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[6] As many as 94,000 people (over 31,000 households) are on groundwater during peak periods.
[7] All exchange rate conversions in this report are based on exchange rates from the International Financial Statistics Yearbook. The exchange rate used is the average market exchange rate for the year in

(CAN$26 - CAN$56) for the study period. These figures are lower than the averting expenditures estimated for the Fraser Valley. This may be due to differences in survey design and/or estimation methodology, or could be due to the fact that different contamination issues were examined in this study.

Hanley (1989) estimated the value to households in Eastern England of a change in policy that would guarantee water supplies with a nitrate level not exceeding the EC limit of 10 mg/l NO_3-N (the article did not state what level the nitrates were to be reduced from, although he did say that the area suffers the most in the UK from excess nitrate in the water supply). The study surveyed 400 households and found that the average WTP was approximately 13 British pounds per household per year (CAN$25/year per household). Extrapolating this figure to the relevant population (835,212 households) gives an aggregate benefit of 10 million British pounds per year (CAN$19 million per year).

Figure 2 shows graphically the range of estimates in the literature of the benefits of clean drinking water based on studies of willingness to pay and averting expenditures. Given the geographical location of the studies by Athwal (1994) and Hauser et al. (1994), the estimates from these studies are estimates most likely of direct relevance to the Lower Fraser Valley. However, the other studies show that while the costs are not certain, there is most likely some significant benefits of clean drinking water.

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which a study was conducted, or, if the year of the study is not stated, the average market exchange rate in the year prior to the date of publication of the study.

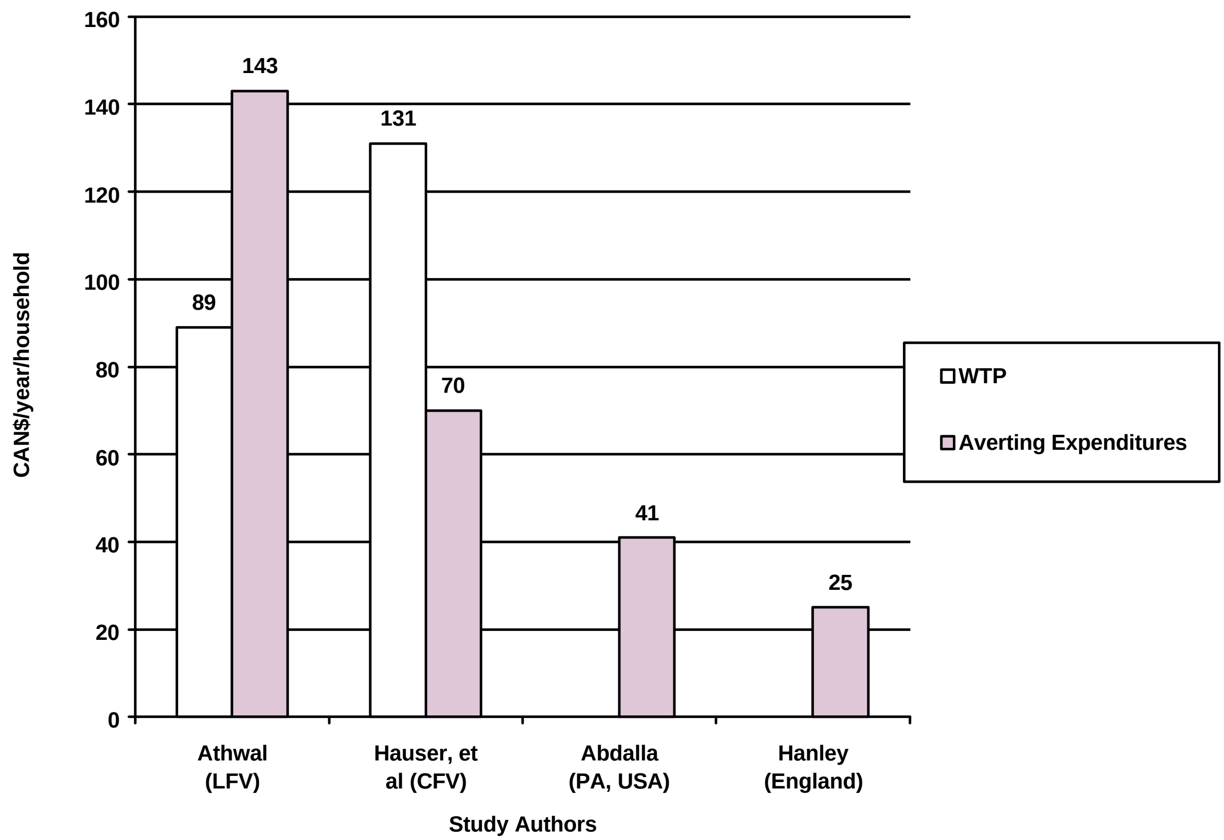

Figure 2: Estimates (Midpoints) of the Benefits of Clean Drinking Water

It is important to remember that the averting expenditure estimates are the financial outlays to avoid or reduce nitrates in drinking water; these figures do not include any of the benefits of cleaner air, better animal health, or improved fish stocks. As such, they are often considered to be lower bounds to the "true" benefits. The advantage is, however, that people can usually accurately state how much they have spent on water systems. Willingness to pay estimates, on the other hand, may include the values from other benefits, but they are hypothetical estimates that may or may not truly reflect how much people value a particular resource. Furthermore, caution should be used in drawing inferences from studies done in other areas as the potential benefits from improvements and the base scenario are likely to vary widely by location.

Any cost or benefit estimates are useful only when they can be used in a benefit-cost analysis, i.e., the costs of composting may be high, for example, but if the benefits (including both the private and the public benefits) exceed these costs, it may be worthwhile to find a way to finance that option. Athwal (1994) did a benefit-cost analysis of composting manure in the Abbotsford. She estimated the total costs of converting all manure produced in the Abbotsford region (890,000 tonnes) to be CAN$32 - CAN$62.5 million each year. Assuming that revenues from compost are CAN$7.1 - CAN$13.4 million (based on a price of CAN$8 - CAN$15/tonne), the private shortfall is CAN$18.6 - CAN$55.4 million. Since the benefits (as estimated using WTP and averting expenditures) do not justify this shortfall, she concluded that composting is not economically feasible. However, the author did not consider the feasibility of composting only the surplus manure rather than all manure in the Abbotsford region.

5.2 Costs of Impacts to Fish

Fish, particularly salmonids, are extremely sensitive to degraded water quality. Measuring the effect of agricultural waste management options (both current and potential) on fish production in the Lower Fraser Valley is difficult. The data regarding the status of the salmon stocks is incomplete (Department of Fisheries and Oceans, 1996a; 1996b). Coho salmon, which are of particular interest in this geographic area, are difficult to enumerate because there are numerous small populations.

The BC Ministry of Agriculture, Fisheries, and Food (1994) estimates that in 1994, the total value of the BC seafood harvest was CAN$685 million. Salmon were identified as the single most important commodity of the agri-food industry, and accounted for about 55% of the total value of all BC seafood products. The report also states that the salmon harvest in 1994 (excluding farmed salmon) was down 23% from the previous year, and below the industry's long-term average. The cause of the decline was not specified.

It is difficult to attribute the portion of the decline in fish stocks that is due specifically to agricultural practices as there are numerous other potential causes of declining fish stocks (e.g., other sources of contamination, habitat losses due to urban development, over-fishing, etc.). Nonetheless, there is evidence that wild coho stocks originating from the Strait of Georgia area (which includes the Lower Fraser Valley) have declined by 30-40% (data cited in Department of Fisheries and Oceans, 1996b) and that populations have not rebounded with a reduction in fishing pressures. Coho salmon stocks are vulnerable to surface water contamination from agricultural wastes given that these fish are produced mostly in the low gradient watersheds and rear in these small streams for a year or more (Department of Fisheries and Oceans, 1996b). The loss of fish stocks is particularly worrisome because the losses become irreversible if populations fall below a level at which the fish can reproduce at a sustainable rate. The geographic area discussed in this report is an important one for fish populations; approximately 85% of Fraser River chum salmon and approximately 69% of Fraser River coho salmon spawn in tributaries downstream from Hope, an area of intensive agriculture (Department of Fisheries and Oceans, 1996a; 1996b). The links between inputs of nitrate, ammonia (which is toxic), and phosphorus to surface waters and effects on aquatic receptors and fish stocks are well established. Other contaminants found in manure such as bacteria and oxygen-consuming substances can contribute further to the degradation of surface water quality.

Even if the relative contribution of current agricultural waste management practices to the health of the coho and chum stocks were known, it is difficult to quantify the "value" of a healthy fish stock. The "value" of the stocks derive from many attributes of the stock in addition to dollars generated through commercial and recreational fishing sectors. Value also derives from the contribution the coho or chum stocks make to genetic diversity of the species, the value to recreationalists who enjoy fishing or observing the fish, particularly in intact watersheds, and the inherent value of the life of the fish and the ecosystem of which salmon are a part. The value of tourism drawn to the area is not considered part of the "value" of the fish since this represents a transfer of income from one group to another. However, it should be noted that many tourists visit British Columbia for fishing and water recreation. Anglers (including BC residents, other Canadians, and non-residents) spent an estimated $611 million fishing for all species in BC tidal waters in 1994 (ARA Consulting Group, Inc. 1996) and approximately 25% of BC's anglers come from out of province.

The Agricultural Land Use Survey in the Sumas Watershed Summary Report (IRC Integrated Resource Consultants, Inc., 1994a) indicates that concentrations of phosphorus in the waterways throughout the basin exceeded the provincial criteria of 0.015 mg/L for lakes, indicating nutrient enrichment. These surveys also categorized sites according to the relative quality and permanency of fish habitats. Although the sites varied in quality, and all sites had fish, there were some sites at which the number of species was considered restricted due to water quality. The Agricultural Land Use Survey in the Matsqui Slough

Watershed Summary Report (IRC Integrated Resource Consultants, Inc., 1994b) found that some sampling sites (Page Creek and Matsqui Slough) had dissolved oxygen concentrations that were too low to sustain fish populations. The survey reported that in order for migratory fish to swim upstream to suitable spawning areas they must swim through the lower reaches of Matsqui Slough where dissolved oxygen concentrations may present an obstacle.

Low oxygen levels in the Serpentine River in the mid 1980s were responsible for the death of over half of the coho run before it could spawn (Fraser River Estuary Management Program 1990). Low oxygen levels resulting from agricultural practices could stem from a number of contributing factors including chemical fertilizer residues, silage runoff, milk-parlor floor runoff, and woodwaste leachate, as well as over application of manure. The FREMP report does state that "manure is the single largest agricultural waste concern in terms of the amount of waste generated, the amount used in farming practices, the amount of storage needed, and the magnitude of the environmental impact" (p. 19). The FREMP report concludes that the attitude of the waste producer, and the approach normally taken by the producer towards waste management may be the most significant protection afforded the environment.

A study prepared by ARA Consulting (1996) estimated the value to society of each additional coho salmon caught through either the commercial or recreational fishery. The study estimated the value of an extra fish caught in a recreational fishery by surveying anglers about their willingness to pay an extra amount over actual expenditures for the opportunity to fish. The value to commercial fisheries was estimated by what labour and other production inputs would earn if they were not used in the fishery. The study estimated that the economic value of an extra coho salmon was $10-$20 per recreational coho, and $8.00 per commercial coho. These figures do not account for any economic activity generated as a result of more fish being caught, nor do they reflect the value of fish already caught.

Estimating the value to society of coho stocks in the Lower Fraser Valley is limited by a lack of reliable fish population data, the difficulty of measuring the impact of one land use on these fish species, and the lack of reliable values for fish. Although evidence indicates that wild Lower Fraser coho populations have declined by 40% since the 1970s, many fish were lost before the 1970s as a result of diking, stream straightening, pollution, and other causes. Furthermore, salmon have complex life cycles, and it is difficult to know to what extent factors other than agriculture influence fish populations. It is known that the Lower Fraser River and tributaries support a large portion of salmon stocks and are threatened by the detrimental effects from agriculture. There are also other species that are affected by agricultural activities, such as searun cutthroat trout (100% of Fraser stock spawn in tributaries downstream from Hope). Based on the information above, the economic impacts of historical and current agricultural practices on Lower Fraser salmonids might be on the order of several million dollars each year.

The value of lost fish stocks in other parts of the world have been estimated in other studies. Silvander and Drake (1991) estimate the costs to society of continued nitrogen loss from Swedish agriculture in terms of the effects on fisheries. The costs include the losses associated with the reduced commercial fishing, aquaculture, and angling due to contamination from agriculture, and the losses associated with contaminated drinking water. The results do not include the costs associated with reduced recreational opportunities (other than angling) or the value of fish stocks to genetic diversity. The losses due to nitrogen leaching from agriculture are estimated by the authors to be 1836 million Swedish kroner/year (CAN$337 million/year), plus or minus fifty percent. Commercial fishing in Sweden employs 4,500 people and is estimated by Silvander and Drake to have a financial value of 318 million Swedish kroner per year (approximately CAN$58 million/year). The estimate of losses is based on the value of the current fishing industry plus consumers' willingness to pay for the continued ability to angle and have clean drinking water. Although direct comparisons with the Canadian fishing industry cannot be made, this study illustrates that substantial economic losses can result from the deterioration of fish stocks.

5.3. Costs to Farmers of Continuing Current Practices

Although there may be no immediate financial implications to producers of excess application of nutrients, there are direct costs that may accrue to farmers in the future if over application continues. These include the costs of the effects of air and soil pollution that affect the financial position of a farm. Gases from manure, for example, can cause respiratory problems for both animals and farm workers. Furthermore, the increased potassium levels of forages that result from excess potassium application have created health risks for dairy cattle that consume the high-potassium forage. Other costs include the cost of lower quality of irrigation water and, without a nutrient management plan, likely losses associated with the expense of inorganic fertilizer rather than manure nutrients in cases where there are substitution possibilities. The Agricultural Nutrient Management in the Lower Fraser Valley (Brisbin 1995) reports that $12 million a year could be saved in the Lower Fraser Valley by reducing inorganic fertilizer to 30% of crop removal and using manure to supply the balance of nutrients.

It is clear from the literature reviewed that there are "costs" associated with continued over-application of manure to the land base in the Lower Fraser Valley. The estimates of the magnitude of these costs is elusive, given their qualitative nature, however, it is evident that these costs are significant. Reducing the burden to society of environmental contamination from manure application requires that farmers change their manure-management practices. These changes may have financial implications (some of which may be positive if the new practice is both environmentally and financially sound) for producers and/or for the government/public if subsidies, financial incentives, and "green" charges on produce to fund environmental programs are involved. Changing management options may also require informing and educating the public about associated consequences (e.g., increased odour from composting). The next section reviews the literature on the private costs of manure-management options.

5.4. Estimates of Private Costs of Various Manure Management Options

This section begins with a presentation of the literature related to the private costs of various options in areas other than the Lower Fraser Valley and is followed by costs for the Lower Fraser Valley.

5.4.1. Private Costs of Management Options Elsewhere

Bosch and Napit (1992) examine the economics of transporting poultry litter from manure-surplus to manure-deficit areas in Virginia. They found that the export of litter from surplus to deficit areas for use as fertilizer is economically viable. Their calculations are based on the difference between the estimated fertilizer value of manure and the costs of obtaining, storing, delivering, and applying litter to cropland. They assume hauling distances of between 40 and 80 kilometers, a cost of shipping litter of US$13.33 (CAN$15.78) per metric tonne of manure, and a delivery charge of US$0.069 (CAN$0.082) per metric tonne per kilometer. The authors state that despite the financial feasibility of transporting litter from surplus to deficit areas, such movements are not currently taking place. They suggest that government policies such as subsidies to crop producers who purchase poultry litter may be needed to stimulate the transfers. They also discuss the potential for educational programs to show farmers the economic value of litter used as fertilizer.

Moore et al. (1995) indicate that in the US, poultry operations, which are mostly vertically integrated[8], prescribe most of the management decisions, including the feed, water, medication, housing, light, heat, ventilation, and harvesting requirements for contract growers. However, the vertical integrators seldom consider the management of the manure. The authors suggest that part of the problem of excessive manure application to land could be solved if integrators were more involved in the manure management. They indicate that transportation of poultry litter is generally limited to short distances (10-20 km). Although they do not cite any figures, they state that composting is probably not cost-effective since it is time consuming and costly and does not result in a product that is any higher in nutrient value than fresh litter. The authors do not note, however, that composting may result in a product that is more marketable to users than fresh litter.

Wood (1992) discussed the limited potential in Alabama, Arkansas, Georgia, and North Carolina to move broiler litter from surplus to deficit regions. Although he does not cite any figures, he claims that because broiler litter is a low-density material, transportation costs exceed the nutrient value within short distances.

Martin and Matthews (1983) compared alternative dairy manure management systems under full-scale commercial conditions. Manure from an experimental dairy production facility was handled in three different ways on separate experimental plots over a three year period. The three methods included: 1) manure was spread on a daily basis, 2) manure was moved by gravity into a liquid manure storage tank for spring application and immediate plow down, and 3) manure was moved by hydraulic ram to a roof-covered above-ground storage area for spring and fall spreading and immediate plow down. Their results show that a manure storage system can reduce annual labor requirements by 65 percent and fuel requirements by 60 percent compared to daily spreading. The study also shows that daily spreading of manure is the least-cost system for herds up to approximately 60 cows, while a roof-covered semi-solid manure storage and handling system is a lower cost system for herds above 60 cows.

Klassen (1994) presented the private costs of controlling ammonia emissions in 33 regions in Europe. The abatement options he considered included low nitrogen feed, stable adaptations, covered manure storage, cleaning stable air, and low ammonia applications of manure (e.g., ploughing down of manure on arable land). He concludes that the wide variation in cross-region cost figures makes it difficult to recommend any blanket policy scenario that would be effective in all regions. He does conclude, however, that the costs of manure processing are too high to justify the application for the control of

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[8] Vertically integrated operations are ones in which successive stages in production and distribution are placed under the control of a single enterprise.

ammonia emissions only and the efficiency of various policies is region specific; each region should therefore be free to set its own policies.

Rulkens and ten Have (1994) argue that the Dutch experience of central processing of manure into fertilizer is not viable. In the early 1990s, The Dutch set up a central treatment plant with a processing capacity of 500,000 tonnes of raw manure annually. The purpose of the plant was to reduce the environmental problems associated with excess manure nutrients mainly from pigs, and to a lesser extend from poultry (Rulkens and ten Have). The total amount of manure for which no agricultural land is available was estimated to be 10 million tonnes by the year 2000. The authors state that the value of the fertilizer produced per tonne of raw manure was only 20-35 Dfl. per tonne (CAN$13.89 - CAN$20.84 per tonne) while the gross operating costs of the central treatment plant are 60 Dfl./tonne of raw manure (CAN$41.67 per tonne of raw manure). Furthermore, the initial investment for a processing plant with a capacity of 500,000 tonnes of manure was estimated to be approximately Dfl.100 million. (approximately CAN$69 million). Although the article does not state why a treatment plant with a capacity of 500,000 tonnes was chosen, it does state that the Netherlands intended to reach a central treatment capacity of about 6 million tonnes per year in 1995. Rulkens and ten Have conclude that it is critical to have better established markets for the final product before this kind of operation becomes economical. It should be noted, however, that the conclusions are based solely on the direct financial costs and benefits of processing and do not include any benefits to society.

The experience of the Netherlands provides an interesting case study because the area has experienced many of the same problems that are evident in the Lower Fraser Valley.

The Dutch livestock industry grew dramatically between 1950 and 1990, due primarily to a growing international demand for animal products, a favourable EC Common Agricultural Policy, and an excess labor supply in agriculture (Dietz 1992). One consequence of this change was contamination of the environment due to the increased amount of livestock manure and a shrinking land base on which to apply it.[9] Dietz (1992) reports that thirty percent of Dutch soils are saturated with phosphate, nitrate concentrations in groundwater have led to several well closures, and ammonia from manure contributes for more than thirty percent of the total acid deposition in the Netherlands.

The Netherlands has the highest density of animals in the EU; there are 45.1 poultry head, 6.1 pigs, and 2.6 cattle per hectare of cultivated area (Tamminga and Wijnands 1991)

The Manure Act was implemented in the Netherlands in 1987 to address these problems. It sets limits on the amount of phosphate equivalent that may be applied to land without penalty. Although farmers may apply phosphate equivalents above this amount, any amount above the standard is taxed, with the revenues generated accumulated to a government-managed Manure Fund which finances the development of manure treatment plants, the transportation of excess manure to shortage areas, and the reduction of phosphate (and nitrogen) contents in animal feed. The current policy regulates only phosphates, not other nutrients that are also harmful to the environment when present in excessive amounts. The current policy regulates only cattle, pigs, and poultry; many farmers have bypassed the regulation by changing production to ducks, geese, and goats,

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[9] The shrinking land base in the Lower Fraser Valley has been due, in part, to increases in development

which are not regulated. Nutrients from chemical fertilizers are not regulated, despite the potential for contamination from these fertilizers. Dietz's recommendation was to focus not on manure, but on nutrients, and to aim at a sustainable use of nutrients in agriculture. Standards for nutrients would be deduced from the maximum losses of nutrients to soil, water and air that are acceptable from an environmental point of view. Once the standards had been set, he recommended the introduction of a nutrient accountancy per farm whereby a levy would be imposed on surplus nutrients. Although this sounds theoretically sound, implementing it may be difficult.

MacDonald (1982) also argues that anaerobic digestors constructed purely for energy production are unlikely to be financially viable. However, he also states that "if other aspects of manure management such as pollution control (primarily odor) and cell biomass recovery for feed are considered, digestors may become economically practical" (p. 12M).

The studies cited above regarding anaerobic digestion and litter incineration conclude that based on current energy prices and high capital costs, these options are not economically feasible. These findings, however, are based solely on the energy benefits of processing and do not include any benefits to society as discussed above. The results of the studies from other parts of the world attempting to deal effectively with the contamination from manure have implications for the Lower Fraser Valley. Most of the studies reviewed here highlight the "costs" associated with the management of excess manure. These studies support the argument that the costs of current practices outweigh the benefits. However, these studies do not point to any "success stories" or cost-effective ways of achieving a stated objective. Since it is becoming well established that

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of golf courses, hobby farms, and other non-agricultural uses of land.

the costs of current practices are high, finding cost-effective ways of reaching an agreed upon level of environmental quality in relation to animal densities should be the next research question addressed in the literature. Innovative management options in which farmers and the environment both win must be explored.

5.4.2. Private Costs of Management Options in the Lower Fraser Valley

Moon et al. (1994) evaluated the animal waste nitrogen production relative to the present land based N-loading capacity of the Abbotsford aquifer area to determine the contribution agricultural waste makes to the problem. They concluded that the manure production levels of N exceeded the land-based absorptive capacity in dry years by between 847 and 1542 tonnes (50.6 - 92.1 kg/ha),[10] and the current land base could support on-aquifer use of livestock manure **only if** the area of grass and corn production were increased.[11] The study also found that at 1994 production levels, gross revenues from dairy, swine, poultry, grass, silage corn, and raspberry were about CAN$112.4 million, while the adjusted gross margin (gross revenues minus direct costs and fixed costs associated with manure storage) were CAN$44 million. The additional costs associated with storage and transportation of manure to meet health safety limits in drinking water in dry years (including depreciation, interest, repair and maintenance on structures and loading and hauling costs) would total approximately CAN$1.1 million.

[10] Assumes no chemical nitrogen fertilizer is used.

[11] It should be noted that under the Waste Management Act - Agriculture Waste Control Regulation, manure can only be applied to land as a fertilizer or soil conditioner. Application of manure to land as a means of disposal requires a Waste Management Permit and should not be considered normal or acceptable practice.

Several studies were carried out in the early 1990s looking at the economic feasibility of various manure management options. These studies are summarized in the next sections according to commodity.

5.4.2.1. Poultry

Chipperfield (Sustainable Poultry Farming Group, personal communication) has found the transport of poultry manure from the Lower Fraser Valley to ranchers in the Merrit area to be a cost-effective means of disposing of manure and believes there is long-term potential for poultry producers to benefit financially from such a strategy. The soils in the Merrit area are responsive to manure and a few ranches have the potential to absorb as much as 40,000 - 50,000 cubic yards (approximately 16,730 to 20,912 tonnes)[12] of imported manure annually. The fee for trucking manure to Merrit is approximately $4.00 - $5.00/cubic yard, while the fee charged to poultry producers for the conveyor loading system is about $1.00/cubic yard. Overall, Chipperfield finds that it is cost-effective to transport light manures to Merrit as well as other areas, such as Ashcroft. The manure from layer barns is too wet to make transport financially feasible, however, there is some potential for pelleting of this manure. For the broiler and turkey farms, the manure is generally of adequate dryness to transport. Chipperfield identifies producer attitudes about manure as a potential constraint to making effective use of manure as a fertilizer. Although he claims that the attitude is changing, Chipperfield believes some ranchers and crop producers still feel that they are doing poultry producers a favour by taking the manure off the hands of the poultry producers; ranchers and crop producers therefore do

[12] The conversion from cubic metres to metric tonnes is based on the conversion factors of 1.307 cubic yards/cubic metre and 320 kg/cubic metre (Rick van Kleeck, Waste Management engineer, Ministry of Agriculture, Fisheries and Food).

not believe they should have to pay for the manure. As the economic value of manure as a fertilizer becomes even more apparent to crop and other producers, this attitude will likely not remain a constraint.

Stennes (1992) estimates the private costs of improved litter handling by South Coastal BC poultry farmers. He calculated that the total on-farm costs for aerated static pile composting are CAN$9570/farm/year (CAN$43.14/tonne of litter) higher than for traditional on-farm storage. Furthermore, he estimates that transport costs for poultry litter are about CAN$0.179/tonne per km and the maximum tipping fee a central processing facility could charge would be between CAN$13.83 - CAN$20.09/tonne, depending on the destination. As Stennes states, "the main benefit to 'appropriate' poultry litter handling is likely to be a 'public' benefit" (p.7). "Public" benefit is not defined in the report.

Fullerton (1991) also considered the financial implications to poultry farmers of several manure treatment alternatives including moisture control and storage compliance, composting and pelleting of manure, and anaerobic digestion and litter incineration. The capital investment of the various options ranges from $10,850 for nipple drinkers (includes quoted price and installation for 15,000 bird/year capacity; $0.72/bird) to $675,000 for a large-scale regional pelleting plant that has annual intake of 45,000 tonnes of litter and layer manure; $0.34/bird).

The estimated cost of transporting manure ranged from $50-$70/tonne, depending on the transport route and destination. The costs included storage costs, investment costs, cleaning and handling costs, and transport, but did not take into account any marketing costs or return for nutrient value. The study concluded that the nutrient value of manure is quickly eroded because of the high transportation costs. However, the gas and trucking costs are quite variable over time, and the feasibility of transporting litter changes quickly. The study also suggests that there must be incentives for crop producers in the Delta area to want to use manure over fertilizer, since such a change may require capital outlays for new equipment such as a liquid manure spreader.

Composting methods range from simple windrow to an “in-vessel” system with varying levels of capital investment. Based on the operational assumptions made (15,000 bird/year capacity), the compost production costs were estimated to be $47.35 to $71.35/tonne ($0.067/bird - $0.100/bird). The study concluded that a compost price of between $40-$63/tonne is necessary before composting becomes financially feasible.

The high capital investment required for pelleting ($675,000; $0.034/bird) limits the feasibility of this option; the break even cost was close to $50/tonne pelleted product.

Overall, the study found that the installation of nipple drinkers and pit fans would reduce operating expenses on an average-sized poultry farm because of the consequent reductions in fly control, wetness of litter, and manure transportation costs. However, these systems require initial capital costs which may prove constraining. The financial analysis does not include the value of decreased odor or lower handling expenses, or any of the off-farm savings.

Figure 8.1 from Fullerton (1991) showing the advantages and disadvantages of each manure treatment alternative is reproduced here as Table 1 and Table 2. Fullerton’s report did not attempt to quantify the benefits (to the environment) of various options relative to the private costs. The potential for composting and pelleting depend on a market for the end product. Ference Weicker & Company (1994) looked at the market potential for composted product. They found that poultry manure is currently positioned as a low-value product, probably because the benefits of manure as a source of nutrients and as a soil conditioner are not well recognized in the marketplace. The study findings identify a short term market potential to sell 2500 tonnes of value added slow release poultry manure fertilizer. The largest identified market is for fertilizer blenders, which could absorb 85% of the initial market.

Zbeetnoff Consulting (1995) estimated that the potential market in British Columbia for pelleted and crumbled, composted poultry manure at a bulk price of $100 to $150 per tonne is in the range of 1694 to 2823 tonnes annually. Approximately 140,000 tonnes of poultry manure are produced annually in the Fraser Valley (1990 estimate from Zbeetnoff Consulting); the potential for this market to absorb a significant quantity of poultry manure appears to be small.

Table 1: On-Farm Poultry Manure Treatment Alternatives (Reproduction of Fullerton, 1991, Figure 8.1)

Option	Application	Advantages	Disadvantages	Special Consideration
Nipple Drinkers	All Sectors Note: Can be problems with turkeys.	Reduced: • manure/litter moisture • fly control expenses • handling/transport • barn odour levels	Increased: • capital expenditure • supervision	• Higher maintenance expenses for larger birds (turkeys). • Minor modifications to barn water system may be needed.
Pit Drying Fans	Deep Pit Barns Note: Can be used in converted deep pit barns for broiler breeders.	Reduced: • manure moisture levels to 25-30% • reduce/eliminate fly control expenses • handling/transport • barn odour levels	Increased: • capital expenditure • annual operating expenses (approx. $120/fan/year for electricity)	• Nipple drinkers should be installed first. • Barn may require improved wiring and controls.
Manure Dryer	Generally manure & litter from layer and broiled breeder sectors.	Achieve: • simple operations • diversification/revenue • consistent low manure moisture levels • on-farm solution to excess manure weight/volume • stable storable product	Increased: • capital expenditure • annual operating expenses • reliance on fossil fuels • labour and management Other: • odour control will require planning and investment	• Small-scale dryers expensive on dry tonne basis. • Market niche required. • Competition from other organic products likely.
Composting*	Manure & litter from all sectors. Note: Small-scale on-farm and larger scale regional systems can be feasible.	Achieve: • diversification/revenue • pathogen destruction • on-farm solution to excess manure weight/volume • dead bird disposal Other: • simple systems exist	Increased: • capital expenditure for both equipment and buildings likely • annual operating costs • labour and management Other: • odours dependent on system	• Limited compost needed on limited land bases. • Large production needs successful marketing program (supply of other compost and "organic" products critical factor). • Bagged sales increase profit margin.

*** Composting is also an alternative for regional or semi-centralized manure treatment.**

Table 2: Regional Poultry manure Treatment Alternatives (Reproduction of Fullerton, 1991, Figure 8.2)

Option	Application	Advantages	Disadvantages	Special Considerations
Pelleting	manure/litter from all sectors Note: Large capacity. Regional use.	Achieve: • bulk/bagged product sales • pathogen destruction • stable storable product • freight efficiency (major advantage over compost)	Increased: • capital expenditure • annual operating expenses • full-time staff/management Other: • odours dependent on controls	Successful marketing program required. Competition with other "organic" products such as compost will exist. Bagged sales increase profit margin.
Anaerobic Digestion	Wet Slurry Note: High-solids systems currently being studied	Achieve: • biogas and electricity produced from "wastes" • energy savings • increased self-sufficiency • nutrient preservation • farm-assisted diversification (i.e., greenhouse production)	Increased: • capital expenditure • annual operating expenses • staff needed to operate Other: • Most common technology uses wet slurry • reliability	Financial success dependent upon level of total capital investment, financial assistance, management skills, availability of appropriate system and the capability to use or sell the energy and electricity produced.
Incineration	Poultry litter	• Litter disposal and energy production. Ash recovery and sales.	Potential: • smoke • excessive particulates • odour • difficulties in obtaining appropriate equipment	The economic feasibility of on-farm and regional litter incineration is very remote, under the current conditions in British Columbia. The use of litter to produce products (compost, pellets) has a much higher probability of success.

Table 3 shows a comparison of the estimated on-farm costs of composting poultry manure and the price at which compost would have to sell before it became financially feasible to compost. These results suggest that composting is most likely not financially feasible since the wholesale price of compost is approximately $20/tonne.

Table 3: On-Farm Costs of Composting and Break-Even Cost of Compost

Study	**On-Farm Costs of Composting (per tonne)**	**Break-Even Cost of Compost (per tonne)**
Athwal (1994)	$32-$70	NA
Stennes (1992)	$54	$43
Fullerton (1991)	$47-$71	$40-$63

5.4.2.2. Dairy

The manure management on dairy farms is strongly influenced by the availability of a land base on which to spread or apply manure. The challenge then is to fully utilize waste resources in an efficient manner. Fullerton (1992) explored the economic feasibility of various dairy waste handling systems in the Lower Mainland region. The results are based on a representative 100-cow operation with 50% land cultivated and 50% land devoted to permanent forage. The model farm did not use a solid-liquid separator and had an open concrete pit with a 6 month storage capacity. The study estimated that such a farm had a net annual expense related to manure handling of $30,000, after accounting for the nutrient benefits of the manure. A lagoon based system was found to be the lowest cost manure storage option, followed by a covered concrete pit. Custom liquid application was the most inexpensive utilization alternative. Fullerton concluded that solid liquid separation was not economical, as the additional nitrogen benefits through separation did not offset the increase in annual expenses related to the additional capital investment required. This study did not, however, examine the possibility of composting the solid waste and marketing it as an ingredient for use in potting soil mixtures. This possibility may make liquid-solid separation financially viable (Agriculture and Agri-Food Canada 1995).

Although there are no data available to evaluate the option of moving from a “conventional” grazing system to an “intensive” grazing system, there is anecdotal evidence that this arrangement can be privately profitable without sacrificing the environment. A Washington State farmer is raising a small herd of Jersey cows by grazing cows on pasture from about March 20 to November 10. For seven months of the year, 90% of the manure management is accounted for by applying manure to pasture area (during the spring and during the growing season). An earthen lagoon that holds about 700,000 gallons of manure is used during the five months of the year when the cattle are confined (Dairy Producers’ Conservation Group 1996). This system proved to be more profitable for this farmer than the former, more conventional farming operation.

5.4.2.3. Hogs

Stennes (1994) examined the economic implications of alternative waste treatment options for hog producers. The alternatives considered included no treatment of wastes with either covered or uncovered storage, solid/liquid separation with further treatment of solids by composting, and treating liquids with a sequencing batch reactor system. The study varied the amount of land available and considered a 250-sow farrow to finish operation with a flush system for in-barn manure handling. The lowest-cost management option varied with the amount of land available for application. If there was no local land available, the lowest cost alternative was treatment and storing liquids in a covered storage pit for eventual transport off farm; if 13.8 hectare of local land was available for application, a sequencing batch reactor became the lowest cost option.

A previous study by Fullerton (1990) analyzed three manure treatment systems for varying farm sizes. The systems were liquid manure handling with 5 months of storage and application on cropland, solid/liquid separation with 5 months of storage for both liquid and solid portions, and solid/liquid separation with sequencing batch reactor treatment of liquids. That study examined the implications of the different systems for capital costs, labour, requirements, annual expenses, liquid storage, liquid disposal, and value added. Not surprisingly, the standard treatment (liquid manure handling with 5 months of storage) had the lowest annual operating costs, although the advantage varied with the farm size. The study did find that the savings in handling costs associated with a covered concrete tank were not sufficient to offset the additional interest and depreciation of the extra investment cost.

5.4.2.4. Horses

Stennes (1993) examined the economic implications of various waste handling systems on South Coastal horse farms.[13] As in the studies discussed above, the analysis considered farms with varying amounts of land available for manure application. The costs of handling manure with 6 months of storage capacity ranged from $400/horse to $600 depending on the amount of pasture available and the size of farm etc. The study concluded that the potential for composting appears to be small, given the relatively small volumes of product from horse farms. Net revenues of $51/tonne would have to be realized for the compost before it became financially feasible on a private basis.

5.4.3. Summary of Findings From Studies of Private Costs of Manure Management

The studies of the private costs of manure-management options reviewed here suggest that there is no one "magic-bullet" solution. The financial feasibility of the different options varies not only by farm type, but also by farm size and the availability of pasture land. Furthermore, the financial feasibility of various options should be considered in conjunction with the reductions in contamination that result.

6. CONCLUSIONS AND OTHER CONSIDERATIONS

This report surveyed the literature covering both the private and the social costs of manure-management options. Although the qualitative nature of the social costs makes these costs difficult to estimate, the studies cited indicate that the social costs of current practices are likely substantial. These social costs suggest that even if the private short-term financial implications of various manure handling options do not warrant their use on a financial basis (and it is not always the case that this is so), if the broader social costs are accounted for, it may be beneficial to society to find effective farm management techniques to solve environmental problems associated with manure. Furthermore, the long-term financial viability of farming in the area will be harmed by degradation of the resource base.

The studies reviewed suggest that there is no clear consensus on the feasibility of composting as a management option. In some regions, the high transportation costs of manure, and the lack of a widespread recognition of the nutrient value of manure, may make composting and processing options not privately feasible. On the other hand, there

[13] It should be noted that unlike the other commodities discussed herein, the horse industry is somewhat different in that it does not produce a "food" commodity for consumers.

have been "success stories" of composting as a management option. None of the studies reviewed accounted for the social benefits, however, which, if included, may make such options attractive more frequently. An obstacle to be overcome in turning to composting as an alternative is the unpleasant odour associated with compost.

Options to be explored further include changing feeding strategies for better nutrient management and recycling litter as a feed source. The first option involves altering the composition of the diet fed to animals such that the amount of nitrogen in animal excretion is reduced. This may help reduce the environmental problems associated with excess manure in a region by altering nutritional properties animal waste, although it does not deal directly with the excess problem. The second option addresses the problem of excess manure in a region by employing the manure as a valuable resource.

Once it has been determined that new mechanisms for changing the incentives associated with manure management are in order (in addition to current regulations), there are several options to consider. Although the purpose of this report has not been to determine the most cost-effective mechanism for achieving a pre-determined result, some options to consider will be briefly discussed here. One approach is developing, communicating and committing to implementing an enforcement policy in combination with the current regulations as well as encouragement for farmers to adopt best management practices. Encouragement can come in the form of strong communication efforts regarding the effects of current practices and in the form of subsidies and financial incentives to assist in bringing operations in to compliance with regulations. "Green" charges on produce to fund environmental programs is also an option.

Taxes and fees pose the difficulty of determining the "optimal" fee or subsidy. They also rely on the assumption that once the rate is set, that it will have the desired effect. This option relies on farmers responding in predicted ways to changes in their incentive structure. If the predictions are wrong, an undesired outcome may result. There are many ways of designing tax and subsidy policies - they may be by crop production, manure application, input use, pollution produced by the farm, etc. Subsidies may also be designed in a variety of ways. Farmers may be subsidized for the use of certain equipment or storage facilities, for reductions in the use of harmful inputs, or for adopting best management practices.

An option not considered in this report is establishing strict standards regarding the registration, manufacture, marketing, storage, application, and disposal of nutrients (both organic and inorganic) (Dupont 1992). This option may involve training and education for farmers before equipment can be bought and used.

A promising option for further research is the labeling of products that meet with certain standards. This would be similar to the current "Environmental Choice" logo found on consumer products signaling that the commodity was produced according to government-determined standards. This type of arrangement rewards and supports farms that meet pre-determined standards with very little financial outlay by the government.

Researchers are also evaluating more radical departures from traditional practice. One such option as the "Eco Barn," a specially designed barn that offers an alternative approach to hog farming by using a bedded housing system and on-farm composting facilities. The ultimate goal of an option such as the "Eco Barn" is to move the manure-derived product off farm, thus addressing the excess manure problem. Luymes (1995) reports that this experimental design has met with “considerable enthusiasm.” The financial feasibility of such options should be considered.

Two information gaps can be identified in the literature that would be important to fill before any conclusions can be definitively drawn. First, although there is now a plethora of studies that estimate the social costs of contamination as well as studies that estimate the private costs of various options, only one study cited here (Athwal 1994) weighs the social benefits against the private costs of various options to determine if these benefits outweigh the costs. This must be addressed. Second, Hanley (1989) argued that “given the difficulty of estimating the external costs of contamination from manure application and coming up with an “optimal” solution where the benefits just equal the costs,” attention should be devoted to “efficiently achieving given ‘arbitrary’ standards of water quality and/or nitrate input limits at least cost.” (Hanley, p 136) None of the studies reviewed here give the least cost method for achieving water quality standards. This also must be addressed. In both cases, the options discussed above should be considered in the context of the Lower Fraser Valley.

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