Economic Assessment of Manure Phosphorus Regulations for Manitoba's (Canada) Pig Industry

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Abstract

Environmental concerns about phosphorus loadings in Lake Winnipeg and other water bodies have led to proposed phosphorus-based nutrient management regulations for the province of Manitoba (Canada), including maximum threshold levels for phosphorous on agricultural lands. The proposed regulations will require costly changes in the manure management practices of the province's pig farmers. This article focuses on the direct annual cost to the pig producers in the province of complying with the proposed regulations should they become law. A recent set of farm-level survey data provides a base for the analysis. A GIS data system is used to facilitate measurement of impacts at level of the individual producer which are aggregated to determine the added provincial cost. The estimated added annual cost to the Manitoba pig industry under a maximum threshold regulation of two-times phosphorus removal is 17.88 million dollars, representing 18% of the estimated annual 2005 net income accruing to pig producers in the province. The estimated added annual cost under a maximum threshold regulation of one-times phosphorus removal is 27.86 million dollars, representing 28% of the estimated annual 2005 net income accruing to pig producers in the province.

KEYWORDS: phosphorus, nutrient management regulations, manure application, Province of Manitoba

Introduction

New phosphorus threshold regulations for the province of Manitoba (Canada) have been proposed by the provincial government. One of the proposed amendments to the current manure regulations is the introduction of soil test phosphorus threshold levels to prevent over-application of manure phosphorus. The proposed thresholds are set to allow manure to be applied at rates equal to crop nitrogen removal (N-based), twice the crop phosphorus removal (2xP), and one times the crop phosphorus removal (1xP). Once soil phosphorus levels exceed 180 parts per million, manure application is to be prohibited without special consent (Manitoba Phosphorus Expert Committee 2006). To comply with the proposed amendments, many agricultural producers will be required to make costly changes in their managing of manure.

The new regulations are designed to protect waterways and water bodies, offering important ecological and social benefits. The scope and magnitudes of such benefits are very much worthy of study but beyond the reach of this particular research. The objective of this study is simply to assess the cost to the individual hog producers of complying with the new regulations. These individual costs are aggregated to obtain costs at the watershed, rural municipality and provincial levels.

Two manure management simulations have been selected in order to assess the threshold recommendations, namely the maximums of two times the removal rate of phosphorus and one times the removal rate of phosphorus. The framework for analysis of the cost related to changed manure management practices follows the framework set forth by Salvano et al. (2006).

Earlier Studies

A number of earlier studies have assessed the added manure management costs incurred by agricultural producers who act to comply with new phosphorous regulations that supersede existing nitrogen regulations (Brethour et al., 2004; Huang et al., 2003; Koehler and Lazarus, 2000; Lory et al., 2004; Olson, 2004; Olson and Paterson, 2005; Ribaudo et al., 2003; Yap et al., 2004). The costs outlined in the studies fall under the general headings of manure storage, application, transportation and treatment with the overriding issue being the larger land base required for spreading and the costliness of such land base due to its scarcity, particularly in regions of dense livestock population. This study adds to that literature by targeting a specific region that has experienced rapid hog expansion (i.e. the Province of Manitoba), and by summing the individual pig farms' added costs for hog manure management to obtain aggregate costs at the levels of watershed, rural municipality and province at large.

Objective

The objective of this study is to estimate the direct effect proposed phosphorus regulations in Manitoba will have on manure management costs to the province's pig producers should the proposed phosphorus regulations come into effect. The pig industry has been selected because it is among the largest agricultural sectors in Manitoba. Since the direct costs are those to be borne by pig producers they have not been adjusted to include social costs or benefits associated with the proposed phosphorus regulations. The task is to apply the framework for analysis outlined by Salvano et al. (2006) to determine an estimated direct annual provincial cost. The provincial costs will also be divided into estimated annual costs for several Manitoba watershed regions, rural municipalities and the province at large.

Method

To establish an aggregate estimate of changed manure management costs requires first a determination of the estimated cost at the individual operation or farm level. The individual costs can then be aggregated to determine an estimate at the provincial level as well as watershed level.

For the individual operation, the cost estimation is a three-step process: first, establish the base-level cost and land area. The base-level is defined as the cost and land required to spread manure based on nitrogen content (ie. N-based). Nitrogen-based application has been selected as the base-level to compare with simulation outcomes since pig operations in Manitoba are currently managing manure applications on a nitrogen basis. It is taken that all operations in Manitoba have a sufficient land base for standard nitrogen-based application since earlier manure management plans have been established on that basis; second, establish the cost and land area required under compliance to the new regulation simulations which limit manure application to two times annual phosphorus removal or one times annual phosphorus removal; third, subtract the simulation estimates from the base-level to determine the changes.

Figure 1 illustrates the method of calculation. The N-based, $2xP_20_5$ (for simplicity in nomenclature, P_20_5 is denoted as P throughout this report) and 1xP land area requirements are calculated for each pig operation in Manitoba. Each operation is then classified as either having enough land (enough now or ready access to additional adjacent land), or not having enough land to comply with the new phosphorus regulations. For those operations with sufficient land, the additional costs associated with spreading over a larger area are calculated. For those operations with insufficient land, the least-cost means for dealing with the regulation is applied – either transport manure or treat manure. The change in costs between N-based and both the 2xP and the 1xP simulations are calculated. The per-farm changed costs are then aggregated to find the total change in manure management costs for Manitoba pig producers under each level of the proposed new threshold regulations.

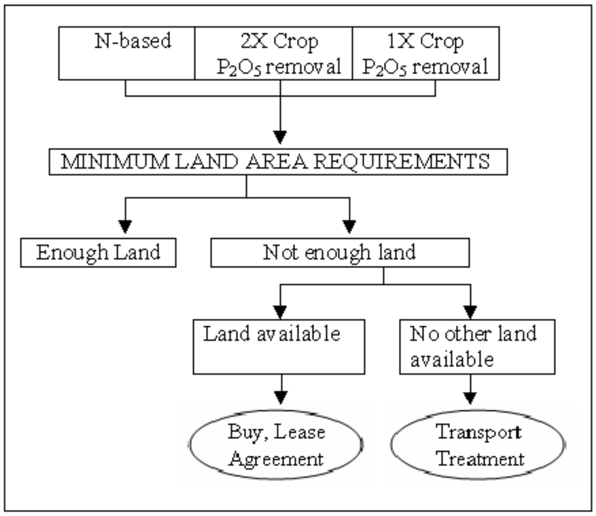

Figure 1: *General framework for minimum land requirements and cost assessment (Salvano 2006)*

Total Manure Produced

The total amount of manure produced by a pig operation is an input variable required to calculate land requirements. The total volume of manure produced by an individual pig operation is a function of operation type and size. The manure production per day for five operation types is given in Table 1. These numbers are averages for pig farmers in Manitoba assuming phytase is being added to feed rations (the addition of phytase increases phosphorus digestibility and reduces the amount phosphorus content in pig manure).

Table 1: *Total volume of manure produced per day for five types of pig operations (Dick 2006)*

Operation Type	*Description*	*Manure Produced*	*Units*
Sow, Farrow to Nursery	0 kg – 5.4 kg	23	liter/sow/day
Sow, Farrow to Weanling	0 kg – 21 kg	23	liter/sow/day
Sow, Farrow to Finish	0 kg – 108+ kg	63	liter/sow/day
Weanling	5.4 kg – 21 kg	2.3	liter/weanling/day
Finisher	21 kg – 108+ kg	7.1	liter/finisher/day

Using the manure production values in Table 1, total volume of manure produced in liters for operation i in a single year is calculated with equation 1.

$$[1]\ Total\ \ Manure_i\ \ (L) = \left(\lambda_{i1} \times 23 + \lambda_{i2} \times 23 + \lambda_{i3} \times 63.2 + \lambda_{i4} \times 2,3 + \lambda_{i5} \times 7.1\right) \times 365$$

- λ_{i1} Number of sows, farrow to nursery in operation i
- λ_{i2} Number of sows, farrow to weanling in operation i
- λ_{i3} Number of sows, farrow to finish in operation i
- λ_{i4} Number of weanlings in operation i
- λ_{i5} Number of finishers in operation i

Maximum Application Based on Nitrogen Removal

Land area for N-based manure application is a function of crop nitrogen removal rate, operation type, operation size and land availability. The nitrogen removal rate (NR_i) is the amount of nitrogen removed from the soil through cropping. A unique NR_i has been calculated using Fraser et al (2001) for each of the 25 largest pig producing municipalities in Manitoba. The calculated NR_i incorporates information on the crop mix including annual crops, forages, and grasslands. For all other rural municipalities in Manitoba a NR_i of 78.4 kilograms per hectare is used (Plohman, 2006).

In addition to NR_i, operation type and operation size a land availability index (LA_i) has been included in the land base calculation to account for land not able to receive manure (ie., treed areas, wetlands, water, urban areas, and competition from other livestock sectors). In essence, the land availability index increases the land area for N-based application by the average amount of land not able to receive manure in the municipality. For example, operations located in a municipality with a LA_i of 1.5 would require an average of 150 hectares to have access to 100 hectares for manure application. A unique LA_i has been calculated for each of the 25 largest pig producing municipalities in Manitoba based Fraser et al (2001), Flaten et al (2003), and Flaten (2006). A standard LA_i of one is used for the remaining municipalities because they contain less than 25 percent of the Province's pig operations. A low concentration of pig operations often accompanies a low concentration of other livestock sectors indicating that the competition for land is very low which is the rationale for assigning an index of one.

The N-based area for operation i is calculated with equation 2 (Plohman 2006).

$$[2]\ N-Based\ \ land\ \ area_i\ (ha) = 4.4 \times \begin{pmatrix} \lambda_{i1} \times 1 \times 18 + \lambda_{i2} \times 1 \times 19.5 + \lambda_{i3} \times 1 \times 34.6 + \\ \lambda_{i4} \times 6.4 \times 0.226 + \lambda_{i5} \times 2.9 \times 2.69 \end{pmatrix} \div NR_i \times LA_i$$

- NR_i Nitrogen removal rate (kg/ha) at location *i*
- LA_i Land availability index at location *i*

N-based manure application cost is a function of total manure and the cost of spreading manure. The N-based cost is calculated with equation 3.

$$[3]\ N-Based\ \ TC_i\ (\$) = Total\ \ Manure_i\,(l) \times C_1$$

- C_1 Cost per liter to spread manure on N-based land area

(The values for the Manitoba cost constants, C_i are listed in section Table 2 and are discussed with applying the framework to the Manitoba pig industry.) Using GIS computer software a ring can be drawn around individual farms encompassing the area of land required for manure application. Figure 2 shows the area required for the N-based manure application for three individual operations.

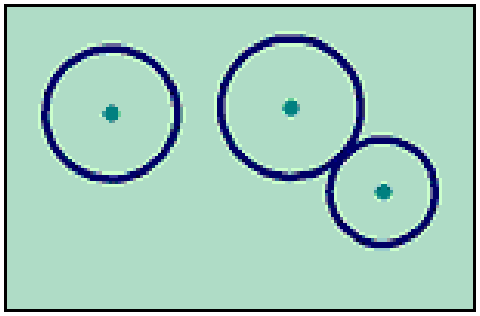

Figure 2: *GIS rings around three individual farm locations (The N-based land area is that which lies within the GIS ring)*

Maximum Application Based on 2xPhosphorus Removal

The first simulation parallels the proposed threshold for the new phosphorus regulations not to exceed two-times the crop phosphorus removal rate. If the new regulation is mandated at this level, both the area and cost of manure management will change from the existing N-based level.

The area of land required to apply total manure produced at a rate up to twice the phosphorus removal is a function of phosphorus removal rate, operation type, operation size, and land availability. The total area of land required is calculated using equation 4 (Plohman, 2006).

$$[4]\ 2 \times P\ land\ area_i\ (ha) = 2.2 \times \begin{pmatrix} \lambda_{i1} \times 1 \times 12.3 + \lambda_{i2} \times 1 \times 13.3 + \lambda_{i3} \times 1 \times 21.5 + \\ \lambda_{i4} \times 6.4 \times 0.117 + \lambda_{i5} \times 2.9 \times 1.47 \end{pmatrix} \div (2 \times PR_i) \times LA_i$$

- PR_i Phosphorus removal rate (kg/ha) at location i
- LA_i Land availability index at location i
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Land area for P-based manure application is a function of crop phosphorus removal rate, operation type, operation size, and land availability. The phosphorus removal rate (PR_i) is similar to the NR_i in the sense that it is the amount of phosphorus removed from the soil through cropping. A unique PR_i has been calculated using Fraser et al (2001) for each of the 25 largest pig producing municipalities in Manitoba. The calculated PR_i incorporates information on the crop mix including annual crops, forages, and grasslands. For all other rural municipalities in Manitoba, a NR_i of 33.8 kilograms per hectare is used (Plohman, 2006). The land availability index (LA_i) is the same as described in the previous section.

Using the 2xP land area in hectares each operation i is classified into one of two categories; having enough land or not having enough land available to spread manure produced by their pig operation. There are three options for operations that are classified into the second category:

- Truck surplus manure up to 20 kilometers
- Truck surplus manure up to 40 kilometers
- Treat the manure to remove phosphorus and then spread it on existing land

The trucking distances have been customized for the province of Manitoba by Salvano et al. (2006). Trucking distances should be customized by province to represent industry standards. The two scenarios and three options leave four mutually exclusive and exhaustive cases.

This leaves the decision to be made for each operation i as to which classification it receives. A GIS program is used to map the 2xP land area for each location by placing a ring around the barn encompassing the area calculated using equation 4. An illustrative example is shown in Figure 3 for the same three individual operations as depicted in Figure 2. By assessing the GIS ring each operation i is classified as one of the four cases according to the following procedure:

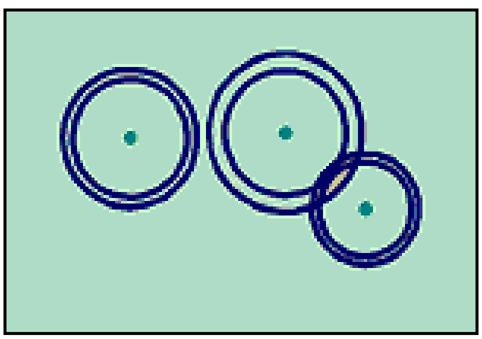

Figure 3: *GIS rings around three individual farm locations (The 2xP land area is that which lies within the outer GIS ring, the N-based land area is that which lies within the inner GIS ring)*

Case 1: Enough land If the GIS ring around operation i is not overlapped by any other operation's GIS ring, the operation is classified as Case 1. The manure management cost can be calculated by equation 5 and is denoted as 2xP TC_{i1}.

$$[5]\ 2\times P\ TC_{i1}\ (\$) = \frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i} \times Total\ Manure_i \times C_1 + \left(1 - \frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i}\right) \times Total\ Manure_i \times C_2$$

- C_1 Cost per liter to spread manure on N-based land area
- C_2 Cost per liter to spread manure on land beyond N-based land area

Case 2: Not enough land, Truck surplus up to 20 km If the GIS ring around operation i is overlapped by adjacent GIS rings by less than 25 percent, the operation is classified as Case 2. The manure management cost is calculated with equation 6 and is denoted as 2xP TC_{i2}.

$$[6]\ 2\times P\ TC_{i2}\ (\$)=\frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i}\times Total\ Manure_i\times C_1+\left(1-\frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i}\right)\times Total\ Manure_i\times C_2+Percent\ Overlap_i\times Total\ Manure_i\times C_3$$

- C_1 Cost per liter to spread manure on N-based land area
- C_2 Cost per liter to spread manure on land beyond N-based land area
- C_3 Cost per liter to transport manure up to 20 kilometers

Case 3: Not enough land, Truck surplus up to 40 km If the GIS ring around operation i is overlapped by adjacent GIS rings by less than 25 percent and the operation is located in La Broquerie, De Salaberry or Hanover (the concentration of livestock operations in these rural municipalities, together with more-limited land availability creates a condition where their producers are forced to truck surplus manure further than would be the case in other Manitoba municipalities, hence the special treatment), the operation is classified as Case 3. The manure management cost is calculated with equation 7 and is denoted as 2xP TC_{i3}.

$$[7]\ 2\times P\ TC_{i3}\ (\$)=\frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i}\times Total\ Manure_i\times C_1+\left(1-\frac{(N-Based\ land\ area_i)}{2xP\ land\ area_i}\right)\times Total\ Manure_i\times C_2+Percent\ Overlap_i\times Total\ Manure_i\times C_4$$

- C_1 Cost per liter to spread manure on N-based land area
- C_2 Cost per liter to spread manure on land beyond N-based land area
- C_4 Cost per liter to transport manure up to 40 kilometers

Case 4: Not enough land, Treat manure If the GIS ring around operation i is overlapped by adjacent GIS rings by more than 25 percent (the cost threshold between purchasing a treatment system and trucking manure occurs at a 25 percent overlap) it is classified as Case 4. The manure management cost is calculated with equation 8 and is denoted as 2xP TC_{i4}.

$$[8]\ 2xPTC_{i4}(\$)=(N-BasedTC_i)+TotalManure_i\times C_5+C_6$$

- C_5 Variable cost per liter to treat manure
- C_6 Fixed cost per year for treatment system

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Maximum Application Based on 1xPhosphorus Removal

The second simulation parallels the proposed threshold for the new phosphorus regulations not to exceed the crop phosphorus removal rate. If the new regulation is mandated at this level, both the area and cost of manure management will change from the existing N-based level.

The area of land required to apply total manure produced at a rate up to the crop phosphorus removal is a function of phosphorus removal rate, operation type, operation size, and land availability. The total area of land required is calculated using equation 9 (Plohman, 2006).

$$[9]\, 1\times P\ land\ area_i\ (ac) = 2.2\times\begin{pmatrix}\lambda_{i1}\times 1\times 12.3+\lambda_{i2}\times 1\times 13.3+\lambda_{i3}\times 1\times 21.5+\\ \lambda_{i4}\times 6.4\times 0.117+\lambda_{i5}\times 2.9\times 1.47\end{pmatrix}\div PR_i\times LA_i$$

- PR_i Phosphorus removal rate (kg/ha) at location i
- LA_i Land availability index at location i

Equation 10 follows with the simplification of equation 9.

$$[10]\, 1\times P\ land\ area_i\ (ha) = 2\times(2\times P\ land\ area_i)$$

The 1xP land area is then used to classify each operation i into one of the four mutually exclusive and exhaustive cases by analyzing the GIS map according to the same procedure as the previous section, under a maximum application of 1xP removal. To avoid duplication, equations 5 through 9 can be modified by replacing 2xP with 1xP to form equations 10 through 14. An illustrative example is shown in Figure 4 for the same three individual operations as depicted in Figures 2 and 3.

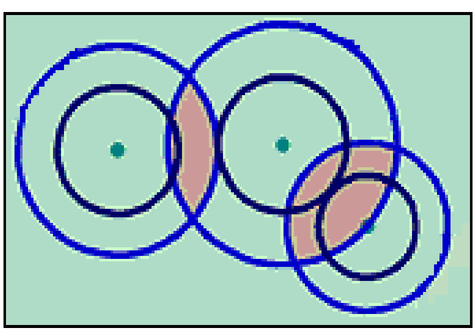

Figure 4: GIS rings around individual farm locations (The 1xP land area is that which lies within the outer GIS ring, the N-based land area is that which lies within the inner GIS ring)

The Change in Total Manure Application Costs

To find the increase in cost of manure management to an individual operation i due to the implementation of proposed phosphorus regulations, the results from previous steps are applied and subsequent calculations are made as follows:

Proposed Threshold 1: Manure can be applied up to a maximum of two-times the crop removal rate of phosphorus.

$$[15]\ \Delta 2 \times P\ TC_i\ (\$) = (2 \times P\ TC_i) - (N - Based\ TC_i)$$

Proposed Threshold 2: Manure can be applied up to a maximum of one-times the crop removal rate of phosphorus.

$$[16]\ \Delta 1 \times P\ TC_i\ (\$) = (1 \times P\ TC_i\ ) - (N - Based\ TC_i)$$

Total Manure Application Cost Increase to Industry due to proposed Phosphorus Regulations

Given the individual operation costs determined with equations 15 and 16, the total cost of proposed phosphorus regulations to the total pig industry (an industry aggregate cost) is calculated with equations 17 and 18 that follow:

Proposed Threshold 1: Manure can be applied up to a maximum of two-times the crop removal rate of phosphorus.

$$[17]\ TC_A(\$) = \sum_{i=1}^{n} \Delta 2 \times P\ TC_i$$

Proposed Threshold 2: Manure can be applied up to a maximum of one-times the crop removal rate of phosphorus.

$$[18]\ TC_B(\$) = \sum_{i=1}^{n} \Delta 1 \times P\ TC_i$$

Applying the Framework to the Manitoba Pig Industry

Data used to Model the Manitoba Pig Industry

To calculate the cost of the proposed phosphorus regulations to the pig industry in Manitoba, data was obtained from the Manitoba Pork Council Premises Registration Form. There are approximately 1,000 (Clark, 2006) operations in Manitoba, with 851 fully completed Premises Registration Forms submitted as of March 31, 2006. The 851 surveyed pig operations are assumed to be representative of the approximate 1,000 pig operations in the Province.

Data is reported on the Premises Registration Form in animal units. Producers are asked to report the maximum capacity of their operation for each of the five facilities shown in Table 1. The animal units are converted to number of head in each class for use in modeling.

Calculation of Model Constants

Cost figures are assigned to each of the six constants (represented as C_i) in the model. The value of each constant depends on production practices as well as technology, land availability, and fuel prices. Salvano et al. (2006) have calculated the cost constants for the province of Manitoba. These constants are used to find the total cost of complying with the regulations and are listed in Table 2.

Table 2: *Values for cost constants C_i for the province of Manitoba*

Constant	*Description*	*Value*
C_1	Cost to spread manure over base-land area (per liter)	0.36¢
C_2	Cost to spread manure over land beyond N-based (per liter)	0.45¢
C_3	Cost of transporting manure up to 20 kilometers (per liter)	0.73¢
C_4	Cost of transporting manure up to 40 kilometers (per liter)	1.50¢
C_5	Variable cost of treating manure (per liter)	0.40¢
C_6	Fixed cost per year for treatment system (Cost includes a basic LISOX system with concrete tanks, including the cost of electrical and process installation calculated with a 7.5% interest rate and straight-line depreciation over 10 years)	
	▪ Less than 11,365,225 liters	$55,000
	▪ 11,365,225 to 22,730,450 liters	$82,500
	▪ More than 22,730,450 liters	$140,037

Model Assumptions

As with any economic model, there are a set of assumptions incorporated. These assumptions should be kept in mind when interpreting the final results. The assumptions include:

i. Classification of manure management practices are representative of industry practices.

ii. The 851 surveyed pig operations are representative of the total of approximately 1000 pig operations in the Province.

iii. All landowners in Manitoba are willing to have manure spread on their land.

iv. Cost constants (C_i) are assumed to be non-decreasing.

Care has been taken to underestimate rather than overestimate the direct cost when forming each assumption. If any of the above assumptions were to be relaxed the direct cost would most likely increase rather than decrease.

Results

The estimated added annual cost to the Manitoba pig industry under a maximum threshold regulation of two-times phosphorus removal rate is 17.88 million dollars and the estimated added annual cost to the industry under a maximum threshold regulation of one-times phosphorus removal rate regulation is 27.86 million dollars, representing 18 and 28 percent of the estimated annual 2005 net income accruing to pig producer in the province respectively.

The added annual costs are not distributed evenly across the province. The Red River Basin faces the greatest added annual costs of 23.27 million dollars followed by the Assiniboine River Basin and the Lake Winnipeg Basin, as listed in Table 3. To give a geographical representation, the added annual costs to each watershed basin in Manitoba are illustrated in Figure 5, with darker regions indicating larger direct costs than lighter regions.

Table 3: *The added annual cost for compliance to the maximum threshold regulations of 2xP and 1xP removal for the major drainage areas contributing to Manitoba*

Rural Municipality	*Δ1xP*	*Δ2xP*
Red River Basin	$23,274,000	$15,123,000
Assiniboine River Basin	$1,490,000	$781,000
Lake Winnipeg Basin	$1,370,000	$1,161,000
Lake Manitoba Basin	$1,017,000	$439,000
Winnipeg River Basin	$803,000	$434,000

Note: There is no added cost for the northern water basins ie. Seal River, Churchill River, Nelson River, Hayes River and Saskatchewan River Basins

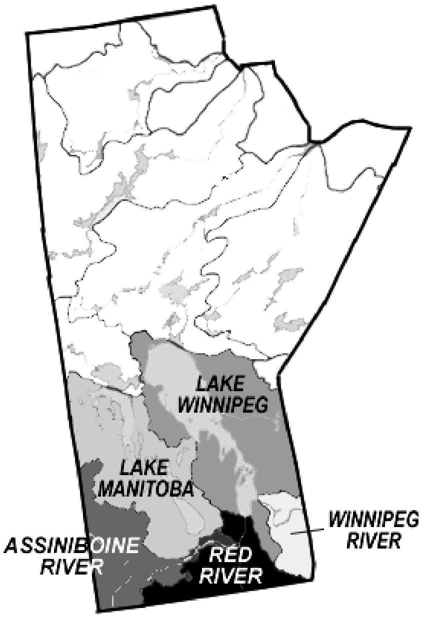

Figure 5: *Geographical representation of the added annual cost for compliance to the maximum threshold regulations for the major drainage areas contributing to Manitoba*

The annual costs on an R.M. basis are reported in Table 5 since many environmental and political decisions are made at the R.M. level. The R.M. of Hanover faces the greatest added annual costs followed by La Broquerie, De Salaberry, Morris, and Ste. Anne, as listed in Table 4.

Table 4: *The R.M.s with the largest added annual cost for compliance to the maximum threshold regulations of 2xP and 1xP removal*

Rural Municipality	*Δ1xP*	*Δ2xP*
Hanover	$6,682,000	$4,862,000
La Broquerie	$2,924,000	$2,001,000
De Salaberry	$1,871,000	$1,344,000
Morris	$1,608,000	$1,050,000
Ste. Anne	$1,213,000	$ 861,000

The added annual costs are also not distributed evenly across all operations. Operations with enough land face less added costs than those that require trucking or treatment. Table 5 lists the percentages of operations falling into each of the four cases – enough land, truck up to 20 km, truck up to 40 km, and treat manure for the province of Manitoba.

Table 5: *Percentage of operations being classified as each of the four cases – enough land, truck surplus up to 20 km, truck surplus up to 40 km and treat manure*

	2 x Phosphorus Removal (Percent of Operations)	*1 x Phosphorus Removal (Percent of Operations)*
Case 1: Enough land	68.86%	56.87%
Case 2: Truck surplus up to 20 km	6.93%	9.75%
Case 3: Truck surplus up to 40 km	5.99%	4.58%
Case 4: Treat manure	18.21%	28.79%

Discussion and Conclusions

The intent of the proposed phosphorus soil test threshold regulation in the province of Manitoba is to protect Manitoba waterways and water bodies by preventing over-application of manure phosphorus. The proposed policy change will benefit the environment and society at large, however the changes do not come without a cost to livestock producers. In the case of the proposed phosphorus threshold regulation the cost to pig producers alone is substantial, at 18 and 28 percent of net income for the 2xP and 1xP simulations respectively. The direct effect of the proposed phosphorus threshold regulation on manure management costs to the province's pig producers should the proposed phosphorus regulations come into effect are 18.88 and 27.86 million dollars. These figures do not include costs borne by other livestock sectors nor have they been adjusted for environmental and social costs and/or benefits. With many of the benefits of the policy being public goods, it brings about several questions on whether or not the public should be responsible for fully or partially compensating primary producers. When evaluating the proposed phosphorus threshold regulations on manure management decision makers should not ignore the fact that the changes come at a cost to the Province's primary livestock producers.

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