Cost Benefit of

Organized Drainage

Stewardship Practices Project

Prepared for

Moose Jaw River Watershed Stewards Inc.

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by

Cecil N. Nagy MSc.

Ken Belcher PhD

Department of Bioresource Policy, Business and Economics,
University of Saskatchewan

Executive Summary

A cost benefit analysis of the Okabena Drainage Cooperative established in 2012 and the Madrid Conservation & Development Area established in 1975 was carried out. The setup costs, capital cost, yearly maintenance and operating costs of the projects were compared to the net gains in efficiency, and net return to the flooded area.

The benefit to cost ratio for the Madrid project as a whole was $7.03 for every dollar of capital cost with the Public getting $4.70 for every dollar spent and the Private (landowners) getting $2.32 back for every dollar of capital cost (Figure 1). Given that landowners in the Madrid Conservation & Development Area contributed 33% of the capital cost, the share of the benefits appears to be consistent with the contribution to the capital cost of the project.

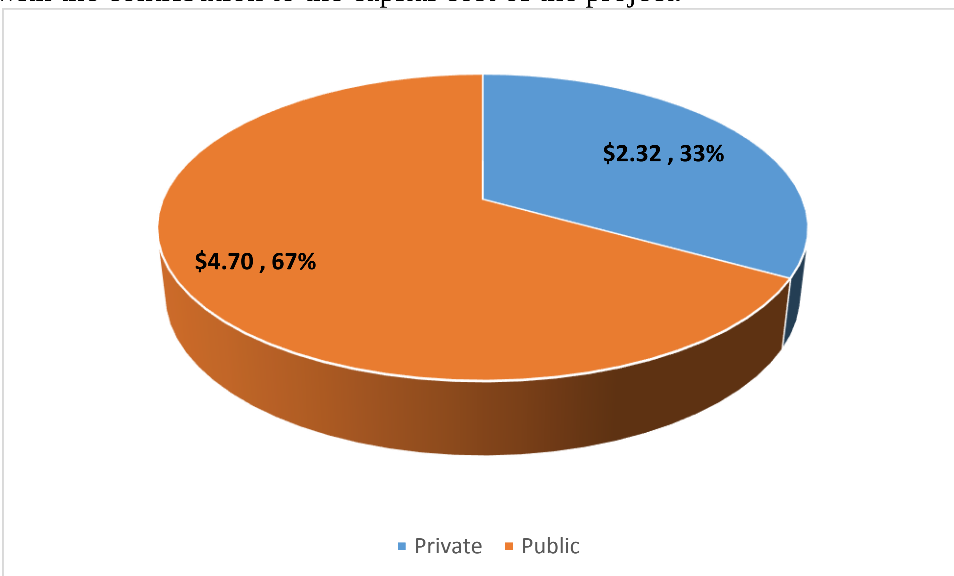

Figure 1: Madrid Public & Private Benefit to Cost Ratio

The expected benefit to cost ratio for the Okabena Drainage Cooperative as a whole was $2.65 for every dollar of capital cost with the Public getting $2.43 for every dollar spent and the Private (landowners) getting $0.22 back for every dollar of capital cost (Figure 2). Given that the landowners in the Okabena Drainage Cooperative contributed 58% of the capital cost the public is getting a relatively high return on their share of the project development costs.

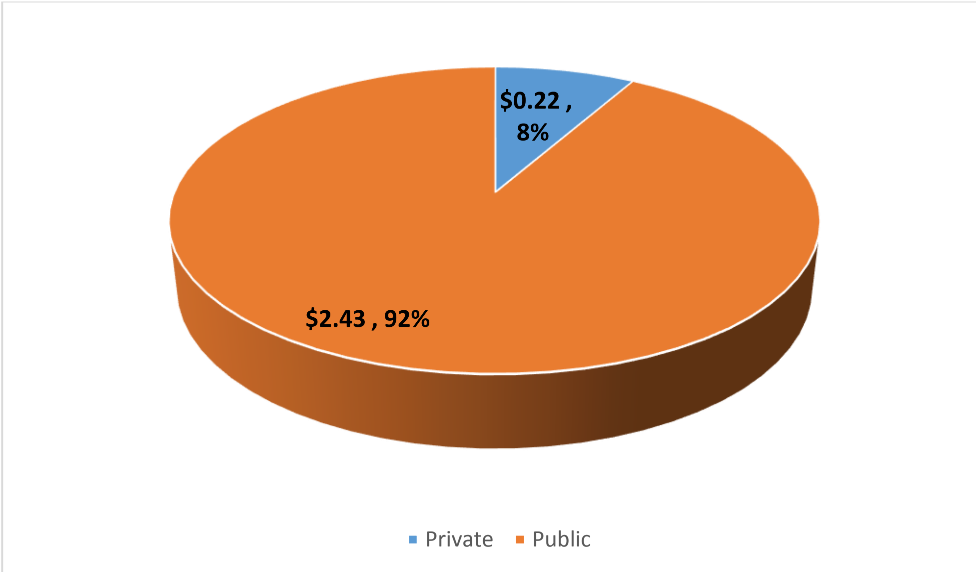

Figure 2: Okabena Public and Private Benefit to Cost Ratio

To compare the net impacts of co-ordinated to uncoordinated drainage a "What-If" scenario was developed for the Madrid Conservation & Development Area. Specifically this analysis examined what if the Madrid project didn't get established in 1975 so that the comparison is the difference in the stream of benefits and costs over the 1975-2012 period of having a project to not having a project. The net present value of the difference between having a drainage project to having an uncontrolled area is $3.9 million.

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Introduction

With the development of agricultural land and the intensification of crop production there has been a stronger focus on maximizing the productivity of the land resource by agricultural producers. As a result, there has been ongoing private and public investment in the drainage of surface water from agricultural land. More heavily drained land has the potential to contribute greater levels of nutrients and sediments to surface water thereby decreasing downstream water quality and impacting society. Further, unorganized drainage activities have also been linked to increased costs to downstream landowners due to flooding issues associated with greater flows of water moving across fields and longer durations of standing water restricting agricultural production activities.

Within the province of Saskatchewan the Water Security Agency (WSA) is the government branch that oversees provincial legislation dealing with drainage of farm land. The Drainage Control Regulations 1981 amended 1982; 2006; outlines the requirements for a drainage proposal that is to be submitted for permit approval, notification of proposal and appeal procedure for those affected. The program specifies that: *Any person who claims to have suffered or anticipates suffering any damage, loss or injury caused by construction, extension, alteration, or operation of any drainage works may file a written complaint with the Water Security Agency. The Water Security Agency's investigation will focus on verifying if works are present, the effect on the timing and volume of surface water flows and deciding if the impact will cause or is anticipated to cause significant damage* (Water Security Agency). In 2011, a particularly wet year after a series of years with average or below average precipitation, complaints about illegal drainage increased dramatically and resulted in a backlog of complaints about illegal drainage to the WSA (CBC news Saskatchewan). Addressing complaints about these drainage activities imposes significant costs, increased administrative and legal activities to address the complaints as well as the costs to landowners of loss of land use with increased flooding, municipal investment in ad hoc water conveyance infrastructure as well as the impacts of neighbouring landowners being pitted against each other. In August, 2013, the WSA launched an online consultation forum to develop new approaches and regulations on agricultural drainage with discussion focused on downstream flooding, water quality and effects on biodiversity (Water Security Agency, 2013).

An example of a local response to address some of the issues around agricultural land drainage is to develop organized drainage initiatives that depend on agreement from all potentially impacted landowners within a watershed or sub-watersheds. The mechanism for these drainage projects is to manage the water within the watershed such that the drainage infrastructure is developed to enable water to be held in the upper reaches of the watershed for a period of time until water in the lower reaches is allowed to flow off the land. In this approach all landowners in the watershed agree to the water management plan. In addition, these organized drainage initiatives have the capacity to develop an infrastructure to convey water off the land that can minimize the erosion of soil and nutrients and thereby decreasing the downstream effects of surface water pollution. A cost benefit analysis of two such drainage projects in the Rouleau-Drinkwater area of the Moose Jaw River Watershed was developed to compare the net economic impact of the Madrid Conservation & Development Area and Okabena Drainage Co-operative Ltd. Construction and maintenance costs over the life of a project were estimated to represent the primary costs imposed by the development of the projects. The benefits that could be attributed to the project included private landowner benefits related to changes in land productivity as well as the public benefits of reduced government program expenditures, reduced cost of litigation to the government and net environmental benefits. As part of the analysis the data will be used to develop an interpretation of the net impacts of uncoordinated drainage as compared to the impacts calculated for the two subject organized drainage projects.

Drainage Projects' Description

The two projects for analysis are the Okabena Drainage Cooperative established in 2012 and the Madrid Conservation & Development Area established in 1975. Both projects are southeast of Moose Jaw in the Rouleau-Drinkwater area with the Madrid project in the rural municipalities of Pense #160, Moose Jaw #161 and Redburn #130 and the Okabena project in the RM of Redburn #130 and Pense #160 (see Appendix A for maps). The Okabena project comprises approximately 14,800 acres while the Madrid project covers approximately 22,000 acres. The Madrid project cost $250,000 in 1975 ($1,060,345; 2012 dollars) while the Okabena project cost $900,000 in 2012. The land in this region is highly assessed for property taxes as it is very productive farmland. The Trans-Canada Highway, the Canadian Pacific Rail mainline and a CPR branch line crosses the Madrid project while a CPR branch line and Provincial Highway #39 goes across the Okabena project area.

Land and Cropping Activities

In general, the cropping history of this region of Saskatchewan was primarily a wheat-fallow rotation until the mid-1990s when lentils and canola started to take hold. Also, since 2000 there has been a significant decline in summerfallow in this region. The land use activities in the two municipalities that contain most of the two drainage projects is presented in Figure 3 and Figure 4 for the RM of Redburn and the RM of Pense, respectively. Crop production is the dominant activity at over 82% of the area with summerfallow and pasture (Tame & Natural) comprising most of the rest of the land use activities.

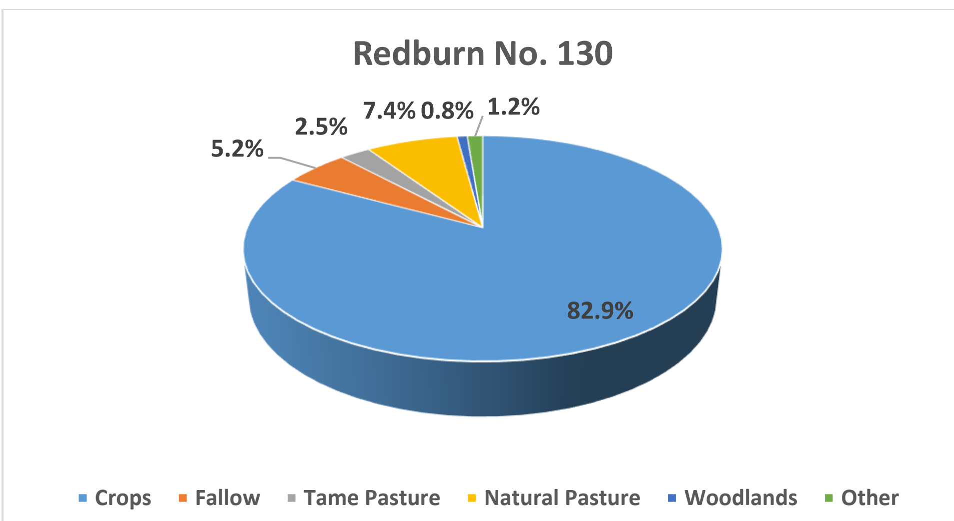

Figure 3: 2011 Land Use in the Rural Municipality of Redburn #130
Source: Statistics Canada, Census of Agriculture, 2011

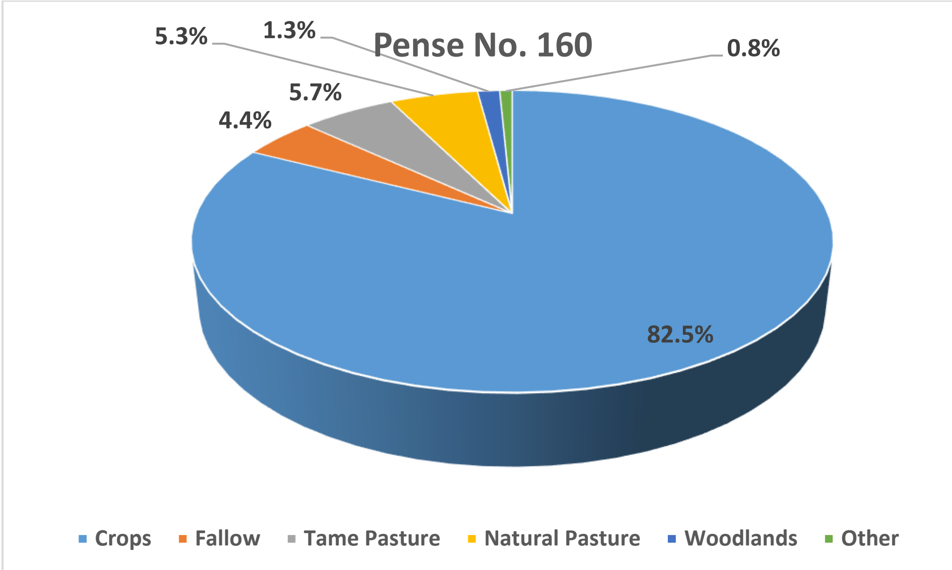

Figure 4: 2011 Land Use in the Rural Municipality of Pense #160
Source: Statistics Canada, Census of Agriculture, 2011

As a percentage of area of annual crops plus summerfallow, 94% of the cultivated area is cropped in the two RMs. The major crops grown in the two RMs are durum, spring wheat, canola, lentils, barley and field peas. Cereals dominate with pulse crops and oilseeds combined making up 55% of the rotation (Table 1). Lentils and field peas comprise most of the area in pulses while canola and flax are the main oilseeds grown.

Table 1: Cropping Activities as a Percentage of Cropped Area 2011

Municipality	Cereals	Oilseeds	Pulse	Hay
Redburn No. 130	41.1%	24.7%	31.6%	2.6%
Pense No. 160	39.7%	26.4%	28.8%	5.1%

Source: Authors' estimates from Statistics Canada, Census of Agriculture, 2011.

Since 1975, the crop rotation in these RMs have changed considerably with a dramatic decline in summerfallow and increase in area seeded to pulse and oilseed crops. Aerial photos taken of the townships that contain the drainage projects over the 1978-1982 period reveal most of the land used strip cropping practices and that a considerable amount of land was fallowed (Saskatchewan Government 1982). The pattern of strip cropping would suggest that some fields with low spots where water might collect were generally farmed separate from adjacent cropland. However, current Google satellite images reveal that the practice of strip cropping is almost nonexistent. Some half sections and whole sections appear to be farmed as a complete block.

Changes in tillage practices have also occurred in this region where once conventional tillage (two or more pre-seed tillage passes) dominated to now where zero tillage is the dominant practice (Pense 51.1%; Redburn 67.6%; Statistics Canada, Census of Agriculture, 2011). The change in tillage practices has implications as to the effect of wind and soil erosion on the quality of drainage water overtime.

Livestock Activities

The number of farms that have cattle, horses Llama, or poultry in the RMs of Pense and Redburn is presented in Table 2. Livestock operations can be non-point sources of nitrogen and phosphorus that can end up in waterways. In 2010 solid manure was applied and incorporated on 295 acres and 585 acres in RM Redburn and RM Pense, respectively while the area of manure that was not incorporated was 532 acres and 720 acres, respectively (Statistics Canada, Census of Agriculture, 2011). The area of natural fertilization by livestock was 14,336 acres and 5,345 acres, in RM Redburn and RM Pense, respectively (Statistics Canada, Census of Agriculture, 2011). There was no liquid manure applied in the RMs in 2010. Within the drainage districts there appears to be no livestock facilities or pasture areas. Therefore, no non-point sources from livestock activities will be included in the estimation of net environmental estimates.

Table 2: Number of Livestock Farms that have the Type of Livestock

Municipality	Cattle	Pigs	Horses	Llamas	Bison	Poultry	Other
Redburn #130	16	0	10	0	0	3	0
Pense #160	24	1	18	15	1	21	3

Source: Statistics Canada, Census of Agriculture, 2011.

Crop Inputs

Most of the cropland in the RMs of Redburn and Pense would have received commercial crop inputs that could end up in water that drains from the project area into the Moose Jaw river system. In 2010, fertilizer and herbicides were used in commercial crop production in these RMs on most acres (Table 3). Insecticides and Fungicides were used on a significant area in these RMs in 2010. Most of the fungicides would have been used on pulse and oilseed crops during the growing season. Crop input application prior to a major precipitation or flood event could result in these chemicals getting into the drainage water. There is no data on the application timing, method or rates for these pesticides or fertilizer for any given year. However, given how the seeding technologies, cropping practices and intensity of seeding has changed overtime some general assumptions can be made so that net environmental estimates can be made.

Table 3: Percentage of Cropland that Commercial Crop Inputs were Applied

Municipality	Herbicide	Insecticide	Fungicide	Fertilizer
Redburn No. 130	86.7%	16.1%	31.2%	74.3%
Pense No. 160	95.8%	7.6%	24.6%	86.7%

Source: Statistics Canada, Census of Agriculture, 2011.

Precipitation in the Rouleau-Drinkwater Area

Environment Canada's estimate of average precipitation at Moose Jaw over the 1971-2000 period is 365.3 mm, with growing season[1] at 206.2 mm and winter season[2] 108.8 mm. From 1975 to 2012 nineteen of the thirty-eight years had above normal growing season precipitation and 18 of thirty eight years above normal yearly precipitation (Figure 5). Winter season precipitation was above normal in 17 of the 38 years. Highest monthly precipitation was 236.6 mm in June of 1999 with 26 months over the 1975-2012 period in which the precipitation exceeded 100 mm. The highest

[1] Growing season is the May to August period.

[2] Winter season is November to April period.

annual precipitation was in 1999 at 722.3mm. Notable drought years in this period were 1988 (217.1mm), 2001 (246.5mm), 1980 (235.7mm) and 1984 (242.8mm) having substantially lower than average annual precipitation. Given that most of the precipitation falls during the growing season it is not surprising that annual and growing season precipitation are highly correlated (94.6%). Average net evaporation for the Rouleau-Drinkwater area from Saskatchewan Watershed Authority 2009 is 575 mm for the 1997-2006 period for lakes and small water bodies. Typically water levels in sloughs and potholes rise in the spring or when there is a wet fall especially if the soil is saturated. In most years the drainage system would only run in the spring (April-May) or after high rainfall events.

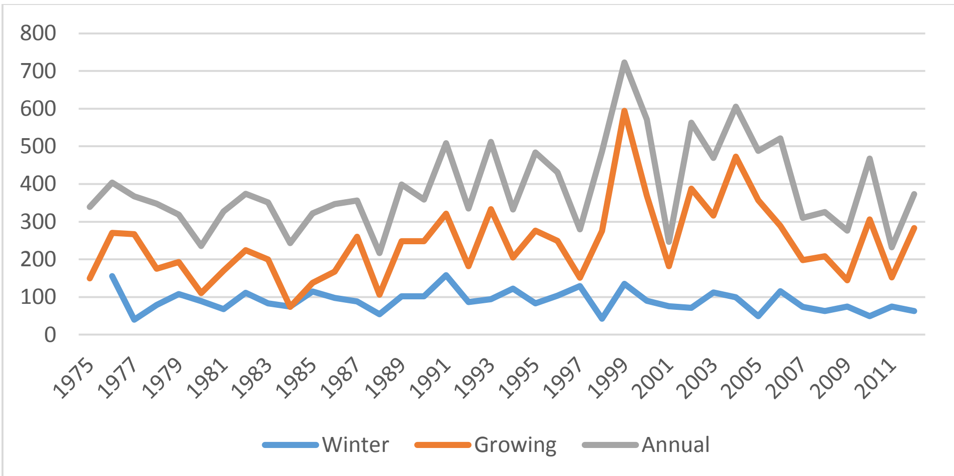

Figure 5: Annual, Growing Season & Winter Precipitation (mm)

Source: Environment Canada.

1. Growing season is the May to August period.
2. Winter season is November to April period

Literature Review

In a year when there is excess water on the land a surface drainage system will change the pattern of surface water movement from the land. Changes to a specific quarter section of land may be positive or negative depending on the pre and post drainage patterns. The time available for machinery operations and warming of the soil will also be dependent on the drainage patterns. Soil temperature of a wet saturated soil is from 4˚C to 8˚C lower than a comparable well drained soil (Irwin 1977). Soil bearing strength is also affected by wet soil as machinery traffic can leave ruts affecting crop yield and other machinery operations. Effects on machinery operation and efficiency along with the number of operations that are needed to complete a specific task will change with the timing of drainage. Crop yield and quality can be affected as delays in planting can affect the yield and quality as the crop could be subjected to higher summer temperatures at critical periods in the crop's development and a greater chance to be affected by fall frost. All crops are not affected to the same extent and quality discounts vary significantly between crops. Delayed seeding may result in a preferred crop not being planted on a given quarter section of land.

Downstream effects in changing the peak flow rate and timing of the peak flow rate can occur with surface drainage however, it is the cumulative effect of drainage projects on a watershed that can have a major effect on the peak flow rate of streams (Whitely 1979). Nitrogen, phosphorus and pesticides from agriculture activities can be carried by surface water drainage affecting the quality of water in streams and lakes (Evans et al. 1995; De Jong et al. 2009; Domagalski et al. 2008). Where surface water flow control structures are present the effect of pollutants entering streams and lakes is reduced (Evans et al. 1995).

Removal of surface water can affect the water table as less water percolates into the ground water which can be positive in reducing nitrates leaching into ground water and negative as a lower water table can negatively impact wells in the area. Salinization in areas affected by artesian pressure can be a problem in some areas, and surface water not being filtered by the soil could impact water quality (Manitoba Agriculture Food and Rural Initiatives 2013).

A drainage project with the proper ditching and water course constructing may have lower soil erosion compared to the pre-drainage project era (Agriculture and Agri-Food Canada 2007). Changes in the quality of water leaving the drainage area are a concern for management of the rivers and lakes downstream of a drainage project.

In a relevant study Wanchuk and Apedaile 1988 estimated the cost and benefits of 15 surface drainage projects in Alberta for the 1972-84 period. They found that 14 of the 15 projects that they analysed were viable with surface drainage providing a 15 year internal rate of return ranging from 39.2% to 77.9% using a 5% discount rate. The benefits of increased production from the drained area, reduced costs as fields are consolidated and less waterfowl damage were estimated. Initial project cost, land reclamation cost, yearly maintenance and operating costs of the drainage project were included to calculate the net benefit. Project cost includes all survey engineering design, culverts, and drainage construction costs. Land reclamation cost may include breaking, rock picking, weed control and tillage operations that were extra relative to adjacent non flooded land. The drainage system requires yearly maintenance to insure that the water can flow as designed through the ditches and culverts. Yearly operating costs of running the drainage project were also included and farmer interviews were used to estimate private costs and benefits, while yearly maintenance costs of a project was estimated at 3% of the project cost if data was missing.

Taxable Land Assessment

The construction of a drainage ditch can affect the taxable assessment if it constitutes a "man-made hazard" that affects farm operation costs (Suchan 2013). Also, land that is subjected to periodic flooding may have flooding deductions used in estimating the taxable assessment which would be removed with an operating drainage project.

> For property assessment purposes:
> 1. *Cultivated land impacted by drainage ditches may be eligible for a "man-made hazard" allowance if it impacts typical farm operation costs. See document number 2.1.9, page four of our Assessment Manual which is on our web site www.sama.sk.ca. If the drainage project is successful, the assessment of the land that has been drained may be updated to reflect the new use (i.e. land can now be cultivated) and/or removal of flooding deductions as the flooding risk has been mitigated. Flooding adjustments are based upon long term flooding patterns (i.e. 25-30 years) and can be found on document 2.1.8 pages 1-2 of the Manual.*

2. Some drainage ditches could be considered structures and this potentially be assessed. At this time we have not inventoried or assessed drainage ditches.

Model

A cost benefit analysis over the life of the drainage project where all costs, both private and public, along with the stream of benefits is used to estimate the economic return of a project.

When public funds are used the cost of capital should be considered when evaluating projects as either there is a cost to raising the funds from taxpayers or governments borrow the required funds. The modified internal rate of return (MIRR) was estimated where the cost of finance for investments and the interest on reinvestment is used in the calculation of the internal rate of return. The MIRR is also useful for estimating the private rate of return as other uses for the limited funds may offer a higher return. Using a cost of finance of 8% and an interest rate on reinvestment of 10% the MIRR for the drainage projects is estimated.

Since, the Madrid project life is 38 years (1975-2012), the return to the Okabena project will use the same period. It will be "What If" Okabena had been in place in 1975 so that a comparison of the two projects' Benefit/Cost analysis can be made. Area cropping intensity and crop rotation from 1975 to 2012 are estimated from data for Crop District 2B. This enables an estimate of the net return to the land that would have been flooded in the Madrid and Okabena projects.

Data for each quarter section that is in a project is used to estimate the net benefit for each quarter section of land. Percent of land in the project, cultivated area, flood prone area and cropping intensity, along with the share of the drainage project's construction, maintenance and operating costs are the variables used to estimate the net benefit. A pre and post project assessment is made of these variables to arrive at the net effect of a drainage project. By generating the Benefit/Cost on a quarter section basis the differences in area flooded and permanent drainage infrastructure effects on the net return can be estimated. This will enable an assessment as to whether land that has post drainage permanent infrastructure is compensated for the loss in revenue. Part or all of 139 quarter sections are in the Madrid Conservation & Development Area with an estimated 22,000 acres. The Okabena Watershed Cooperative Ltd has parts or all of 106 quarter sections in the project covering about 14,880 acres.

The equation used to estimate the Benefit/Cost ratio and MIRR is presented below where the cost of the project is composed of the onetime setup and capital cost plus the annual maintenance and operating costs. The stream of benefits from reduced flooded area are the reduced delayed seeding costs, revenue from the flooded area, efficiency gains, reduced crop insurance payouts, foregone legal costs, minus the lost revenue from the permanent infrastructure where there was nothing before and the net environmental benefit.

$$Life\ Time\ Cost = [Set\ Up] + [Capital\ Cost] + [Annual\ Maintenance\ \&Operating]$$

$$\begin{aligned} Life\ Time\ Benefit \\ &= [Cost\ of\ Delayed\ Seeding] + [Net\ Crop\ Revenue] \\ &+ [Net\ Efficiency\ Gains] + [Reduced\ Crop\ Insurance\ Payouts] \\ &+ [Foregone\ Legal\ Costs] - [Lost\ Revenue\ from\ Drainage\ Ditch] \\ &+ [Net\ Environmental\ Benefit] \end{aligned}$$

$$B = \sum_j^q \left(\sum_i^n (Rji - Cji - Oji - Mji + Fji + Sji) - Ej - Pj\right) - Y - G + L$$

J = 1 to q quarter sections of land in the drainage project,
I = 1 to n years over the life of the drainage project,

Where

B = the net benefit of the drainage project,
R_{ji} = revenue from the flooded area for quarter section j in the i^{th} year,
C_{ji} = costs of cropping the flooded area for quarter section j in the i^{th} year,
E_j = net environmental cost,
P_j = drainage project capital cost funded by landowner for quarter section j,
O_j = drainage project yearly operating costs for quarter section j in the i^{th} year,
M_j = drainage project yearly maintenance costs for quarter section j in the i^{th} year,
F_j = net machinery efficiency gains of reducing flooded area minus the loss in efficiency due to permanent drainage channels for quarter section j in the i^{th} year,
S_j = net reduction in crop insurance costs for quarter section j in the i^{th} year,
Y_j = one time setup costs
G = drainage project capital cost funded by government expenditure,
L = reduction in cost of supplying court services by the government and reduced congestion costs.

Data

Drainage Project Capital, Maintenance & Operating Costs

Construction, maintenance and operating costs for the two drainage projects were provided by Moose Jaw River Watershed Stewards Inc. Land use and crop data for Crop District 2B, the RM of Pense and the RM of Redburn are from Statistics Canada, Census of Agriculture, 2011 and Saskatchewan Agriculture Statistics. Capital cost for the two projects is presented in Table 4 in 2012 dollars with the private and public share of the costs. Setup costs for the Okabena project were $14,000.

Table 4: Drainage Projects' Capital Cost (2012 Dollars)

Project	Capital Cost	Private Share	Public Share
Okabena	900,000	520,050	280,000
Madrid	1,060,345	353,448	706,897

Source: Moose Jaw River Watershed Stewards Inc.

Maintenance costs for the Madrid project from 2004 to 2013 were available which consist of yearly mowing, 3/10 years rock placement, 4/10 years backhoe earth work and cleanout, 2/10 repair gates and culverts, and 2/10 years snow removal. On average for the 10 years $4,345 (2012$) was spent on maintenance. It is assumed that this average yearly amount would be consistent over the life of the project given that the 2004 to 2013 costs are representative.

Delayed Seeding

A delay in seeding due to saturated soil can have an effect on the yield of a crop. Data collected by the Saskatchewan Management Plus Program for Crop District 2B was used in estimating the yield by week (Table 5). Except for Durum the earliest week in the study had the highest average yield. It appears that seeding delays for field peas/lentils have the highest yield decline. An average of the difference in yield loss between seeding weeks of these crops is used in the model to estimate the cost of delayed seeding for cereals (durum), oilseeds (canola) and pulses (field peas). It certainly raises a question as to whether land that is prone to flooding would include a pulse crop in the rotation as flooding during the growing season would more adversely affect pulse crops relative to other crops. The average yield loss due to delayed seeding used in the model for cereal, oilseed and pulse crops is 2.46, 1.62 and 2.88 bushels per acre, respectively.

Table 5: Crop Yield by Week Seeded for Crop District 2B

Crop	Week Seeded	Yield(bu/ac)	Difference
Durum	April 30th - May 6th	43.8	0.0
	May 7th- May 13th	40.3	-3.5
	May 14th – May 20th	40.5	-3.3
	May 21st – May 27th	39.3	-4.5
	May 28th – June 03rd	44.7	0.9
	June 4th – June 10th	34.0	-9.8
Canola	April 23rd – April 29th	31.4	0.0
	April 30th – May 06th	30.4	-1.0
	May 7th – May 13th	30.9	-0.5
	May 14th – May 20th	28.8	-2.6
	May 21st – May 27th	28.0	-3.4
	May 28th – June 03rd	28.4	-3.0
Field Peas	April 23rd – April 29th	43.2	0.0
	April 30th – May 06th	36.8	-6.4
	May 7th – May 13th	36.2	-7.0
	May 14th – May 20th	33.0	-10.2
	May 28th – June 03rd	37.9	-5.3

Source: Saskatchewan Crop Insurance 2007. Saskatchewan Management Plus Program.

Crop Insurance Unseeded Area Claims

Unseeded acreage coverage for cultivated land that was not able to be seeded is available from Saskatchewan Crop Insurance (SCI) (Table 6). The program has varied substantially over the 1975 to 2012 period as to dollar per acre amount, method of calculation and which land qualifies. The SCI payment is currently $70/acre with a $15/ac or $30/ac buy up option with land subject to a historic seeding intensity calculation defined as a four year average of the percentage of acres summerfallowed to acres seeded in a year. For the period 1975 to 1998 the benefit was paid only on summerfallow land that could not be seeded. The benefit was $20/acre from 1975 to 1990 ; $25/acre from 1991 to 1999; $50/acre from 2000 to 2010 and extended to all unseeded acres subject to a seeding intensity calculation which was the greater of (1) current year's annual insurance intensity; (2) previous year's annual insurance intensity; or (3) four-year average insurance intensity. In 1999 there was an ad hoc payment of $25 per acre to all producers who were unable to seed even if they had no crop insurance. A separate calculation was used for unseeded summerfallow area using the percentage of seeded area of the farm.

Table 6: Saskatchewan Crop Insurance Unseeded Acreage Payments 1975-2013

Period	Rate $/ac[1]	Description
1975-1990	$20.00	Applied to Unseeded summerfallow area only, optional endorsement
1991-1999	$25.00	Included as a basic feature in 1997
2000-2009	$50.00	Total cultivated times seeding intensity with a 5% acreage deductible
2010- 2010	$50.00	4 yr average seeding intensity, 5% acreage deductible, & intensity calculation.
2011-2012	$70.00	A $15/ac or $30/ac buy up option; 4 yr average seeding intensity, 5% ac deductible.
2013	$70.00	A $15/ac or $30/ac buy up option; 4 yr average seeding intensity

Source: Saskatchewan Crop Insurance Annual Reports various years.

1. In Nominal dollars.

SCI provided information on unseeded area claims (UAC) for the townships where the two projects are located. The data is for the period 2000 to 2012 when the Madrid project was operating and for Okabena with no operating drainage project. The data was tested for whether the means of the series of claims for the different projects is the same (Table 7). The mean of claims from the townships where the Madrid drainage project exists is significantly different from the mean of the claims from the townships for Okabena. The inference from the data would be that about half the amount of UAC are made when there is a wet spring event in the drainage control area. Therefore in the model the amount of UAC that would have been paid out if the drainage project had not been constructed is estimated as half the per acre payment times the seeding intensity on the cultivated area of the quarter section.

Table 7: Unseeded Area Claims T-Stat for Two Samples for Means

	Madrid	Okabena
Mean Claims	35	74
T-Stat	-3.545	

T-Stat: One Tail Test = 1.782; Two Tail Test = 2.179

Source: Authors' calculations from Saskatchewan Crop Insurance Corporation data.

Determination of a "Wet Year"

Since, the effect of excess water varies with the time of year and amount of water, five descriptive categories of precipitation that could lead to flooding were used to quantify if there was an event and the extent in any year. If annual, growing season and winter precipitation was greater than 125% of the long term normal then 0.25, 0.35 and 0.10, respectively was added to the wet year factor. If in a year a monthly precipitation total was greater than 100mm a factor of 0.3 was added to the wet year factor. Also, if annual precipitation was above normal a factor of 0.25 was added to the wet year factor. The wet year factor can vary from 0 to 1.25. The estimate of the wet year factor used in the model is presented in Figure 6.

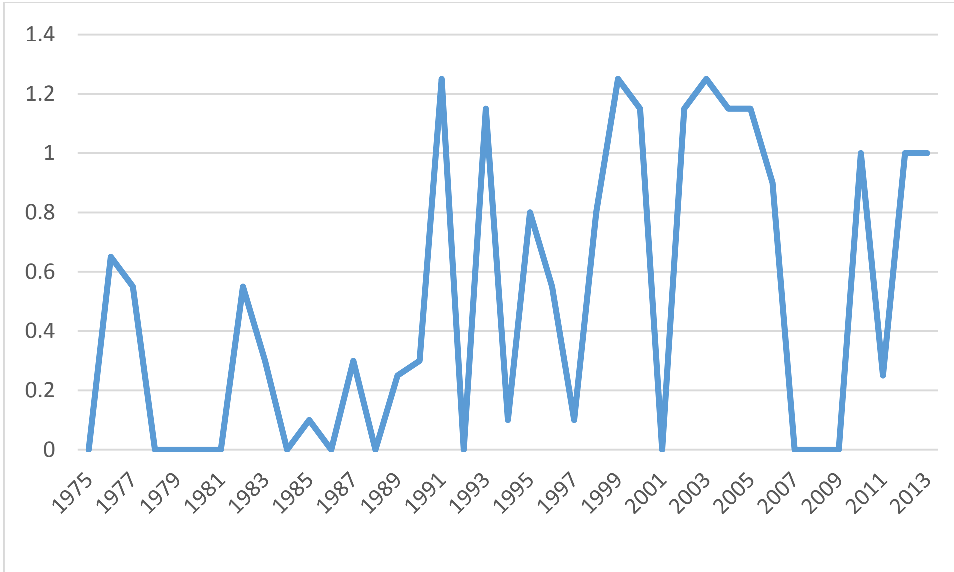

Figure 6: Estimate of Wet Year Factor 1975-2013

Estimation of Revenue and Costs from Flooded Land

The loss in revenue from the flooded area in a quarter section of land in the drainage project is estimated as the yield of crop k times the area if there was no flooding minus the yield of crop k times the effect of delayed seeding on yield of crop k times crop mix share for crop k times cropping intensity times price of crop k times flooded area for quarter section j.

$$\sum_{i=1}^{n}(\sum_{j=1}^{q} Rji = (\sum_{k=1}^{p} Pki * Yki * Mk - \sum_{k=1}^{p} Pki * Yki * Dki * Mki) * Aji * Fi) * Gi$$

i = 1 to n years,
j = 1 to q quarter sections,
k = 1 to p crops,

Where

R_{ji} = revenue for quarter section j in the i^{th} year,
Y_k = yield for crop k on non-flooded land in the i^{th} year,
D_k = effect of delayed seeding on crop k in the i^{th} year,
M_k = percentage share of crop k in Crop District 2B in the i^{th} year,
F_i = intensity of crop production in Crop District 2B in the i^{th} year,
P_k = price of crop k in 2012 $ in the i^{th} year,
Aji = area of flooded area on drainage quarter section j,
G_i = 0 to 1.25 based on level of precipitation and five categories that would indicate use of the drainage system in the i^{th} year.

Variable costs of producing a crop are from Saskatchewan Agriculture Crop Planning Guide for the Dark Brown Soil zone (1987-2013) and are estimated for 1975 to 1986 by the authors. The Farm Input Price Index for Western Canada is used to estimate input costs from 1981 to 1986 using 1987 as the base year for costs. Most of the area seeded in the Dark Brown Soil zone in the 1975 to 1980 period was on summerfallow with either durum or spring wheat being the crops of choice. Minimal fertilizer was used and seed was generally from the previous year's crop therefore the main cash expenses were fuel, herbicides, insurance and property taxes.

$$\sum_{i=1}^{n}(\sum_{j=1}^{q} Cji = \sum\nolimits_{k=1}^{p}(Zki * Mki)\} * Fi * Aji) * Gi$$

i = 1 to n years,
j = 1 to q quarter sections,
k = 1 to p crops,

Where

C_{ji} = cost of the flooded crop area for land quarter section j, in the i^{th} year,
Z_{ki} = cost of producing crop k on quarter j in the i^{th} year,
M_{ki} = mix of crops in Crop District 2B in the i^{th} year,
F_i = intensity of crop production in Crop District 2B in the i^{th} year,
Aji = flooded area on drainage quarter section j in the i^{th} year.
G_i = 0 to 1.25 based on level of precipitation and five categories that would indicate use of the drainage system in the i^{th} year.

Cropping intensity defined as annual seeded area divided by the annual seeded area plus summerfallow for Crop District 2B is presented in Figure 7. The value of the loss due to flooding would be impacted by whether the land was to be summerfallowed which up until the mid-nineties was highly likely. The sharp declines in seeding intensity in 1991, 1998, and 2002 would indicate problems with seeding either too much or not enough moisture. The drought of 2001-2002 would likely be the cause of reduced seeded area in 2002. While 1991 and 1999 are likely to be caused by excess moisture.

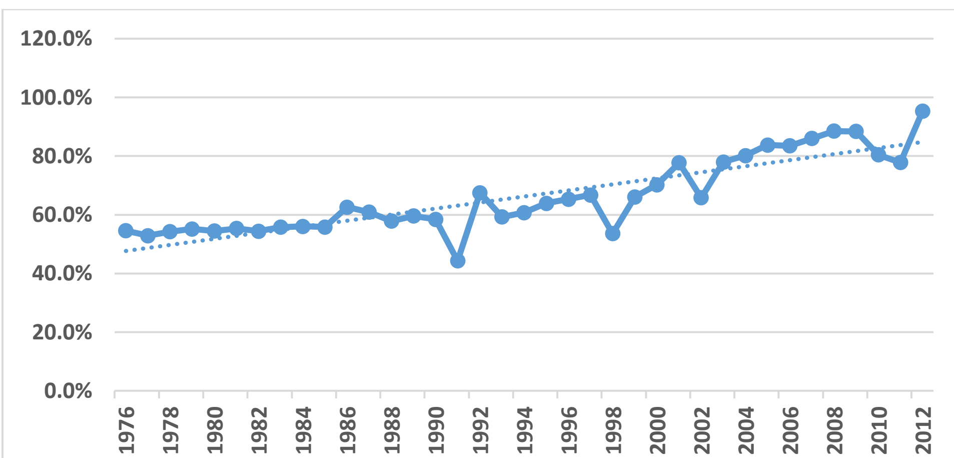

Figure 7: Cropping Intensity for Crop District 2B
Source: Statistics Canada 2013

Machinery Efficiency

The effect on machinery efficiency due to flooded land is the extra time required to treat the area separate from the other farmed land plus the reduction in efficiency from not having one contiguous block. Loss in efficiency also occurs to land that pre-drainage project had no formal drainage ditch however, it could be farmed in most years. But post drainage the ditch results in a loss in efficiency every year. Since, the size of machinery has changed over time the loss in efficiency due to flooding will also change overtime. Also, by comparing aerial photos from the late 70s and early 80s to recent google satellite images reveals the changes in farming practices. Strip cropping or breaking up a quarter section into blocks of land which appears to have been a common practice in the 1970s and likely continued until summerfallow area was greater than 65%. The practice was primarily done to reduce wind erosion when summerfallow was a major part of the rotation. However, a secondary benefit would have been the more efficient farming of land that had different seeding times due to low areas.

The loss in efficiency of farm operations is estimated by using the difference in the time it takes to do a field operation on an 80 ac block when it is split into three parcels from the time it takes when farmed as a complete field. The sizes of the three parcels are 600 meters, 150 meters and 50 meters by 400 meters. The difference in cost between a complete field and a field in three sections is mainly the extra fuel and labour. Estimation of extra fuel use requires that the size of equipment, field completion time, and power requirement be determined. The sizes of machinery typically used in the decade is presented in Table 8.

Table 8: Size of Equipment Used by Decade (Feet)

Decade	Seed	Harvest	Tillage	Spray
1970s	20	15	24	50
1980s	30	20	35	60
1990s	40	25	45	65
2000s	50	30	55	80
2010s	60	35	65	90

Source: Author`s estimates.

Field efficiency rate is the effective field capacity as calculated using the formula from Hunt 1995.

$$\mathbf{EC} = \frac{\mathbf{S * w * L * Ew}}{\mathbf{(c1) * L + D*S*w*L*Ew + (c2) * S * t}}$$

EC is Effective Capacity Ha/hour [acres/hour]
S is speed km/hr [mi/hr]
w is the rated width of implements, m [feet]
Ew is the effective swath coverage percentage,

$$Ew = 1 - overlap / w$$

D is unproductive time, mainly for seeding and harvesting operations
L is the length of field, m [feet]
t is the time spent turning to do the same amount of area per field operation
c1 is a constant, 10 [8.25]
c2 is a constant, 2.7778 [12.1]
Source: Hunt 1995.

The difference in time it takes to complete the field operations in hours by the size of machinery typically used in the decade is presented in Table 9. Fuel use coefficients for various sizes of field operations are from Nagy 1999. The fuel consumption in litres per hour for each field operation given the different sizes of machinery and power used is presented in Table 10.

Table 9: Difference in Time to Complete a Field Operation by Decade (Hours)

	Seed	Harvest	Tillage	Spray	Swath
Decade	**Hours per quarter section**				
1970s	1.99	2.81	1.81	0.80	2.39
1980s	1.52	2.49	1.14	0.63	1.70
1990s	1.07	2.02	0.83	0.55	0.78
2000s	0.80	1.54	0.64	0.42	0.63
2010s	0.63	1.08	0.51	0.17	0.52

Source: Author`s estimates.

Table 10: Fuel Used to Complete a Field Operation by Decade

	Seed	Harvest	Tillage	Spray	Swath
Decade	**Litres/hour**				
1970s	12.7	22.6	19.7	8.9	11.67
1980s	14.6	27.6	32.9	9.6	14.00
1990s	39.6	34.2	41.4	15.7	14.00
2000s	46.0	43.0	46.9	34.0	15.00
2010s	39.6	47.7	49.9	48.9	15.00

Source: Author`s estimates.

The amount of extra fuel needed to complete the field operation given that the field is split into three parcels is presented in Table 11. The average cost of diesel in each of the decades is then used to estimate the value of the loss in machinery efficiency. These estimates are only for land that was seeded or has a man-made post-drainage project ditch. It is assumed that the cost of summerfallow would not change if the land was flooded in the spring.

Table 11: Difference in Fuel Use by Field Operation by Decade

	Seed	Harvest	Tillage	Spray	Swath[1]	Total
Decade	**Fuel Litres per quarter section**					
1970s	25.16	63.66	35.53	7.15	27.84	159.34
1980s	22.15	68.76	37.64	6.02	23.87	158.45
1990s	42.14	68.94	34.53	8.65	10.98	165.24
2000s	36.86	66.39	30.12	14.13	3.75	151.25
2010s	24.90	51.29	25.53	8.44	3.75	113.91

Source: Author`s estimates.

1. It is assumed that twenty-five percent of the land is swathed in the decades of 2000s and 2010s.

Cortus et al. 2011 estimated nuisance costs of potholes which included machinery efficiency loss along with extra inputs at $112.55/ac to $164.77/ac depending on the size of farm. The level of crop inputs used in this area was quite low up until the mid-1990s when more stubble started to be cropped and lentils and canola gained in seeded area. The main loss in crop inputs would be overlap of pesticide application as there may be limited or negative benefit of extra pesticides. The estimated costs to farm potholes separately in the drainage projects is presented in Table 12. Fuel cost is estimated as the real price of fuel times the extra fuel. Given the field parcels an extra 0.47 acres is overlapped at $16/ac pesticide application for the 70s, 80s and 90s. While the extra herbicide cost for the 2000s is 1.5 spray applications and 2010s is 2 spray applications to account for increased area in specialty crops and oilseeds. The extra labour cost uses the average real minimum wage for the decade times the extra hours needed to complete the field operations.

Table 12: Difference in Cost to Farm Potholes Separately

	Fuel	Pesticide	Labour	Total
Decade	**2012 $ per quarter section**			
1970s	117.95	7.58	106.43	231.96
1980s	77.34	7.58	65.70	150.62
1990s	81.20	7.58	40.34	129.13
2000s	101.23	11.37	33.64	146.24
2010s	104.29	15.16	28.23	147.68

Source: Author`s estimates.

Estimate of Flooded Area

For the quarter sections where main drainage ditches were located it was estimated that 60% of the land would be flood prone, quarter sections adjacent to the main drainage ditches were estimated at 25% prone to floods while other quarter sections 6.451% of the area was flood prone. Milt Rigetti of the Madrid project estimated the flooded area in the project at 3,900 acres (Personal communication, 2013). Similar method was applied to the Okabena project resulting in an estimate of 2,302 acres of flood prone land.

Estimate of Drainage Ditch Area

The length of the main drainage ditch on a quarter section was estimated from a map of the Madrid Conservation Area (Water Security Agency 2012) and from the Okabena Drainage and Erosion Control map (2012). The main drainage ditches run through 26 quarter sections in the Madrid

Project and 15 quarter sections in the Okabena project. For the Madrid project the area of ditches was estimated as length times 2 meters wide for 8 quarter sections, times 3 meters wide for 13 quarter sections and times 5 meters wide for 5 quarter sections. The area of ditches for the Okabena project was estimated as length times 3 meters wide for 5 quarters and times 5 meters wide for 10 quarters. The total area of the main ditches is 17.0 acres for the Madrid Project while the total area of the ditches for the Okabena project is estimated at 11.8 acres. The loss in revenue from the area of drainage ditches that were man made during non-flood years is subtracted from the stream of benefits.

Commercial Crop Inputs

The percentage of area receiving crop inputs in 2010 is presented in Table 3. Fertilizer and herbicide application to crop land is a widespread practice in the two RMs. In the RM of Pense 26 quarters of land are listed as being organic while no designation of organic land is made in the RM of Redburn. Insect application could be for wheat midge, bertha army worm, diamond back moth, aphids, grasshoppers and flea beetles. Sclerotinia (canola, pulses), leaf and stem rust (cereals), ascochyta blight (pulses), blackleg (canola), and powdery mildew (pulses) are the most common diseases that can cause economic losses in grain crops. Fungicide application would be mainly on pulse crops with some application on canola. A wetter than average growing season may result in the need for multiple applications of fungicides to pulse crops. The types of crops grown and percentage of cultivated area has changed significantly over the 1975 to 2012 period, as well as the type and use of pesticides. For example, the application of herbicides to cropland can now be a combination of pre-seed, in crop, preharvest, or post-harvest while prior to the mid-1990s it was mainly in crop. Also, pre-harvest desiccation of pulse crops and some cereal crops are now common cropping practices.

Since, no sampling of the water from the Madrid project and a non-drainage control was done over the 1975 -2012 period it is difficult to (A) estimate the pesticide load and (B) determine the net environmental affect that a drainage project has on the pesticide load.

Fertilizer application practices have changed quite substantially over the 1975-2012 period as to type of application and amount of nutrients. Since, summerfallow was the main cropping practice till the mid-1990s nitrogen fertilizer application would have mostly gone on stubble crops. Amount of fertilizer that could be applied during the seeding operation was limited until the advent of the airseeder combined with single or double shoot ground openers such that higher rates of nitrogen could be applied safely. Broadcasting of nitrogen would have been a typical practice in the 1970s and into the 1980s until spring or fall banding become the common practice. Greater amounts of stubble cropping along with the decline soil organic matter resulted in the need for higher rates of nitrogen to be applied starting in the 2000s.

An estimate of the total amount of nitrogen and phosphorus applied yearly to crop land in the Madrid Drainage area over the 1975 to 2012 period is presented in Figure 8. Over this period an estimated 8,400 tonnes of nitrogen and 4,700 tonnes of P were applied in the Madrid Drainage district. Cessna et al. 2001 estimated the herbicide and nutrient transport from South Saskatchewan River Irrigation District #1 from water samples of the drainage ditch and the amount of nutrients and pesticides applied in the district. They estimated that 1.9% of the nitrogen and 2.2% of the P ended up in the drainage water from this district. Using the yearly intensity of precipitation and the coefficients from Cessna et al. 2001 it was estimated that over the 1975-2012 period 89 tonnes of N and 55 tonnes of P could have ended up in the Moose Jaw River system. The effect on downstream surface water quality of water drained from the project area with the net environmental cost being the difference between pre and post drainage project. However, it is unknown that in the absence of a drainage system what would have been the amounts of the two nutrients entering the Moose Jaw River system. There was insufficient data available to estimate the difference between sediment and nutrient loads in surface water connected to the organized drainage plan and an unorganized drainage system. While there has been research on the costs of increased loads of phosphorus, nitrogen and sediment in surface water bodies within agricultural landscapes, none of the findings examined could be considered directly relevant to this area of Saskatchewan. Due to these data gaps the net environmental cost associated with the organized drainage projects will not be included in the analysis.

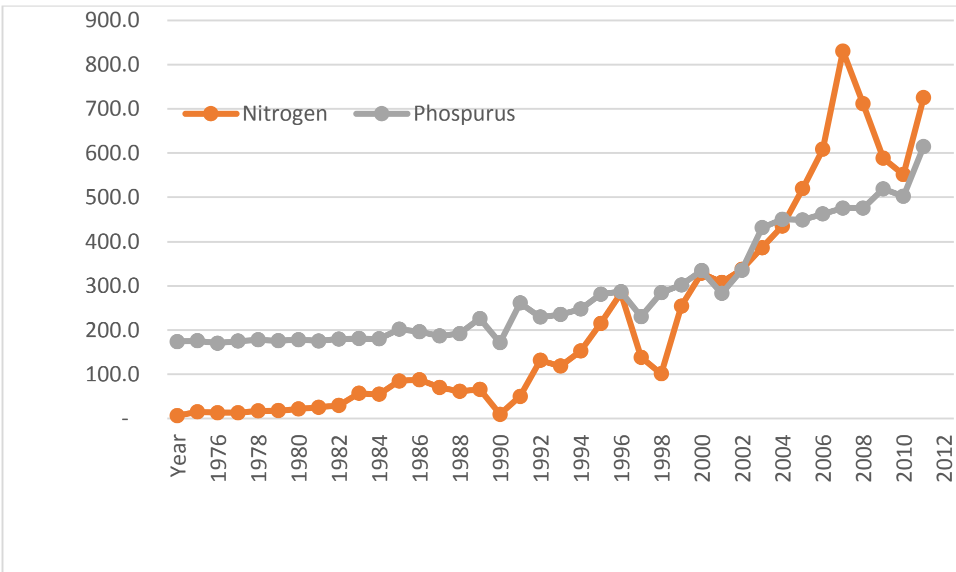

Figure 8: Estimate of Yearly Applied Nitrogen and Phosphorus (Tonnes)

Estimate of Forgone Dispute Resolution Costs

A landowner who believes that they are unduly impacted by water drainage can register a complaint to The Water Security Agency (WSA). A three step process is employed by WSA. First, under a water management inquiry WSA will investigate the complaint as to the presence of the drainage works, the volume and time of year of the flow of water and determine whether significant damage will be caused. However, WSA does not determine liability or award reparations due to the complaint. A fee of $200 is due upon filing a complaint. If no settlement of the complaint is attained then a request for assistance is made to mediate a solution however, the recommendations are non-binding. The third step is a formal complaint which is binding if the parties agree to the process. Both parties have the option of appealing any decision to the Water Appeals Board. It is estimated that Step I and II would cost WSA $5,000-$10,000; while Step III would cost $15,000-$20,000. Typically, over a 50 year period 5 complaints for a water drainage area would be expected.

The provincial government court system would gain if fewer drainage disputes ended up in court both in reduced direct court costs and congestion costs which would be a public benefit. The cost of court room services is partially borne by the litigants and defendant to a court case. Provincial court charges are $15.00 per half hour after the first five hours of court time. Clearly the public would pick up the majority of the variable costs for providing court room services in the case of a drainage dispute. What the cost of supplying those services in Saskatchewan is apparently unknown. Chief Justice Beverley McLachlin is quoted as saying that the average cost for a three day trial in Ontario is $60,000 (Law Reform Commission of Saskatchewan, 2011). Since, any drainage dispute litigation would be between landowners within the drainage district the net benefit/cost would be zero.

To estimate the cost of supplying court services the number of sitting days of provincial court and circuit courts in Saskatchewan was estimated from the Court Locations and Sitting Times. Using the Ministry of Justice Annual Balance sheet for 2012-13 the Total Courts and Civil Justice expenditure was divided by the estimated annual sitting days to arrive at a cost per day of $9,521. Given that a trial is likely to be held over three days the cost to the government of supplying the services would be 3 days x $9,521 per day – ($15per half hour*2*6 hours per day)*3 days = $26,944.

The reduction in congestion costs of not having to hear a drainage dispute would free up the court time for other cases. However, the value of this freed up time to the government would be negligible since these services are at capacity. Most of the benefit would accrue to those involved in civil and criminal court cases and society in general as the cost of waiting for justice would be reduced. Since, no data appears to exist on the wait times for trials or on the net value that parties to a court trial place on reduced wait time no value could be place on the reduction in congestion costs.

Madrid Factual vs. Counterfactual Drainage

To compare the net benefits of having a drainage project to not having a drainage project a comparison is made between the Factual stream of benefits and costs to the drainage area “what actually happened” to the Counterfactual benefits and costs “no drainage project”. The main difference between the Factual and Counterfactual is the revenue stream that can be generated from the flooded area. Specifically, the crop net return on the flooded area plus any payment for unseeded acres in a wet year (Figure 9) and efficiency gains (losses). The difference in the net present value of the two scenarios over the 38 year period is the metric by which a drainage project can be compared to a non-drainage project.

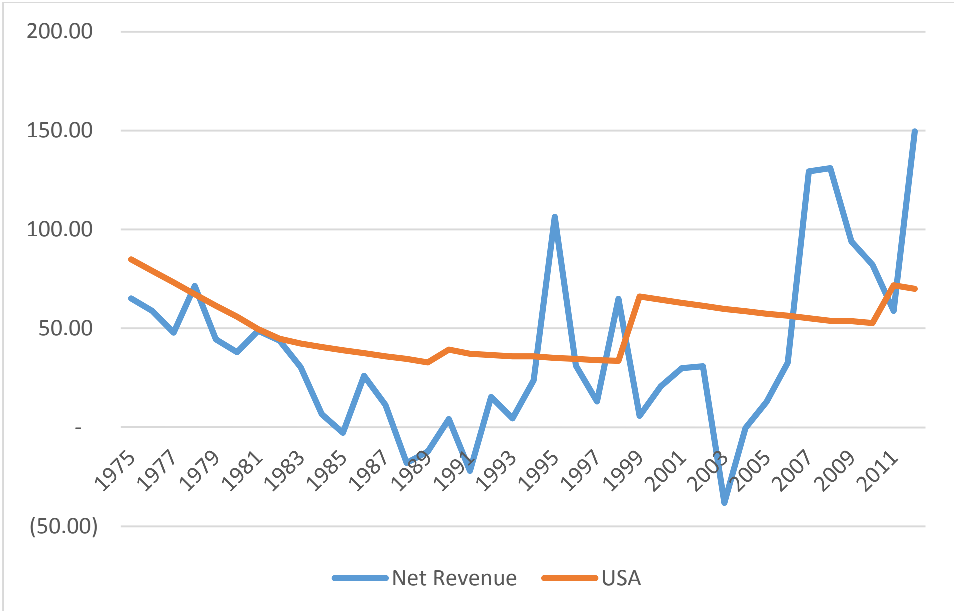

Figure 9: Real Dollar Value of the Net Return to Unseeded Acreage Payment (UAC) 1975-2012

Results

For the Madrid project as a whole the total benefit generated from the total cost of the project gave a 10.1% MIRR with a range of 9.0% to 11.7% for the individual quarter sections (Table 13). A Benefit/Cost ratio (B/C) of $7.03 for the project was estimated with the range for the individual quarter section within the drainage area from $3.92 to $13.82. For every dollar invested, both public and private, the project returned the dollar invested plus $7.03. The Okabena project if it had started in 1975 would have generated a MIRR of 9.3% with a B/C of $2.65 for every dollar invested. At the quarter section level the MIRR ranged from 7.9% to 10.9% with a B/C ranging from $1.08 to $5.92. Given the higher share of the project capital cost borne by the landowners and fewer total acres in the Okabena project compared to Madrid the difference in the return between the two projects was expected.

Table 13: Total Benefit to Total Cost

	Benefit Cost Ratio		MIRR	
Project	**Total**	**Range**	**Total**	**Range**
Madrid	$7.03	$3.92-$13.82	10.1%	9.0%-11.7%
Okabena	$2.65	$1.08-$5.92	9.3%	7.9%-10.9%

Source: Author`s estimates.

Measuring the private benefits generated from the private cost of the projects the MIRR of the Madrid was 9.9% and for Okabena it was 7.4% (Table 14). The B/C ratios for Madrid and Okabena were $2.32 and $0.22, respectively. The quarter sections with the lowest B/C were characterized as having small cultivated area that is prone to flooding, thus making participation in a drainage project problematic.

Table 14: Private Benefit to Private Cost

	Benefit Cost Ratio		MIRR	
Project	**Total**	**Range**	**Total**	**Range**
Madrid	$2.32	$0.33-$9.24	9.9%	7.3%-12.9%
Okabena	$0.22	-$0.84-$5.92	7.4%	3.6%-10.8%

Source: Author`s estimates.

Estimating the returns to the Okabena project over 60 years using a rolling 10 year average for revenue, cost and seeding intensity increased the private benefit to private cost ratio to $4.16 and the MIRR to 9.0%. The range of MIRR for quarter sections is 8.2% to 10.1% with a B/C $1.83 to $9.42 which gives the landowners 20% of the benefits up from the 8% in the base scenario.

The benefit of the drainage project, compared to having no drainage project, is $3.9 million present value for the Madrid project Factual versus Counterfactual over the 1975-2012 period. The average quarter section difference in the two scenarios between the Factual and Counterfactual was $28,742 with the range of $4,663 to $92,710. The extra revenue generated per year on a quarter section basis by having a drainage project would on average be $756.38 with a range of $122.72 to $2,439.74(in 2012 dollars).

Summary and Conclusions

One of the benefits for the government is the reduction in unseeded area claims that farmers would make if the drainage system was in place. This does not mean that there would be no unseeded area claims from the drainage area as there could be situations where the soil is saturated and seeding is delayed. The higher total benefits compared to the private benefits are the result of the reduction in unseeded acreage claims which is a benefit to the public. At the policy level if governments can match contributions to drainage projects that correspond to the expected reduction in UAC then the public at a fiscal analysis would be indifferent. However, due to the uncertainty in climate and climate forecasts this may be a difficult task.

The MIRR of the project as a whole and the range of returns by quarter section should be compared to other investments that could have been made both on and off farm that would have the same amount of risk given the return. In this case it would be similar to buying insurance as the yearly payments for maintenance and operation of the drainage system are analogous to a premium. Most years there would be little or no return to the investment in the drainage system as is the case with insurance. Relative to the investment (premium) there is the potential for a large return (payout). It is important for projects to align returns to each quarter section to the cost and risk borne by the landowner to get maximum buy in. It would be analogous to an insurance company assessing the risk and payout on an insured to assess the correct premium.

There are several key determinants of any future returns to the drainage projects with the most important being the frequency of which the drainage system is used and secondly the cropping intensity. An extended period of drought would obviously negatively impact on the Benefit/Cost ratio as the drainage system would not likely generate any positive benefits. Crops and cropping intensity affect the benefit stream in the value of lost production. Growing crops with a high net return such as lentils and canola along with a cropping intensity greater than 80% as experienced over the last ten years significantly affects the benefits. A return to the fallow/crop regime as experienced in the 1970s and 1980s over the remaining life of the drainage project would make a substantial difference in the benefit stream.

Long term climate studies of Saskatchewan have revealed that there is an underlying 60 year cycle within which dry and wet periods alternate (Sauchyn 2012). Therefore, within the lifetime of a landowner they will have experienced the wettest years and the driest years within that 60 year period. It would be prudent to base their investment decision on whether the long term climate normal would have sufficient wet periods to justify the investment.

The return to an individual parcel of land is dependent on the amount of land that is prone to flooding. Although, a quarter section post-drainage may have a permanent ditch, it appears that the returns from the land post drainage are high enough to compensate for the loss in revenue and efficiency. Over the 1970 to 1998 period farmland in Saskatchewan returned on average 9.6% and long-term bonds 7.9% (Painter 2002). So a landowner could have invested in more land (high risk) or bonds (low risk) rather than a drainage project. For most of the landowners in the Madrid project the decision to invest would have given a similar return given the risk. Given that today's current long term bond rates are at historic lows, most landowners in the Okabena project would generate higher returns from investing in the drainage project for as long as the low rates hold.

Comparing an organized drainage project to ad hoc landowner actions to remove water from their land the cost of legal action to the landowners involved in a dispute is one major cost. Community cohesion is likely to suffer when uncoordinated drainage occurs.

Drainage projects also provide a platform by which other issues in the community can be addressed as you have landowners talking to landowners which is generally not the same group as those who farm the land. This value is hard to quantify and therefore not included in the analysis however it is worth mentioning.

If there are more drainage projects within the Moose Jaw River system co-ordinated drainage and possible holding of water to limit downstream adverse effects may be required. This could change the returns for some quarter sections if water is delayed or held for a substantial period.

The split in the revenue stream between landowners and renters is not explicitly taken into account in the model. For the purposes of this study, it was assumed that landowners and renters were the same entities. However, it is clear that all the benefits will be not captured by the landowner or the tenant. Clearly landlords will be able to extract higher rents on the land that was previously flooded and capture the benefit of the higher land values. Efficiency gains from not having a flooded area will be captured by the farm operator while split in the share of the higher revenue is dependent on the rental contract.

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Appendix A Maps

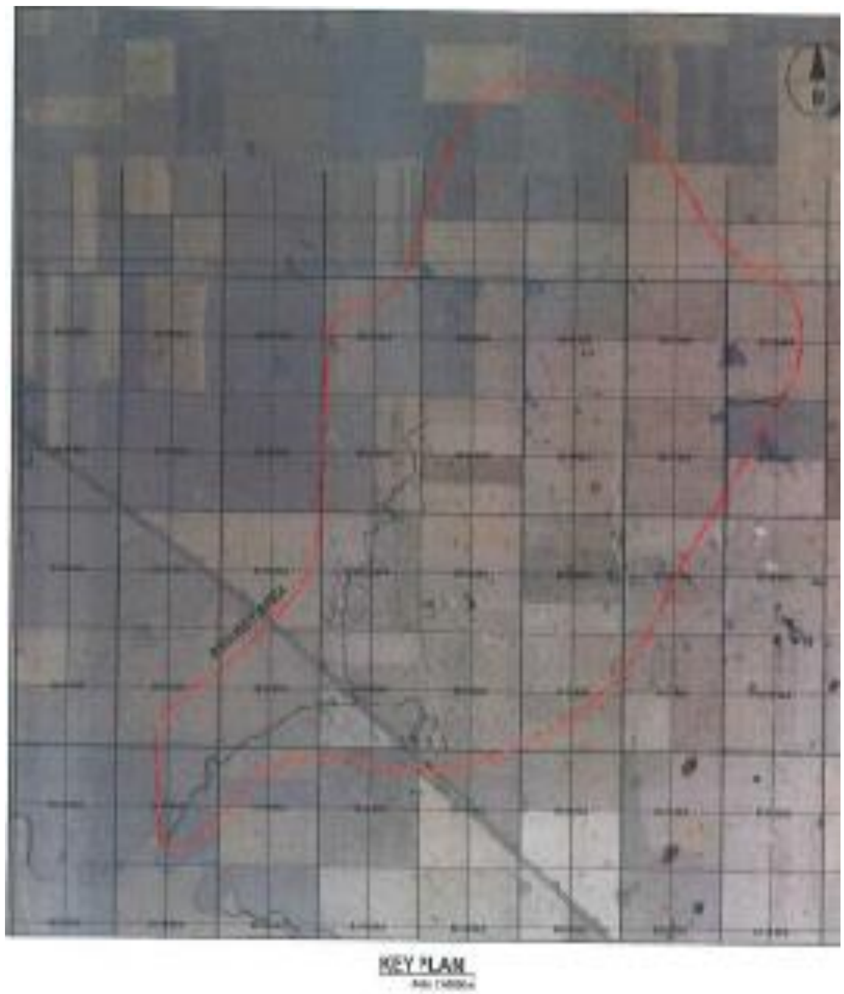

Figure 10: Okabena Watershed Co-operative Ltd

Source: AECOM

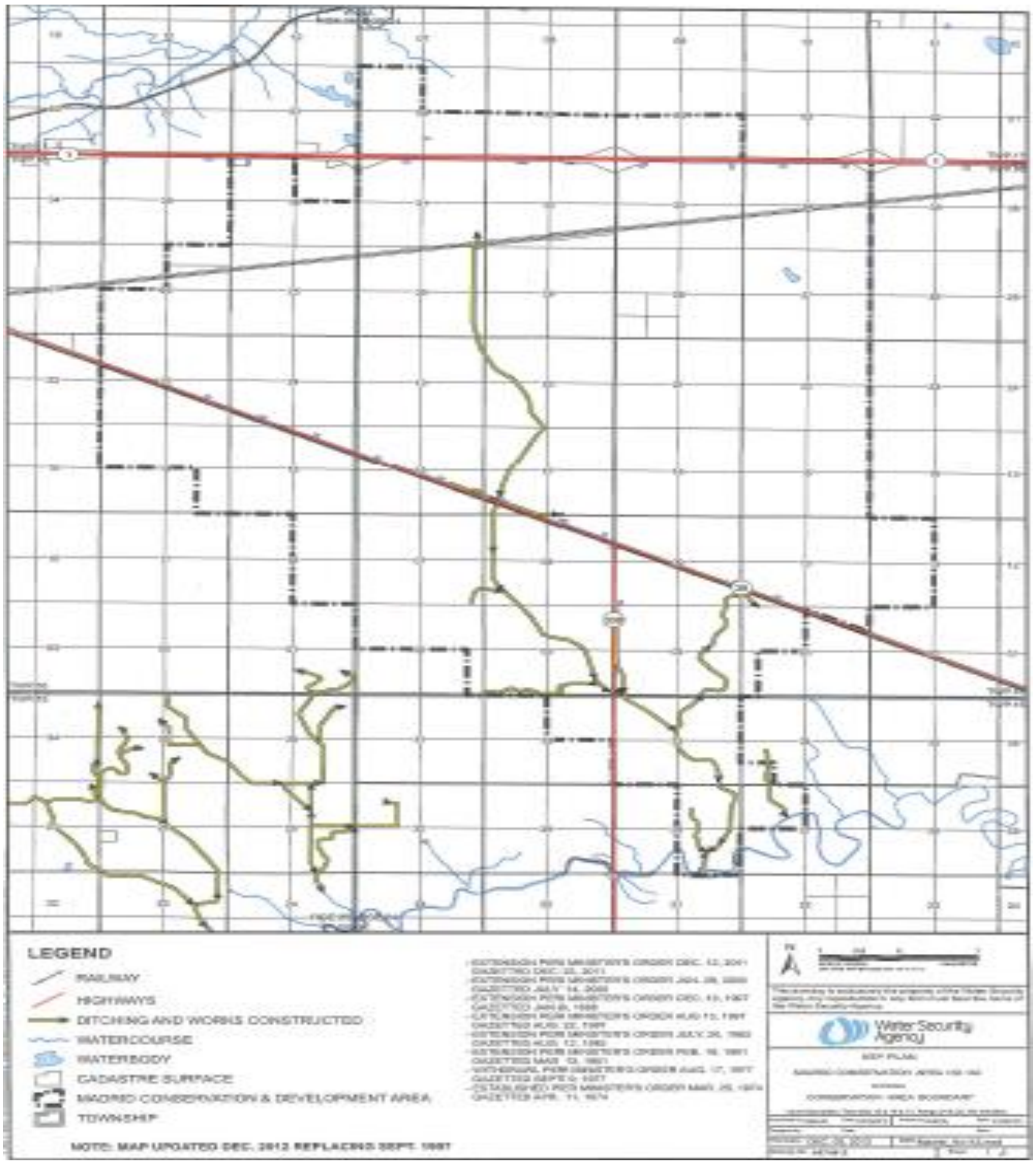

Figure 11: Madrid Conservation and Development Area

Source: Water Security Agency.