Southern Alberta Landscapes: Meeting the Challenges Ahead

Export Coefficients for Total Phosphorus, Total Nitrogen and Total Suspended Solids in the Southern Alberta Region

A Review of Literature

Prepared for
Alberta Environment
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1.Introduction

1.1. Background

Non-point source pollution generally results from precipitation, land runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric deposition. Runoff from rainfall and snowmelt pick up and transport natural pollutants arising from human activity, and ultimately deposit them into lentic and lotic systems, wetlands, coastal waters, and ground water (USEPA 2002). As human activities continue to alter the global nutrient cycle, the ability to predict the impact of increased nitrogen, phosphorus and suspended sediment loading to freshwater systems is becoming increasingly important. (Saunders & Kalff 2001).

Soil erosion, runoff and sediment transport are natural processes. Man and his activities on the land have accelerated the rate of these natural processes. Land characteristics such as soil type, surficial geology, slope and drainage are just as important as land use in determining the extent of soil losses to streams (Switzer-Howse & Coote 1984). Suspended solids are important for both aesthetic and chemical reasons because they can detract from water clarity and serve to bind and transport phosphorus, heavy metals, pesticides and other toxic compounds.

The use of generalized ecosystem models for predictive research for freshwater and grassland ecosystems are well documented (Park *et al.* 1979; Parton *et al.* 1987, 1988). Natural systems possess inherent heterogeneity, and research that is more recent has emphasized the need for general ecological models that can be re-parameterized and applied to different ecosystems for distributed, or spatially explicit, simulation (Costanza *et al.*1990; Band *et al.*1991 and, Costanza and Maxwell 1991). Although models that incorporate hydrology and water quality have been developed, they are not applicable throughout Canada, especially in the Prairies, due to gaps in knowledge of cold region hydrology and the need for integrating water quality modeling (Chambers *et al.* 2002). Research is currently underway to characterize prairie hydrology for water quality modeling. It is against this background that the Southern Region of Alberta Environment is developing the ALCES model as a robust tool to manage anthropogenic effects and use the regions natural resources sustainably. The identification of the contributing effects of the various land uses and natural resources on the export of phosphorus, nitrogen and suspended solids is central to determining some of the key issues to be addressed in the regional strategy for Southern Alberta in order to ensure sustainable development over the next 50 years.

1.2 Objectives

The objectives of the literature review were to:

- Identify and summarize literature that provide quantitative information on Total Nitrogen (TN), Total Phosphorus (TP) and Total Suspended Solids (TSS) export coefficients in the Southern Alberta region,

- Identify and summarize literature that provide quantitative information on TN, TP and TSS export coefficients in the following landscape cover categories provided by Alberta Environment, Calgary: Native Prairie (9) classes, Agriculture (6) classes, Forest Area (7) classes and Miscellaneous (4) classes for input in the ALCES computer simulation model currently under development.

- Prepare a report that presents a descriptive inventory and analysis of literature including a list of all relevant literature reviewed and abstracts of selected literature appropriately categorized, and provide a discussion of data generated.

- Identify and summarize literature that provides quantitative information on TN, TP and TSS export coefficients for Non-native Land Use categories in the Southern Alberta region. This assignment was included on Thursday April 28, 2003.

2. Approach

This section provides information on the methods used to review the literature and the categories selected to organise the findings. Journal publications and relevant gray literature (government reports and documents published outside of the traditional peer review and publication process) were reviewed.

2.1 Literature Review Methods and Sources

Various methods used to search both published literature and gray literature are described in the following sections

2.1.1 Peer Reviewed Publications

Literature searches were conducted in the following databases

University of Calgary Library Electronic Resources

1. Key Environmental Science Indexes and Abstracts
    - Agricola
    - Applied Science and Technology 1983-present
    - Biological Abstracts 1980-Present
    - Environment Abstracts
    - EPA Environmental Publications
    - Pollution Abstracts 1981-Present
2. Key Biology Indexes and Abstracts
    - Biological Abstracts 1980-Present
    - LexisNexis Environmental
    - Web of Science

The searches used the following keywords individually or in combinations: nutrients, phosphorus, nitrogen, suspended solids, total, export coefficients, runoff, transport, loading, prairie, grassland, watersheds, parkland, foothills, rocky mountain, native vegetation, agriculture, urban, industrial, Alberta, Canada and North America

The search produced hundreds of references and a manual review was conducted to identify relevant references for the purpose of this report.

2.1.2 Review of Gray Literature

Literature searches of "gray literature" of government (federal, state, and provincial sectors) were conducted on the Alberta Government Library and the internet. Searches focused on the following organizations:

- Environment Canada,
- Alberta Environment
- Alberta Agriculture, Food and Rural Development
- Agriculture and Agri-Food Canada
- Fisheries and Oceans Canada
- Canadian Water and Waste Association
- National Research Council of Canada
- Food and Agriculture Organization of the United Nations
- Canadian Council of Ministers of the Environment
- United States Environmental Protection Agency and
- United States National Technical Information Service (NTIS)

Once again, a large number of records were obtained through these search strategies and these were manually reviewed and sorted according to relevance.

3. Findings

Nitrogen and Phosphorus are essential components of a healthy ecosystem and occur naturally in the environment (Wetzel 2001). Most human activities can contribute new sources of these nutrients to aquatic systems, increase the rate of loss of nutrients from the landscape, degrade water quality and contribute to eutrophication. Nutrient loading from watershed processes occurs through transport of nutrients from land to water. This is generally more difficult to quantify than direct effluent discharge because it is usually more diffuse, variable, and intermittent. While predominant impacts have occurred in aquatic ecosystems and caused water use impairments, symptoms of negative effects on forest ecosystems have also been observed (Chambers *et al.* 2002).

Nutrient load export in surface runoff is dependent on soil type, vegetation cover, precipitation and the type of land use activities. There is concern about the increasing contribution of agricultural operations to nutrient enrichment of water bodies in Alberta (Howard *et al.* 1999). Primary agricultural non-point source pollutants are nutrients, sediment, animal wastes, and pesticides. Nitrogen (N) and Phosphorus (P) are the two major nutrients in surface runoff that can degrade water quality and contribute to eutrophication. Nitrogen occurs naturally in soils, although often in insufficient quantities, thereby requiring addition from fertilizers and manure in order to meet crop production needs. Phosphorus, however, is believed to control the level of primary production in western Canadian lakes. Many of the lentic and lotic systems in Alberta are naturally eutrophic. They are therefore extremely sensitive to further phosphorus enrichment. (Howard *et al.* 1999).

Nutrient or sediment loads from watershed processes for specific land uses can be calculated from export coefficients. Export coefficients represent the quantity of nutrients or sediment generated per unit area per unit time (kg/ha/yr). Use of export coefficients is based on the assumption that a given land use activity will yield a specific quantity of nutrients/sediments to a downstream waterbody (McFarland & Hauck 2001).

There is a wide range of export coefficients for total phosphorus and total nitrogen in the literature for any given land use in the United States (Oberts 1983 USEPA 1976, 2001; Barker *et al.* 1989; Reckhow *et al.* 1980 and, EPA 1992). There is however, a paucity of similar information in Canada particularly in the Prairies. Therefore, this literature review includes export coefficients from the classic paper of Reckhow *et al.* 1980 mainly for comparative purposes, in addition to other more selective records from the United States. The publication by Riemersma *et al. 2002* documenting phosphorus sources and sinks in watersheds provides significant information for Alberta. Export coefficients were also derived from data extracted and transformed from Sosiak 2000 (Mosquito Creek and Little Bow River), Ontkean *et al.* 2000 (Crowfoot Creek), Wilhelm & Schindler 1999 (Snowflake Lake) and Silva & Davies 1997 (Oldman River). Joanne Little, Alberta Agriculture, Food and Rural Development, Lethbridge, and Anne-Marie Anderson, Alberta Environment, Edmonton, also provided data for inclusion.

3.1 Available literature on export coefficients for phosphorus, nitrogen and total suspended solids

An initial search was conducted using the various search engines with keywords for each of the land use groupings provided for ALCES by Alberta Environment, Calgary (Table 1). No export coefficients were found for any of these classes. A map showing natural ecoregions for Alberta was obtained from the Alberta Natural Heritage Information Centre (ANIC) website:

http://www/cd.gov.ab.ca/preserving/parks/anhic/natura_regions_map.asp

It was adopted for grouping of the cover types in Table 1. Four natural eco-regions were identified in the southern Alberta region. These were Rocky Mountain, Foothills, Parkland, and Grassland (Table 2). Watersheds were also included in this table in order to accommodate data provided by Ellis & Stanford, 2000 from Montana. Forest and Agriculture classes were classified under Native and Agricultural uses (Table 3).

Table 1. Cover Types to be included in the ALCES model for *Southern Alberta Landscapes: Meeting the Challenges Ahead* (Provided by Alberta Environment, Calgary)

Category	Classes
Native Prairie	
	Needle and Thread Dry Mixed Grass (Blue Grama)
	Northern Wheat Dry Mixed Grass (June grass)
	Needle and Thread Sand Grass
	Mixed Grass- Wheat Grass, Needle and Thread Grass
	Fescue Grassland – Foothills and Northern Fescue, Rough fescue, Idaho
	Fescue Parkland – Foothills Parkland and Montane – Rough Fescue –
	Prairie Shrubs
	Badlands and line breaks (valley sides and coulees)
	Riparian Cottonwood Complexes (Lentic and Lotic related)
Agriculture	
	Cereal
	Oilseeds
	Legumes
	Specialty
	Forage
	Tame Pasture
Forest	
	Hardwood
	Mixed wood
	Black Spruce
	Douglas Fir
	Pine
	Prairie treed
Other	
	Alpine
	Rock/Ice
	Forest Shrub
	Forb

3.1.1 NATURAL ECO-REGIONS

Much of Southern Alberta was covered with grassland prior to the advent of mechanized farming. An increase in human land use has significantly decreased the area of grassland in the region. There is limited information on export coefficients for natural eco-regions in the southern Alberta region (Table 2). This is because few areas have remained unaffected by the effects of livestock and fertilizer additions to farmland (Riemersma *et al.* 2002). This has necessitated the data extraction, transformation, and derivation of export coefficients from publications with sufficient information to do so. Such coefficients were derived for Alpine, Foothills Parkland and Dry mixed grass (Wilhelm & Schindler 1999; Sosiak, 2000; Ontkean *et al.* 2000 and Silva & Davies 1997 respectively). Areas of sub-drainage basins were obtained from the Canadian Water Survey database and used for the calculations. Such calculated export coefficient values serve only as estimates as they are based on limited information.

Golder Associates, 1999 reported export coefficients for TP and TN for high and low runoff in a small drainage basin (Red Deer tributary) from the Parkland eco-region. These values are probably from an agricultural basin as they are considerably higher than other values in this category. Values for TP and TN export coefficients were much lower during the low runoff season (TP 0.07 kg/ha/yr: TN 0.10-0.60 kg/ha/yr) than in the higher runoff season (TP 0.26-3.37 kg/ha/yr; TN 2.00-14.00 kg/ha/yr). Higher loads corresponding to heavy rain events have been previously recorded (Jensen *et al.* 1998, Xue *et al.* 1998).

Export coefficients were not found in this search for Montane, Upper and Lower Foothills, Peace River Parkland, Dry Mixed Grass and Northern Fescue. Export coefficients for TN for various watersheds in Montana ranged between 0.18 kg/ha/yr and 1.27 kg/ha/yr. Northern Montana has climatic conditions and eco-regions similar to that of southern Alberta.

No reports were available for export coefficients of total suspended solids. Sosiak 2000 was the only record that was suitable for data extraction and transformation. Values varied between 18.07 kg/ha/yr and 42.90 kg/ha/yr in Foothills Parkland and 24.02 kg/ha/yr and 100.99 kg/ha/yr in the Mixed Grass eco-region.

3.1.2 FOREST OR NATIVE AND AGRICULTURAL CATEGORIES

3.1.2.1 FOREST OR NATIVE CATEGORY

Nutrient losses in surface water runoff arising from forest management practices have been determined for few sites in Canada. The variations in climate, topography, and diversity of vegetation across Canada have made it difficult to assess the effect of forest management practices on water quality and quantity (Chambers *et al.* 2002).

Forested areas discharge less phosphorus than agricultural or urbanized land (Cooke and Prepas 1998). Manipulation of forest watersheds can drastically affect the physical characteristics of water in lentic and lotic systems, with sediment loads being generally high. Clear cutting has been demonstrated to increase the concentration of dissolved nutrients in surface runoffs. Forest removal affects nutrient leaching from forests by eliminating nutrient uptake by trees for a period of time (Douglas St.Onge *et al.* 1999, Devito *et al.* 2000).

There have been several studies on localized impacts from agricultural activities on phosphorus and nitrogen loadings of surface waters on the Prairies (Mitchell 1992; Anderson *et al.* 1995; Green 1996; Sosiak and Trew 1996; Anderson *et al.* 1998a, 1998b, 1998c; Cooke and Prepas 1998; Sosiak 2000, and Ontkean *et al.* 2000). Few studies provide information on export coefficients in the southern Alberta region (Table 3). Attempt was made to search for relevant literature with similarity to Alberta conditions. Selective information from the United States was also tabulated for comparative purposes. Land use categories were grouped as Forest or Native vegetation and Agriculture. Each category was further sub-divided as determined from literature sourced.

TP values from the Forest and Native vegetation were variable and ranged between 0.05 kg /ha/yr and 0.20 kg/ha/yr. TP export coefficients of 0.07 kg/ha/yr to 0.10 kg/ha/yr have been recorded for other areas in the United States (see Table 3), (Oberts *et al.* 1989, MDEQ 2001) and 0.20 kg/ha/yr (Beaulac and Reckhow 1982). The use of a wide range of documented values makes selection of export coefficients for modeling more statistically enabling and error margins lower.

There was less information available in the literature for export coefficients for TN (Table 3). Values ranged between 2.33 kg/ha /yr and 2.50 kg/ha/yr for locations in the United States. Nitrogen is considered as the nutrient that most often limits net primary production in forest ecosystems, particularly those in temperate and boreal regions (Vitousek and Howarth 1991). Fertilization studies involving single N applications have confirmed that N is the major limiting element for tree growth in many Canadian forest ecosystems (Weetman *et al.*. 1987; Morrison and Foster 1990), although not all forests in Canada are N limited.

All three agents of erosion - wind, water, and tillage (PFRA 2000), affect much of the Prairies. Agricultural development on the Prairies has resulted in widespread land clearing and drainage, soil erosion, water withdrawals, livestock concentration areas, land application of manure and inorganic fertilizer and the use of pesticides. These developments have had adverse effect on water quality.

Only two records of export coefficients for total suspended solids were retrieved for Forest and Native vegetation (Table 3). Similar values were cited by USEPA 1976 (250.00 kg/ha/yr) and Reckhow *et al.* 1980 (253.00 kg/ha/yr) for locations in the United States. Surface runoff from grass or non-cultivated soils carries little sediment and is therefore generally dominated by dissolved P.

Table 2 : Export Coefficients for Natural Eco-region Categories

ategory & Subdivisior	Export Coefficients kg/ha/yr			References /Notes
NATURAL ECOREGIONS	TP	TN	TSS	
Rocky Mountain				
Alpine	0.03-0.15			Snowflake lake, Banff- Wilhelm &Schindler 1999 (1)
Subalpine	0.10-0.30	1.75-3.75		Bondelid et al. 2001, USEPA contract report
Montane				
Foothills				
Upper Foothills				
Lower Foothills				
Parkland				
Foothills Parkland	0.03 - 0.08	0.20 -0.82	18.07 -42.90	Sosiak 2000, Mosquito Creek & Little Bow River (2)
Peace River Parkland				
Grassland				
Dry Mixed grass				
Foothills Fescue	0.01 - 0.21	0.05 - 1.24	24.02 - 100.99	Sosiak 2000, Mosquito Creek & Little Bow River
Northern Fescue				
Mixed Grass (Native Grass)	0.11			Timmons & Holt 1977
Mixed Grass	0.11 -0.47	0.05 - 2.34		Ontkean et al. 2000, Crowfoot Creek (3)
Mixed Grass	0.12-0.36	0.24-1.58		Silva & Davies 1997, Oldman River (4)
Mixed Grass	0.04	1.08		Silva & Davies 1997, Oldman River (4)
Watersheds				
Ashley Creek		1.27		Ellis & Stanford 2000, Montana
Stillwater/Whitefish		0.91		Ellis & Stanford 2000, Montana
Main-stem Flathead		0.89		Ellis & Stanford 2000, Montana
Swan		0.58		Ellis & Stanford 2000, Montana
Stoner Creek		0.18		Ellis & Stanford 2000, Montana
Forested Watershed	0.05 - 0.22			Cooke & Prepas 1998, Baptiste Lake AB
Agricultural Watershed	0.12 - 0.82			Cooke & Prepas 1998, Baptiste Lake AB
Wetlands	0.01	0.55		The Cadmus Group 1998, Schuylkill River Basin
Agricultural Basin -	0.7 L	0.10 - 0.60		Golder Associates 1999*.low (L) and high (H) runoff in a small
-	0.26 -3.37 H	2.00 - 14.00		drainage basin located in Red Deer tributary
* Cited in Manitoba (MLMMI) 2002				
1,2,3,4 Data extracted and transformed				

Table 3: Export Coefficients for Native and Agricultural Categories				
Category & Subdivisions	**Export Coefficients kg/ha/yr**			**References /Notes**
LAND USE	**TP**	**TN**	**TSS**	
Forest / Native Vegetation				
Natural vegetation	0.0085	0.44		USEPA 2002
Mostly natural	0.018	0.45		USEPA 2002
Baptiste	0.14			Mitchell & Trew 1992, north of Edmonton
Baptiste	0.05 - 0.22			Cooke & Prepas 1998
Wabamum	0.09			Mitchell & Trew 1992, west of Edmonton
Aspen Birch	0.13			Timmons et al. 1997 (in Riemersa et al 2002)
Native Prairie	0.11			Timmons & Holt 1997*
Two Creek	0.12			Munn & Prepas 1986*
Saskatchewan	0.08			Munn & Prepas 1986*
Forest	0.20	2.50	250.00	USEPA 1976; median values
Forest/Wetland	0.13	2.33		Dodd et al. 1992, North Carolina
Open/Wooded/Park	0.07 - 0.10			Oberts et al. 1989, Minnesota
Forest	0.21	2.46	253.00	Reckhow et al. 1980
Forest	0.20			Beaulac & Reckhow 1982**
Forest	0.05 - 0.12			Lassavils & Berrux 2000, Canada
Forest	0.20	2.50		Montana DeptEnviron Quality (MDEQ) 2001
Unmanaged Forest	0.035 - 0.05			MDEP 2000
Managed Forest	0.50 - 0.75			MDEP 2000
Forest (Clear cutting)	0.18 - 0.60			Douglas St.Onge et al 1999 , Quebec
Forest	0.30			Carmmermeyer et al 2000, Lake Washington/Sammamish Watershed
Agriculture				
Non Intensive				
Range/ Pasture	0.30	5.00	400.00	USEPA 1976
Pasture/Hay	0.81	5.19	514.5	Reckhow et al. 1980
Pasture	1.00			Lassavils & Berrux 2000, Canada
Pasture	0.90	5.10		MDEQ, 2001
Grassland, grazed	0.20 - 1.42			Mitchell & Hamilton 1982**, Lake Wabamum
Cultivated land	0.028 - 0.262			Anderson et al. 1998, **Haynes Creek, AB
Agriculture	0.99	9.80		Dodd et al. 1992, North Carolina
Agriculture	0.50 - 0.70			Oberts et al. 1989, Minnesota
Agriculture	0.031	0.98		USEPA 2002
Mostly Agriculture	0.028	0.63		USEPA 2002
Wabanum	0.16			Mitchell & Trew 1992, west of Edmonton
Baptiste	0.27			Mitchell & Trew 1992, north of Edmonton
Agriculture	0.40			Meals 1987*

Intensive				
Dairy Farms	0.10			Meals 1987*
Mixed agriculture	0.99	14.90		MDEQ 2001
Mixed	1.10			Olness et al. 1975*
Mixed agric/urban/cattle	0.50			Field 1986
Mixed			4900.00	Van Vliet & Hall 1991, Peace River,Saskatoon; fallow/canola/barley
Mixed			1000.00	Van Vliet & Hall 1991, Peace River,Saskatoon; fallow/canola/barley/fescu
Wheat stubble	0.40	10.00		Nicholaichuk & Read 1978, Swift Current, Saskatchewan
Wheat	2.96			Olness et al. 1975*, Oaklahoma
Wheat	1.10, 7.90	2.00, 3.60		Hargrave & Shaykewich 1991; runoff from sandy loam clay and sand loam
Wheat			1440.00	Larney et al. 1995b, Southern Alberta
Wheat			1900.00	Pennock & de Jong 1990, Saskatoon Prairie
Wheat- Agriculture			2100-2716	Pennock & de Jong 1987, Saskatoon Prairie
Fall fertilized,summerfallow	2.90			Nicholaichuk & Read 1978, Swift Current, Saskatchewan
Wheat, summerfallow	1.40			Nicholaichuk & Read 1978 Swift Current, Saskatchewan
Summer fallow	0.10 - 0.32	0.13 - 1.48		Ontkean et al. 2000, Crowfoot Creek(transformed data)
Fallow	5.80, 7.30	3.10, 6.30		Hargrave & Shaykewich 1991^; runoff from sandy loam clay and sand loam
Cotton (Dryland)	5.01			Olness et al. 1975*
La Nonne	0.50			Mitchell & Trew 1992, Northwest Alberta
Cropland	0.01 - 0.63	0.10 - 2.13		Ontkean et al. 2000, Crowfoot Creek(transformed data)
Non row crops	0.70			Reckhow et al. 1980; alfalfa, wheat, corn
Non row crops	0.80	6.80		MDEQ 2001
Row crops	2.20	8.20		MDEQ 2001
Row crops	2.00			Beaulac & Reckhow 1982**
Row crops	2.24	9.00		MDEP 2000
Corn/Soybean	2.20			Reckhow et al. 1980;
Corn/Soybean	3.80, 9.40	12.30, 7.90		Hargrave & Shaykewich 1991^; runoff from sandy loam clay and sand loam
Alfalfa	0.06, 0.33			Hargrave & Shaykewich 1991^; runoff from sandy loam clay and sand loam
Alfalfa	2.48			Olness et al 1975, Oaklahoma
Rotation Crops	1.50 - 3.50			MDEP 2000
Intensive, arable	3.00 - 5.00	1.00 - 6.00		Frissel 1978, N. Carolina, soybeans, wheat, potatoes
Intensive livestock, grazed	0.20	1.0 - 12.0		Frissel 1978, N. Carolina, grazed bluegrass
Flood irrigated farmland	0.20			Oosterveld & McMullin 1979, **Southern Alberta, Hayes
Sprinkler irrigated farmland	0.30			Oosterveld & McMullin 1979, **Southern Alberta, Hayes
Irrigated Watershed	1.93			Olness et al 1975, Oaklahoma
Dryland Watershed	0.71 - 1.23			Olness et al 1975, Oaklahoma
Irrigated land	0.002-0.048			Little AFFRD,unpublished, Battersea Drain
Cattle Wintering sites	0.04 - 0.37			Anderson et al 1998, Hayes Creek AB
Feedlot, manure storage	255.00			Reckhow et al. 1980
Feedlot	250.00	1000.00		USEPA 1976
Feedlot, manure storage	260.00	2900.00		MDEQ, 2001
*Cited in Mitchell & Trew 1992				
**Cited in Riemersma et al 2002				
^ MLMMI 2002				

3.1.2.2. AGRICULTURE

This class was further subdivided into non-intensive and intensive groupings. Considerably more information was available for this class for Alberta and the Prairies, although there have been very few studies relating specific agricultural management practices and suspended solids as export coefficients (Table 3). Farm practices such as tillage, degree of vegetative cover, crop type and inorganic and, organic fertilizer applications yielded different export coefficients.

3.1.2.2a. Total Phosphorus and Total Nitrogen Export Coefficients for Non-Intensive Agriculture

Export coefficients for phosphorus recorded under pasturing conditions ranged between 0.30 kg/ha/yr to 1.00 kg/ha/yr. Records for non-intensive agricultural practices were variable. They ranged between 0.028 kg/ha/yr and 0.40 kg/ha/yr for Alberta (Table 2) (Mitchell & Trew 1992, Anderson *et al.* 1998). Records for the United States were slightly higher, with a range between 0.50 kg/ha/yr and 0.99 kg/ha/yr being recorded.

Values reported for nitrogen from pasture ranged between 5.00 kg/ha/yr and 5.10 kg/ha/yr (USEPA 1976, MDEQ, 2001). Reckhow et al. 980 reported a TN value of 0.33 kg/ha/yr also from the United States. For general agricultural practice in North Carolina, Oberts et al. 1989 reported a TN export coefficient of 9.8 kg/ha/yr.

3.1.2.2b. Total Phosphorus and Total Nitrogen Export Coefficients for Intensive Agriculture

Export coefficients were recorded for various intensive agricultural practices (Table 3). Records for intensive agricultural practices were understandably variable due to the different crops planted. There were few reports for Alberta (Ontkean *et al.* 2000, Osterveld & McMullin 1979, and, Little, pers comm). No distinct trends could be identified between and within subgroups aside from three subgroups with similar records. Closely similar (two to three) records were obtained within the following sub groupings : Non row crops (0.70 TP kg/ha/yr and 0.80 TP kg/ha/yr), Row crops (2.00 TP kg/ha/yr and 2.20 TP kg/ha/yr, and, Feedlot manure storage (250.00 TSS kg/ha/yr to 260.00 TSS kg/ha/yr). Records were from the United States.

The loss of phosphorus in agricultural runoff occurs in sediment-bound and dissolved forms. Sediment phosphorus includes P associated with soil particles and organic material eroded during flow events and constitutes between 60 and 90 percent of P transported in surface runoff from most cultivated land (Sharpley *et al..* 1992). Many studies conclude that dissolved phosphorus loss in surface runoff is dependent on the phosphorus content of surface soil. In a review, Sharpley *et al.* 1996 found that the relationship between surface runoff P and soil P varies with management and is linked to soil P concentration. The timing of application of fertilizers and manure also play a major role in loss of phosphorus in runoff. Phosphorus in runoff from frozen ground loss may account for significant P loss as noted by Nicholaichuk and Read 1978 and the results of Hargrave and Shaykewich 1991 (Table 3).

The dissolved form of P arises from its release from soil and plant material. Most dissolved P is immediately available for biological uptake. Sediment P is not as readily available, although it can serve as a long-term source of phosphorus for aquatic biota (Sharpley, 1993; Elkholm, 1994). Leaching of nutrients might be minimal on the prairies of western Canada because potential evaporation and transpiration rates exceed precipitation by a very wide margin (Fairchild *et al*. 2000).

3.1.2.2c. Export Coefficients for Total Suspended Solids for Non-Intensive and Intensive Agriculture

There were far fewer records of export coefficients for total suspended solids in the literature. Larney et al. 1995b reported an export coefficient of 1440.00 kg/ha/yr from southern Alberta. Other reports from the Saskatchewan Prairie recorded an order of magnitude of three to four times values reported for non-intensive agriculture from the United States (Pennock and de Jong 1987, 1990; Van Vliet and Hall 1991). See Table 3.

Much eroded soil never leaves field boundaries but is re-deposited in depressions or behind clumps of vegetation. Up to 80% of water eroded soil has been found to remain in the field (Novotny and Chesters, 1981, 1989). The key water quality concern related to field runoff is the transport of sediments into surface waters. It is not clear, however, how important sedimentation from field runoff is on the Canadian Prairies (Anderson et al. 1998a; Environment Canada 1990). The sediments and the nutrients or chemicals adsorbed to soil particles can lead to water quality impairment and smothering of some aquatic organisms may occur.

3.1.3 NON-NATIVE LAND USE CATEGORIES

Export coefficients for non-native land use categories are presented in Table 4. Few records were found for Alberta. Coefficients for urban land use varied between residential, commercial or recreational and, location.

3.1.3.1 Municipal Wastewater Effluents

Efflluent from municipal wastewater treatment plants, industrial effluent, and stormwater are regarded as point sources of pollution. There is considerable information on water quality guidelines and total loading of municipal and industrial wastes to surface water. However, much of the information is presented in the form of percentage values relative to total loading, or recorded as g/m^2/yr, mg/l or kg/d. There is comparatively much less information presented as export coefficients from these sources.

Nutrient sources in municipal wastewater include human waste, household cleaning products, and by-products from industries that dispose wastewater to municipal sewer systems. Nitrogen enters domestic wastewater mainly from human waste. Phosphorus sources to municipal wastewater are more varied than nitrogen sources, arising from human waste, detergent and general-purpose cleaners, and, commercial and industrial sources.

Chambers *et al.* 2002 evaluate anthropogenic sources of nitrogen and phosphorus in Canada. Data are provided on sources and total loadings in municipal and industrial effluents. Nutrient losses from agricultural activities to surface and groundwater's were mainly presented as percent of nutrient application in fertilizers and manure. Export coefficients were presented for stormwater runoff for various locations in Canada, which have been incorporated in Table 4. Riemersma et al. 2002 present more region specific information in their review of phosphorus sinks and sources that may affect Alberta's water resources.

In urban areas, snowmelt or stormwater runoff from house roofs, parking lots, and streets discharge into the municipal sewer system. Sewer systems built before the early 1940's disposed of household wastewater by discharge into rivers, lakes or coastal waters. All the major Prairie cities (Edmonton, Calgary, Saskatoon, Regina, and Winnipeg) provide secondary treatment of wastewater. Regina, Saskatoon, Calgary, Toronto and Ottawa also undertake advanced phosphorus removal (tertiary treatment) (Chambers *et al.* 2002). It was for this reason that documented values for Toronto and surrounding areas were included.

Table 4: Export Coefficients for Non-Native Land Use Categories				
Category & Subdivisions	**Export Coefficients kg/ha/yr**			**References /Notes**
Non-Native Land Use	**TP**	**TN**	**TSS**	
Urban				
Urban	0.80	5.00	2000.00	USEPA 1976
Urban	1.10	5.50		Reckhow et al. 1980
Mostly Urban	0.03	0.79		USEPA 2002
Urban, developed	0.45-1.50	5.00 - 9.72		Dodd et al. 1992, North Carolina
Urban, residential	0.60-1.90			Oberts et al. 1989, Minnesota
Urban, residential	0.25	0.35		MDEP 2000
Urban, residential	1.49	6.15	208.60	Reckhow et al. 1980, Philadelphia
Urban, residential - Low densi	1.25			Cammermeyer et al 2000, L.Washington/Sammamish Watershed
Urban, residential - High densi	1.45			Cammermeyer et al 2000, L.Washington/Sammamish Watershed
Urban, high density, commerci	1.70 - 3.00			Oberts et al. 1989, Minnesota
Urban, commercial	2.25			Cammermeyer et al 2000, L.Washington/Sammamish Watershed
Urban - Average	1.80			Cammermeyer et al 2000, L.Washington/Sammamish Watershed
Lawns/Golf courses	0.19	1.52		Reckhow et al. 1980, Philadelphia
Logging Roads	3.50			MDEP 2000
Public Highways	3.50			MDEP 2000
Camp and Private Roads	3.50			MDEP 2000
Municipal Waste Treatment Pl	7.70			White & Bayley 2001, Frank Lake AB
Stormwater	0.22	10.3 NO3-N		Dixon 1974*, Calgary
Stormwater	1.00	5.00		Vokey 1998, Nova Scotia
Stormwater	0.26-2.50	1.30-13.00		Stanley Assoc. Eng. Ltd*, Fraser River Basin, BC
Stormwater	0.70			Singer 1977*, Windsor ON
Stormwater	2.60			Singer 1977*, North York ON
Stormwater – Residential	1.30			Marsalek 1984* Burlington ON
Stormwater – Commercial	1.60			Marsalek 1984* Burlington, ON
Rain and runoff		0.71 NO3-N		Ro et al. 1998*, Esther, AB
Rain and runoff	0.20			Shaw et al. 1989*, Central Alberta
Industrial				
Industrial	7.95	2.25	868.70	Reckhow et al. 1980
Cargill Slaughter house	50.00			White & Bayley 2001, Frank Lake AB
Strip mines/barren land	1.50	8.60		The Cadmus Group 1998, Schuylkill River Basin
* Cited by Chambers et al. 2002				
** Maine Dept.Env.Protection (MDEP) 2000				

3.1.3.2. Industrial Discharges

Larger industries such as pulp and paper mills, mining operations manage their own waste independently unlike smaller lighter industries that discharge their wastes into nearby Municipal Waste Treatment Plants (MWTP). Mining operations, agricultural industries, and electrical power generation are other industrial point sources of phosphorus pollution in Alberta, but contribute less to the phosphorus load of rivers and lakes (Riemersma *et al.* 2002). The role of pulp and paper industries in river eutrophication is only now being recognized (Chambers *et al.* 2002)

Nutrient studies in Alberta have generally tended to examine the combined contributions of municipal wastes and industrial discharges in the form of basin studies. These include studies on the Northern River Basin (Chambers 1996) and Frank Lake (White and Bayley 2001). Data currently being gathered by the Oldman River Basin Water Quality Initiative will enable the calculation of export coefficients for selected sub-basins (Saffran, pers.comm).

3.1.4 OTHER CONSIDERATIONS

Wetlands and Riparian Areas

In the case of river and freshwater wetlands, less information is available about their nutrient status, and available information is not presented as export coefficients. There is suggestive evidence that these systems may be nitrogen or phosphorus -limited when less affected by human activity (Morris 1991, Scrimgeour & Chambers 2000). Wetlands are unique ecosystems that are characterized based on the areas they inhabit, vegetation, morphology, hydrology and chemistry. Riparian wetlands receive only seasonal flooding and records of export coefficients for these areas were not encountered in the review. These areas merit investigations into the dynamics of their nutrient and sediment loadings.

4. Recommendations and Conclusion

4.1. Recommendations

It must be emphasized that that export coefficients are momentary values. They are based on hydrological and precipitation regimes, soil characteristics, land use and management practices, and may vary for even the same drainage basin from year to year. As such, they serve as estimates and are a useful scientific tool for comparative analyses. . Because T (time) of experimental sampling for the determination of export coefficients can be variable, data may be extrapolated to generate the export coefficient in units of kg/ha/yr.

Selection of coefficients are best done when the sample base (in this case, the number of records for a given cover type) is high. Statistical bias and errors will be minimal when the sample size is large (Zar, 1998). This is difficult for this exercise because of the paucity of information for the southern Alberta region. Other techniques need therefore be adopted.

It is recommended that the final selection of export coefficients for use in the ALCES model be made following a deliberation of information presented in this review by a panel consisting of members with knowledge of the southern Alberta region, the ALCES model, and the literature. For each land cover type or use, focus should be given to climate, soil types, topography, and location from where the export coefficient was recorded, spread of the data, and any other variables that could affect the selection of a value.

4.2. Conclusion

Currently, environmental problems caused by excessive nutrients are less severe in Canada than in countries with a longer history of settlement and agricultural production. This is because of the relatively small population of the country compared to its land base, coupled with the protective measures implemented by the federal, provincial and territorial governments over the last 30 years (Chambers *et al.* 2002). There are knowledge gaps for nutrients for export coefficients for various cover types and land uses in the southern Alberta region. This is an area where more studies need to be conducted. Increased knowledge will enable the development and adoption of management practices and technologies that will make the agricultural production and processing industry more environmentally sustainable.

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