Alberta
Southern East Slopes
Integrated Land Management
Pilot Project

Prepared for:

Alberta Environment
Environmental Monitoring and Evaluation Branch

Alberta Sustainable Resource Development
Sustainable Resource and Environmental Management

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September 2008

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1. INTRODUCTION

The Government of Alberta faces a significant challenge on how to accommodate competing economic and social interests that are placing unprecedented pressure on its natural resources and environment. The Government has acknowledged that new policies, systems and tools will be needed to be successful.

The Southern East Slopes Integrated Land Management Pilot Project (SES Pilot) used a real landscape and real data from southwest Alberta to evaluate how selected ecological and economic 'performance' outcomes could be achieved through different land management scenarios and how such integrated evaluations might be of use for policy analysis, economic trade-off analysis, and land use decision making. Economic and ecological indicators (genuine progress indicators) were developed using an integrated Genuine Wealth Accounting system (i.e. integration of natural, financial, and social capital accounts) to account for the physical and qualitative conditions and the monetary value, where possible, of key ecological assets, including water, carbon, and land. These indicators were then used to simulate potential trade-offs among market and non-market resource values using the ALCES© model, including the influence of pre-defined land management objectives on these indicators.

The objectives of the SES Pilot were to demonstrate how:

a. economic and ecological genuine progress indicators can be modeled and tracked in ALCES© to provide a more comprehensive way of understanding, managing and reporting on real progress and trade-offs over the next 50 years (**Ecological Goods and Services** component).

b. managing to achieve pre-defined ecological objectives for four complementary indicators would influence overlapping land uses and trade-offs and how ALCES© can be used to explore under what conditions these objectives could be achieved (**Land Management Objectives** component).

The SES Pilot project was intended to provide insight, learning, and a prototype tool to the Government of Alberta to help them explore the opportunities and challenges associated with alternative land management approaches to regional outcomes through a cumulative effects management approach. As such, the goal of this project is NOT to define ecological management objectives, nor to build the "correct" landscape/land use combination for the SES study area, but to illustrate how different combinations of land uses, operating at different intensities and deploying alternative technologies, influence trade-offs between economic and ecological indicator performance and ultimately achieve the outcomes.

The SES Pilot was conducted for Alberta Environment (AENV) and Alberta Sustainable Resource Development (ASRD) by members of the ASPEN Group, a network of fifteen independent scientists and policy experts with interests in regional cumulative effects and resource management. Project sponsors included Arnold Janz and John Taggart of AENV and Morris Seiferling of ASRD.

Brad Stelfox (ALCES Group) completed ALCES© model revisions, directed management scenario simulations, and developed carbon stock coefficients. Mark Anielski (Anielski Consulting) estimated present market and non-market resource values. Matt Carlson (ALCES Group) conducted management scenario simulations. Terry Antoniuk (ALCES Group) acted as project coordinator and developed ecological management objectives and water quality and economic coefficients.

1.1 STUDY AREA

The SES Pilot study area was adopted from the Southern Foothills Study (SALTS 2007) to facilitate implementation of this ‘proof of concept’ pilot project. The 12,302 km^2 southern foothills study area is bounded on the west by the Alberta-British Columbia border, on the east by Highway 2, on the north by Township road 200 immediately south of the community of Turner Valley; and on the south by Township road 60 located south of Highway 3 (Figure 1). The estimated study area population is 40,000 residents.

Table 1 summarizes the landscape (land cover) and footprint (land use feature) types used in ALCES to characterize the SES study area. Assumptions on past and future land use developed for Southern Foothills Study were also used, except where noted below. This included sector-specific Best Management Practices developed in consultation with industry and Southern Foothills Study project representatives.

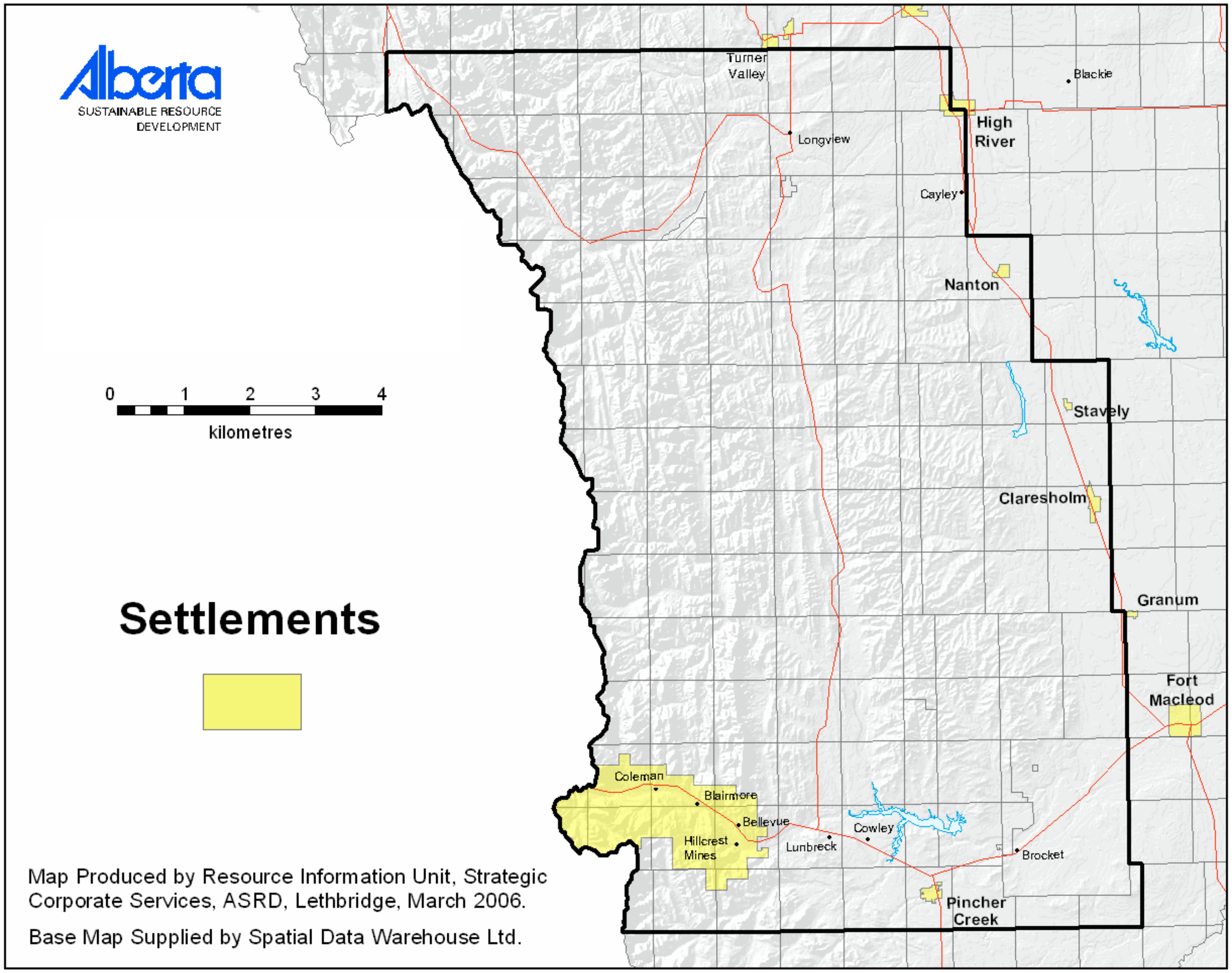

Figure 1. Southern East Slopes Integrated Land Management Pilot Project study area.

Table 1. ALCES Landscape and Footprint Types, commodities, and ecological services Indicators used in the SES Pilot.

ALCES SES Landscape Types	ALCES SES Footprint Types	ALCES SES Commodities (GDP)	Anielski and Wilson (2007) Ecological Goods and Services Indicators	ALCES SES Ecological Service Product (ESP) Indicators
Hardwood Forest	Major Road	Cattle	Atmospheric regulation	–
Mixedwood Forest	Minor Road	Cereal Crops	Climate regulation	Biotic carbon
White Spruce Forest	Wind Turbine	Oilseeds & Pulses	Disturbance avoidance	–
Pine Forest	Inblock Road	Forage	Water stabilization and regulation	Water supply
Spruce Fir Forest	Gravel Pit/Coal Mine	Oil Production	Water filtration	Water quality
Prairie Treed/Riparian	Transmission Line	Natural Gas Production	Erosion control and sediment retention	
Mixed Grassland	Feedlot	Softwood Production	Soil formation	–
Fescue Grassland	Industrial/Rec	Tourism	Nutrient cycling	–
Fescue Parkland	Agricultural Residence	Non-resource Values (service sector)	Waste treatment	–
Grassland Shrub	Town/City		Pollination	–
Forest Shrub	Acreage		Biological control	–
Lotic Water	Seismic Line		Habitat / refugia	–
Lentic Water	Wellsite		Food production (country foods)	–
Reservoir	Pipeline		Raw materials	–
Cereal Crop	Canal		Genetic resources	–
Oilseeds & Pulses	Cutblock		Recreation	Recreation and Tourism
Forage Crop			Culture	–
Tame Grassland				
Rock/Ice				
Badlands				

2. ECOLOGICAL GOODS AND SERVICES

Classical economic indicators, such as the Gross Domestic Product (GDP) and national income accounts, ignore the value of ecological goods and services and natural capital values. GDP only measures the market value of total goods and services so that the conversion of natural areas for development, for example, is counted as monetary income from timber sales without accounting for the loss in natural capital assets and natural values. In addition, the costs of the impacts by humans on natural assets are unaccounted for, such as the loss of natural values or ecosystem services due to pollution. As a result, the way in which we measure and count our wealth and well-being is misleading and incorrect.

Conventional economics does not recognize natural assets and their values (e.g. ecosystem services) as valuable until they become so degraded or scarce that human infrastructure has to replace the natural services that had been provided for free. For example, the build up of carbon dioxide and other greenhouse gases in the atmosphere primarily due to the burning of fossil fuels for energy poses an increasing threat to economic, social and ecological well-being.

Natural capital refers to the natural environment, which provides a long-term stream of goods and services that benefit communities. Goods come from ecosystems (e.g., timber) and non-living sources (e.g., mineral deposits), whereas ecosystem services (e.g., pollination) come from ecological systems or ecosystems.

Ecosystem goods and services have been defined as the benefits human populations derive from healthy functioning ecosystems. Table 1 (above) presents a comprehensive classification system used to describe ecosystem services that includes 17 ecosystem functions. Analysis of ecosystem services is based on ecosystem functions or the capacity of natural processes and systems to provide goods and services that serve human needs. These include the products received from ecosystems (e.g., food, fibre, clean air and water), the benefits from ecosystem processes (e.g., nutrient cycling, water purification, climate regulation) and non-material benefits (e.g., recreation and aesthetic benefits). Some are local services and others are regional or global in nature.

Natural capital accounting helps communities and other jurisdictions take stock of their natural assets and the natural values that they provide, including ecosystem goods and services. Natural capital accounting includes land/water accounts that track: the distribution and area of land and water cover types; the goods and services that are provided by natural capital; the change in provision and value of ecosystem goods and services due to changes in ecosystem land/water cover; and the impacts of human activities such as degradation from pollution.

2.1 CURRENT VALUATIONS

This study follows similar methodological protocols as the Canadian Boreal Initiative's natural capital reports prepared by ecological economists Mark Anielski and Sara Wilson: 'The Real Wealth of the Mackenzie Region' report (Anielski and Wilson 2007);

and ‘Counting Canada’s Natural Capital: Assessing the Real Value of Canada’s Boreal Ecosystems’ (Anielski and Wilson 2005).

The primary goal of the SES ecological goods and services component was to construct a preliminary natural capital account for the SES study area incorporating: a) the market value of natural capital assets (e.g. timber, oil, gas and agricultural land) as measured in terms of GDP and b) the non-market Ecosystem Service Product (ESP) value of ecosystem services.

Based on the Mackenzie study by Anielski and Wilson (2007), GDP and ESP values were considered to be additive, with GDP used as a proxy for the economic (monetary) value of the market economy and ESP as a proxy for the value of ecological goods and services, in the absence of a market where these are exchanged for money. The combination of GDP and ESP values, expressed in dollar terms, is referred to here as a Genuine Progress Indicator (GPI) value. In an ideal situation, GDP and ESP values should be optimized, however, in reality there tends to be a trade off between generating GDP value from natural capital extraction and loss of ESP values due to loss or degradation of various ecosystem functions or services and natural capital, in general (e.g. carbon sequestration by wetlands from conversion to agricultural land).

For the SES pilot project, the term GPI was used in place of the ‘subtotal ecological-economic product’ (SEP) value. The term SEP was used by Costanza and Sutton (2002) to represent the total of both market values of the economy and non-market values of ecosystem services.[1]

2.2 GROSS DOMESTIC PRODUCT (GDP) VALUES

The market value of natural capital consumed for commercial and private benefit was based on GDP estimates. GDP is the total market (monetary) of all final goods and services produced within a nation, province, or geographic region. There is currently no GDP data collected by Statistics Canada at the spatial scale of the SES study area; generally GDP estimates are only available at the provincial scale or for large municipalities like Edmonton CMA or Calgary CMA. Because of this, GDP was estimated using various protocols described below.

GDP estimates were derived for: forestry; energy; agriculture; and all other non-resource-based sectors for the SES study area. First, we collected 2006 GDP statistics for Alberta from Statistics Canada for the forestry (including logging, wood manufacturing), mining,

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[1] The GPI was originally developed in the US by Redefining Progress (an economic think-tank) in 1995 as an alternative measure of economic well-being to the GDP taking into account some of the environmental and social costs as well as unaccounted positive benefits (e.g. unpaid work or volunteerism) of economic progress which national income accounts and GDP currently treat as positive additions rather than negative costs to current and future generational well-being. GPI is an attempt to measure whether or not a country's growth, increased production of goods, and expanding services have actually resulted in the improvement of the welfare (or well-being) of the people in the country. Thus the application of the GPI model to the SES study is rather narrow focusing on only a few ecosystem services and estimates of the loss of ecosystem service values due to industrial development.

oil and gas extraction, agriculture (including crop and animal production), sectors and other non-resource sectors for the entire province of Alberta (see Table 2). Second, we divided these GDP figures by estimates of the land area of the province that was available or allocated to each respective resource sector in the SES study area in 2006. In the case of forestry we assumed an available forest land base of 26.1 million hectare, 59.2 million hectares for the mining/oil/gas sector, 10.8 million for the agriculture sector, and 26.6 million hectares available for recreational activities.[2] In the case of non-resource sectors we assumed that this sector operates across the entire provincial land base. In the case of recreation GDP we used estimates of the value of nature to Canadians..

We assumed that the provincial GDP per ha resource and non-resource sector values could be applied to the SES region in the absence of detailed sector-based economic statistics. We then applied the provincial per hectare GDP figures by sector to the available land estimates provided above.

Current GDP estimates summarized in Table 2 show the significant value of the mining, oil and gas sector ($1.159 billion to the SES) and the non-resource sector ($2.092 billion) in 2006. The range of GDP values per hectare values, from highest to lowest, are mining/oil/gas, agriculture (crops, livestock), recreation and forestry. Total economic (GDP) value per hectare for the entire SES study area was estimated to be $2,958/ha in 2006.

Table 2. Market GDP Values estimates by sector in the Southern East Slopes study area, 2006.

	GDP Market Values ($/ha)	Area (ha)	Total GDP Market Values, 2006
Forestry GDP	$12.63	193,241	$2,441,419
Mining, Oil and Gas GDP	$1,075.34	1,078,555	$1,159,811,013
Agriculture GDP (crops and animal production)	$308.98	553,488	$171,017,383
Recreation "GDP" Values	$58.58	511,737	$214,071,875
Non-resource sector GDP (all other sectors), est.	$1,700.70	1,230,219	$2,092,229,795
Total GDP of total Southern East Slopes study area	$2,958.47	1,230,219	$3,639,571,484

Sources: Derived from Statistics Canada GDP data and ALCES analysis for land area.

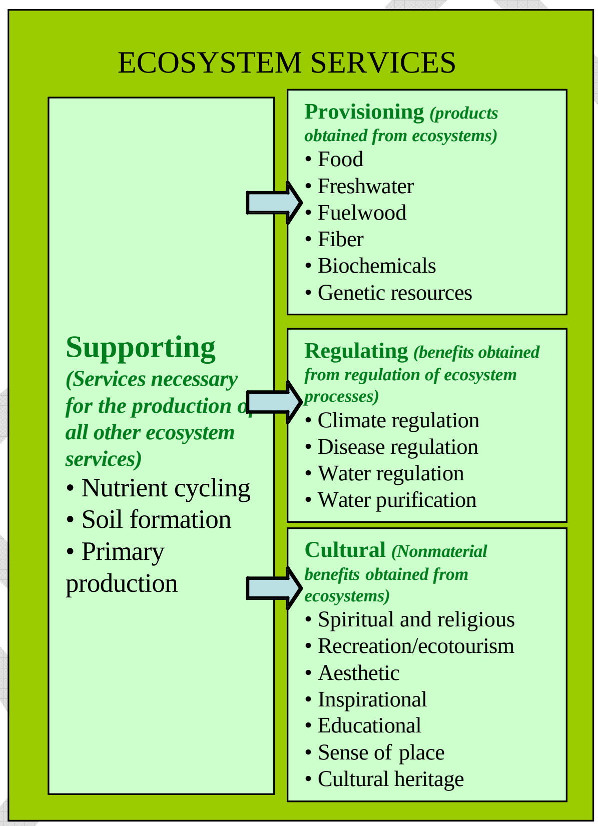
[2] There is naturally some overlap or duplication of land use particularly in the case of oil and gas which can operate on both forest and agricultural lands.

2.3 ECOSYSTEM SERVICE PRODUCT (ESP) VALUES

We then estimated the ESP value (expressed in monetary terms) of a number of ecological goods and services for each land-cover type in the study region. There are as many as 17 possible ecosystem functions performed by various types of ecosystems (see Table 3).

Figure 2 is a graphic developed by the UN's Millennium Assessment in 2005 where services are clustered according to provisioning, regulating and cultural services:

Figure 2. Ecosystem Services (UN Millennium Assessment).



Source: United Nations *Millennium Ecosystem Assessment Synthesis Report*. 2005; p. 9

Table 3. Ecosystem Services and their functions.

Ecosystem Service	Ecosystem Function	Examples of Services
1. Climate regulation (gas regulation and air quality, carbon storage)	Stabilization of atmospheric chemicals	$C0_2$/0_2 balance; stratospheric ozone; $S0_2$ levels
2. Disturbance regulation	Integrity of ecosystem responses to environmental fluctuations	Storm protection; flood control; drought recovery; vegetation structure that helps to cope with environmental variability
3. Water regulation	Stabilization of hydrological flows	Supply water for agriculture use (irrigation), industrial use, or transportation
4. Water supply (filtration)	Storage and retention of water	Water storage by watersheds, reservoirs, and aquifers
5. Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of soil loss by wind and runoff; storage of silt in lakes, wetlands; drainage
6. Soil formation	Soil formation process	Weathering of rock; accumulation of organic material
7. Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	Nitrogen fixation; nitrogen/phosphorous, etc.; nutrient cycles
8. Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess nutrients and compounds	Waste treatment; pollution control; detoxification
9. Pollination	Movement of floral pollinators	Provision of pollinators for plants
10. Seed dispersal by birds	Dispersion of seeds by birds	Forest birds dispersal of seeds.
11. Biological control	Regulation of pest populations	Predator control of prey species
12. Habitat	Habitat for resident and transient populations	Nurseries; habitat for migratory species
13. Food production	Nature foods	Seafood, game, and spices
14. Raw materials	Natural resource primary production	Lumber; fuels; fodder; crops; fisheries
15. Genetic resources	Sources of unique biological materials and products	Medicine; products for materials; science; genes for plant resistance and crop pests; ornamental species
16. Recreation	Opportunities for recreation	Ecotourism; wildlife viewing; sport fishing; swimming; boating; etc.
17 .Cultural	Opportunities for non-commercial uses	Aesthetic; artistic; education; spiritual; scientific; Aboriginal sites

Sources: Based on Amanda Sauer. *The Values of Conservation Easements* (discussion paper, World Resources Institute, presented to West Hill Foundation for Nature, December 1, 2002); Robert Costanza et al. *The Value of the World's Ecosystem Services and Natural Capital. Nature* 387 (1997): pp. 253–260.

Ecosystem services were considered for each SES study area land cover type noted in Table 1 (Section 1.1). It was not possible to estimate values for each ecosystem service because of data limitations or the absence of methodologies for analyzing various ecosystem functions. Conservative estimates of all possible ESP values for the SES study area were derived where possible by land cover type. The methods used to estimate ESP values include a combination of: methodological approaches from Sutton and Costanza (2002)[3]; Mackenzie Watershed study (Anielski and Wilson 2007), and a recent study for the Green Belt region of Ontario (S. Wilson pers. comm.).[4] A detailed description of these methods is beyond the scope of this report; interested readers are invited to contact Mark Anielski for further information.

The ESP values for the total SES study region are summarized in Table 4 for each of the 17 possible ecosystem services (those services missing information reflect lack of data or methods for calculation): Detailed calculations by land cover type are shown in Table 5. Total ESP value for the entire SES study area were estimated to be roughly $2,872 million in 2006 or $2,334 per hectare.

Table 4. Southern East Slopes study area total Ecosystem Service Product (ESP) values.

Ecosystem Service	**Ecosystem Service Product Value ($millions 2006)**
1. Climate regulation (gas regulation and air quality; carbon storage and sequestration)	766.0
2. Disturbance regulation	18.1
3. Water regulation	677.2
4. Water supply (filtration)	1,135.4
5. Erosion control and sediment retention	63.3
6. Soil formation	10.6
7. Nutrient cycling	n.a.
8. Waste treatment	82.7
9. Pollination	53.3
10. Seed dispersal by birds	2.9
11. Biological control	24.2
12. Habitat/refugia	1.5
13. Food production	0.086
14. Raw materials	n.a.
15. Genetic resources	n.a.
16. Recreation	36.3
17 .Cultural	0.054
Total ESP Value	2,871.7

[3] Paul C. Sutton and Robert Costanza, "Global Estimates of market and non-market values derived from satellite imagery, land cover, and ecosystem service valuation," Ecological Economics 41 (2002):509-527.
[4] Wilson, Sara and Peter Lee. 2007. Greenbelt Ecosystem Values Project. Draft report December 15, 2007.

Table 5. Estimated ecosystem service values for the SES study area (2006$/ha).

Ecosystem Service	Forest			Wetlands	Grassland			
	Evergreen Needleleaf	Deciduous Broadleaf	Mixedwood	Wetland (Marsh: Prairie Treed/Riparian)	Mixed Grassland	Fescue Grassland	Fescue Parkland	Grassland Shrub
1. Gas regulation/Air Quality	$386.26	$386.26	$386.26	-	$12.38	$12.38	$12.38	$12.38
1a. Climate regulation (stored)	$677.48	$677.48	$677.48	$552.65	$533.02	$533.02	$533.02	$533.02
1b. Climate (seq.)	$40.05	$40.05	$40.05	$5.33	$29.26	$29.26	$29.26	$29.26
2. Disturbance regulation	-	-	-	$4,136.15	-	-	-	-
3. Water regulation	$1,559.88	$1,559.88	$1,559.88	$53.06	$6.78	$6.78	$6.78	$6.78
4. Water supply (filtration)	$212.76	$212.76	$212.76	$212.76	$212.76	$212.76	$212.76	$212.76
5. Erosion control and sediment retention	-	-	-	-	$51.29	$51.29	$51.29	$51.29
6. Soil formation	$17.69	$17.69	$17.69	-	$10.17	$10.17	$10.17	$10.17
7. Nutrient cycling	-	-	-	-	-	-	-	-
8. Waste treatment	$59.73	$59.73	$59.73	$3,090.03	$149.21	$149.21	$149.21	$149.21
9. Pollination (agri)	$59.52	$59.52	$59.52	-	$94.86	$94.86	$94.86	$94.86
10. Seed dispersal (birds)	$6.79	$6.79	$6.79	-	-	-	-	-
11. Biological control	$26.60	$26.60	$26.60	-	$40.69	$40.69	$40.69	$40.69
12. Habitat/Refugia	-	-	-	$343.13	-	-	-	-
13.Food production	-	-	-	-	-	-	-	-
14. Raw materials	-	-	-	-	-	-	-	-
15.Genetic resources	-	-	-	-	-	-	-	-
16. Recreation & Aesthetics	-	-	-	-	-	-	-	-
17, Cultural/Spiritual	-	-	-	-	-	-	-	-
Total per ha $/ha/yr, 2006$	$3,047	$3,047	$3,047	$8,393	$1,140	$1,140	$1,140	$1,140
Current Area (ha)	344,770	74,777	13,170	4,373	7,750	29,353	249,477	4,101
Initial Area (ha), 1958	450,680	97,748	17,216	5,716	10,131	38,370	326,114	5,361
Total value $M/yr, 2006	**$1,050.4**	**$227.8**	**$40.1**	**$36.7**	**$8.8**	**$33.5**	**$284.5**	**$4.7**

Note: Blank cells denote that no value estimates are available.

Table 5 (cont). Estimated ecosystem service values for the SES study area (2006$/ha).

Ecosystem Services	**Transition Treed Shrubland**	**Water**			**Cropland**	**Snow/Rock/Ice**	**Barren Land/Tundra**	**TOTALS**
	Forest Shrub	**Lotic Water**	**Lentic Water**	**Reservoir**	**Cereal Crop, Oilseeds, Pulses, Forage Crop, Tame Grassland**	**Snow/Rock/Ice**	**Badlands**	
1. Gas regulation/Air Quality	-	-	-	-	$340.58	-	-	-
1a. Climate regulation (stored)	$338.74	-	-	-	$26.01	-	-	-
1b. Climate (seq.)	-	-	-	-	-	-	-	-
2. Disturbance regulation	$0.06	-	-	-	-	-	-	-
3. Water regulation	-	-	-	-	-	-	-	-
4. Water supply (filtration)	$212.76	$12,088	$12,088	$12,088	-	$6,044.21		
5. Erosion control and sediment retention	-	$3,744	$3,744	$3,744	$6.06	-	-	-
6. Soil formation	-	-	-	-	-	-	-	-
7. Nutrient cycling	-	-	-	-	-	-	-	-
8. Waste treatment	-	-	-	-	-	-	-	-
9. Pollination (agri)	-	-	-	-	-	-	-	-
10. Seed dispersal (birds)	-	-	-	-	-	-	-	-
11. Biological control	$13.30	-	-	-	-	-	-	-
12. Habitat/Refugia	$0.32	-	-	-	-	-	-	-
13.Food production	$1.30	-	-	-	-	-	-	-
14. Raw materials	-	-	-	-	-	-	-	-
15.Genetic resources	-	-	-	-	-	-	-	-
16. Recreation & Aesthetics	-	-	-	-	$138.12	-	-	-
17, Cultural/Spiritual	$0.82	-	-	-	-	-	-	-
Total per ha $/ha/yr, 2006$	$567	$15,832	$15,832	$15,832	$511	$6,044		$76,715
Current Area (ha)	66485	7,172	2,743	2,583	262,807	134,891	24	**1,204,476**
Initial Area (ha), 1958	86,908	9,375	3,586	3,372		176,328	31	**1,230,935**
Total value $M/yr, 2006	**$37.7**	**$113.6**	**$43.4**	**$40.9**	**$134.2**	**$815.3**		**$2,872**

More in-depth analyses were completed for four ecosystem services (water regulatory services, water filtration services, gas regulation/climate regulation (carbon storage), and recreational values) to provide inputs for ALCES simulations. These four ecosystem services were selected because: of their perceived ecological value to human populations in the region who benefit from Natures' capital; they make up the majority (91.1%) of the total ESP value estimates for the SES study area (i.e., $2,614.8 million in value in 2006); and sufficient data were available for them to derive values for all landscape and footprint types. Discussion of each of these ecosystem services is provided below.

2.3.1 Water Quantity (Water Regulation Services)

Forests, wetlands, grasslands and other natural land cover types in a watershed provide value by regulating and stabilizing water flows. Water retention and avoiding costs of storm runoff impacts is an important asset to the well-being of people living in the SES study area, as well as others outside of the area who benefit from the integrity of the SES ecosystem.

The value of water regulation was calculated as a replacement value. We adopted Sara Wilson's estimates from her ongoing analysis of water regulatory services for the Greenbelt region of Ontario (Wilson pers. comm.) as a proxy value of water regulatory services. Wilson derived a value of $1,523 per hectare of natural forest cover per year as the annual benefit of forests in water regulations. Her estimates were based on other studies and estimates of the value of the replacement construction costs for water runoff control systems that would have to be built to replace the water regulatory benefits of intact forests, wetlands, and grassland ecosystems. These replacement costs are then converted to estimates of annual stormwater runoff savings amortized over 20 years at a discount rate of 6% then divided by the area of the watershed.

For the purposes of our SES study, we adjusted Wilson's estimate of $1,523/ha to 2006 dollars yielding an estimate of $1,559.88 per hectare for forest cover. We then applied this per hectare value to the forest cover of evergreen needleleaf, deciduous broadleaf, and mixedwood forest in the SES study area.

We also estimated the value of water regulatory services of wetlands (at $53.06/ha) and grasslands ($6.78/ha). The estimated 2006 total value of water regulatory services of forests, wetlands and grasslands in the SES study area was $677,189,744.

2.3.2 Water Quality (Water Supply/Filtration)

The value of water supply and filtration services by nature was derived by estimating the value of the area of forests, wetlands, grassland, snow/ice, and waterbodies (rivers, lakes, reservoir) in the SES area that filter water and provide clean drinking water for the benefit of downstream human populations, including the 40,000 residents in this region as well as Calgarians and other provincial citizens.

We estimated that the water supply services of the SES are the most significant ESP value of all ecosystem services estimated at $1,135 million for 2006. These values are based on a) the estimated value of waterbodies (including snow/ice) in providing clean drinking water to human populations and b) the value of intact forests, wetlands, and grasslands in serving as water filtration services. To derive the value of water supply and filtration services we used the water treatment operating and capital costs for the City of Calgary for 2004 as a proxy. The rationale is that water bodies themselves provide services not unlike the human-built water treatment facilities and would have at least as high if not higher true economic value if they had to be replaced with infrastructure that would provide the same quality of services (i.e. clean drinking water).

In 2004 the water (“Waterworks” budget) treatment operating and capital costs were an estimate $151,081,167 which was then divided by the area of water bodies (rivers, streams, and lakes) in the SES area, which is estimated at 12,498 hectares. This yielded a value for water supply services of $12,088/ha of all waterbodies. We feel this value is a reasonable proxy value for the benefits of water supply services since part of the benefits of these water regulation services accrue to Calgarians given that some of the Calgary’s water originates in this watershed. Another alternative approach to valuing these water regulatory would be to estimate the per capita/Calgarian water treatment operating and capital costs and apply this per capita number to the 40,000 population living in the SES as a proxy for the benefit of these services to the regional population. However, since the benefits of these services accrue to more than the local population we feel our approach is reasonable.

The value of snow and ice in the region, covering an estimated 134,891 hectares, is estimated based on 50 percent of the waterbodies water supply services values, namely $6,044/ha.

The second estimate of water supply and filtration services is based on the value of currently intact forests (evergreen (344,700 ha.), deciduous broadleaf (74,777 ha.), wetlands (4,373 ha.), grasslands (290,681 ha.), and transition shrubland (66,485 ha.) in terms of their respective services in filtering water. The value of these intact landscapes for water filtration is based on estimates of the avoided treatment costs to municipalities like the City of Calgary assuming that these landscapes no longer in integral condition. This avoidance cost method of valuing water filtration services uses a method which measures the difference between actual water treatment costs relative to the current integrity of a watershed (measured in terms of current land cover by land cover type and specifically in terms of current forest (tree) cover of the watershed forest in the watershed) and what the costs would be if there was only 10% integral conditions, or an almost degradation condition. This differential is used as the proxy value for water regulatory services divided by the area of rivers and streams.

This avoidance cost approach is based on studies by the Trust for Public Land and the American Water Works Association in the United States that found that the proportion of forest cover in a watershed is correlated with the cost of water treatment.[5] In 27 studies of water suppliers they found that water treatment costs for utilities using primarily surface water supplies varied depending on the a amount of forest cover in the watershed. Their results showed that for every 10 percent increase in forest cover in the source area, treatment costs decreased by about 20 percent.

The American Water Works Association[6] estimates that the optimum watershed condition (i.e. when ecosystem integrity is high and water treatment costs lowest) is when there is between 70-90% forest cover.

Of the total SES watershed 77% covered with trees, wetlands, grasslands and shrubland in 1958; by 2006 only 59% of the area remained covered with these same land cover types. Again, using the City of Calgary's water treatment cost statistics of $151 million in 2004 combined with the American Water Works Association marginal cost of water treatment with every 10% loss in original forest cover we devised a marginal cost algorithm for the benefits of avoided treatment costs if the watershed was degraded as much as 10% of the remaining original intact land cover.

We estimate that with the current intact forest and other land cover (59% intact in the SES area) the City of Calgary pays approximately $0.90 per cubic meter of water flowing through Calgary water supply system; based on $151 million in water treatment costs divided by 168 million cubic meters of water flow through the system in 2004 (based on Environment Canada data). If only 10% of the land cover types were in an intact condition in the SES we estimate the total cost of water treatment would have been $255.6 million in 2004 Thus we argue that a proxy benefit – the ecosystem service value -- of a relatively intact SES watershed is the much higher avoided cost of $255.6 million divided by the actual area of intact forests, wetlands, grasslands and shrubland which yields a $207.74/ha value for these water supply and filtration services. This value is then applied to the remaining hectares of land cover for each of the important land covers to derive a total water supply and filtration value.

In future analysis we could show the marginal benefit to Calgary or other municipalities from maintaining intact landscapes or the cost of allowing these landscapes to be converted to urban or industrial use. We could argue, for example, that the water treatment costs should decline if the City of Calgary were to encourage increased forest cover and conservation of other land cover types in all the watersheds from which it benefits.

[5] Ernst, C., Gullick, R., and Nixon, K. 2007. "Protecting the Source: Conserving Forests to Protect Water." In: *The Economic Benefits of Land Conservation*. The Trust for Public Land. San Francisco, California. http://www.tpl.org/tier2_rp1.cfm?folder_id=175 (accessed Nov. 5, 2007)

[6] The American Water Works Association (2004), "Protecting the Source: Land Conservation and the Future of America's Drinking Water." Available at http://www.awwa.org/Bookstore/productDetail.cfm?ItemNumber=4746

2.3.3 Carbon

In the calculation of the ESP values of climate regulation services of forests, wetlands, grassland and other land cover types there are two discount components: a) the role of ecosystems in bio-geochemical cycles including gas regulation and air quality control (i.e. the role of natural systems in removing air pollutants from anthropogenic emissions) and b) climate regulation (i.e. biotic carbon capture and storage).

The **gas regulation and air quality control service** values are based on estimates of the value of forests and grasslands in removing carbon monoxide, ozone, nitrogen dioxide and particulate matter from the atmosphere. Forests and trees provide improvements in air and water quality by removing gaseous air pollution by absorption through their leaves and they also intercept airborne particles through absorption by the tree or by retaining the particles on their leaves. Trees also are important for air quality because they release oxygen into our air. A typical person needs 386 lbs of oxygen each year. A healthy tree can produce about 260 lbs of oxygen every year, meaning that two trees provide enough oxygen for each person each year. Studies show that trees can remove 8 to 12 grams of air pollutants per square metre of canopy.[7] The benefits of clean air to human health are significant. For example, a recent study that estimated the costs of air pollution for southern and central Ontario found that the province is incurring almost $10 billion in health and environmental damages every year.[8]

We adopted the methodology used by Sara Wilson in the Ontario Green Belt ecosystem services analysis. CityGreen software was used by Wilson to assess the amount of air pollutants that are removed by the tree canopy cover across the Greenbelt. The value of this service is estimated to be $377.14 per hectare per year for Ontario.

Using the same methods used in the Green Belt study we estimate the value of gas regulation services of the SES forests to be worth $386.26 per hectare in 2006 (our figures are higher since they are adjusted to 2006 dollars) and $12.38 per hectare of grassland. In addition we estimate that cropland also provides similar services valued at $340.58 per hectare of cropland. The total value of gas regulation services for the SES is estimated to be $260,246,085 in 2006.

The second **climate regulation service** is the role of ecosystems in the capture and storage of biotic carbon. Using ALCES estimates of biotic carbon stored in the SES ecosystem and estimates of annual carbon sequestration the value of biotic carbon is then calculated using an average social cost of carbon estimate from IPCC (Intergovernmental Panel on Climate Change) namely US$43/t C or converted to CDN $49.94/t C in 2006. This value can be applied to the annual carbon sequestered or absorbed by forests,

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[7] Nowak, D.J., Wang, J., and Endreny, T. "Environmental and Economic Benefits of Preserving Forests within Urban Areas: Air and Water Quality." The Economic Benefits of Land Conservation. The Trust for Public Land. San Francisco, California. http://www.tpl.org/tier2_rp1.cfm?folder_id=175 (accessed Nov. 5, 2007)

[8] Yap, D., Reid, N., de Brou, G., and Bloxam, R. 2005. Transboundary Air Pollution in Ontario. Ontario Ministry of Environment. www.ene.gov.on.ca/envision/techdocs/5158_index.html (accessed Dec. 8, 2007)

wetlands, grasslands and other land cover types. The value can also be applied to the benefit of accumulated or stored carbon in the ecosystem. To estimate the annual value of carbon stored in forest and other land cover types we apply an annuity calculation; in other words we calculate the annualized value using an annuity calculation with a 20 year time horizon and a 5 percent discount rate. [9]

Based on the ALCES analysis there is an estimated 169.1 tonnes of carbon per hectare of all forest types in the SES region which implies there is an estimated 73.15 million tonnes of carbon in forest land and 3.65 million tonnes stored in grassland, prairie treed/riparian and grassland shrub land cover. The annual value of this stored carbon, using our annuity calculus, is estimated at $479,868,443.

The value of annual carbon sequestered by all land cover types in the SES study area is estimated to be worth $25,860,154 in 2006. This is based on average carbon sequestration rates of forest types which amounts to an estimated value of $40.05/ha. Wetlands carbon sequestration is estimated at $5.33/ha of wetland and $29.26/ha of grassland.

2.3.4 Native Landscapes (Recreation Values)

We have estimated the recreation value of the SES region in terms of the value of nature to Albertans. Recreation service values are more akin to market natural capital values since these value estimates are based on what citizens spend on nature-related activities.

Our estimates are based on previous studies of the value of nature Canadians; the last study completed in 1996 by the Canadian Wildlife Service and Environment Canada. According to the *Value of Nature to Albertans* portion of these national studies, in 1996 residents of Alberta spent $1.2 billion on nature-related activities during 1996. The average participant in these activities spent $836 during the year, or $56 per day of participation. Wildlife viewing expenditures alone were estimated at $171.6 million. On average, these participants spent $433, or $23 per day of participation. Expenditures for recreational fishing amounted to $147.8 million. The average yearly expenditure for fishing was $409, or $22 per day of participation. And in 1996 Alberta residents spent $71.0 million hunting wildlife. The average hunter spent $843 during the year, or $51 per day of participation. Of the total expenditures, approximately $349.2 million, or 29.8 percent, was spent on equipment used primarily for nature-related activities. Another $300.0 million (25.6 percent) was spent on transportation, $223.3 million (19.1 percent) on food, $149.0 million (12.7 percent) on accommodation and $79.3 million (6.8 percent) on other items such as entry fees.

For the purposes of the SES study we estimate the value of nature to Albertans based on the 1996 estimated total value of $1,200 million inflated to 2006 dollars (assuming the same value as in 1996) yielding a figure of $1,559 million for the entire province. We can translate these values on a tourist-activity-day (TAD) basis; in 2001 Alberta had an estimated 40 million TADs which suggests a value of $38.99 per TAD. We can also estimate recreation values on a per hectare basis of land used for recreation; we estimate

[9] 20 years investment at 5%. Adapted from Anielski and Wilson 2007.

that Alberta has about 26.6 million hectares that is suitable for recreation. Using this figure with the value of nature estimates suggests a recreation value per hectare in 2006 of $58.58.

We have estimated that 13.7% of the tourist-activity-days in Alberta occur in the SES region. Thus we estimate the recreation values of the SES region to be $214 million. This is then divided by the area in the SES suitable for recreation (511,737 hectares) which yields a recreation value in the SES of $418.32 per hectare.

2.4 GPI VALUES

When the SES region's GDP value of $3,639 million for the region is combined with the estimated ESP value of $2,872 million would suggest a combined "GPI" value of $6,511 million for 2006. In addition we have calculated the estimated annual loss of ESP values due to the conversion of original land cover classes to industrial, urban or other commercial use (including conversion of native prairie to cropland) at $706.6 million. This is a proxy for the depreciation cost for natural capital degradation or depletion.

3. LAND MANAGEMENT OBJECTIVES

Four ecological land management indicators were selected by project sponsors for the SES pilot project:

1. water quality,
2. water quantity,
3. grizzly bear mortality exposure, and
4. anthropogenic edge (land use metric).

Management objectives were developed for each indicator in collaboration with AENV and ASRD representatives (Table 6). These objectives were selected to be consistent with existing government policy and management guidance. They were also designed to be compatible with existing ALCES© model outputs and Southern Foothills Study assumptions to ensure that they could be readily applied in ALCES© for this pilot project. Additional information on the land management objectives used in the SES Pilot and the modeling assumptions applied in ALCES is provided below.

Table 6. Ecological land management indicators and objectives adopted for the SES Pilot.

Ecological Land Management Indicator	Management Objective
Water Quantity	Maintain net water balance in the study area within 25% of estimated minimum historical defined by estimated 50 year range of natural variability.
Water Quality	Maintain Total Suspended Solids, Total Nitrogen, and Total Phosphorus within Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life 1. Total Suspended Solids: <10 mg/L above background (background estimated to be 33.4 mg/L as an annual average) 2. Total Nitrogen (Inorganic and Organic): 1 mg/L (chronic) 3. Total Phosphorus (Inorganic and Organic): 0.05 mg/L (chronic)
Grizzly Bear	Reduce grizzly bear RSF exposure rating by 50% over the next 50 years (to 1.125) to reduce risk of grizzly bear population declines (current RSF exposure rating is 1.25X higher than the pre-disturbance rating of 1).
Anthropogenic Edge	Total edge in any year to be no higher than current value to reduce further direct degradation of native vegetation and associated species (current total edge is approx. 15,000 km and average access density is approx. 1.20 km/km^2).

3.1.1 Water Quantity

ALCES© incorporates all elements of a classic hydrological model to estimate surface and subsurface regional water balance and simulate changes in surface and groundwater quantity within the study area (Figure 3). Although ALCES has the ability to track net groundwater balance for the SES study area, this was not included in simulations because reasonable data quantifying the pre-disturbance or current total groundwater volume have not been located. This means that empirical comment on the proportion of groundwater that is being used by land uses cannot be provided.

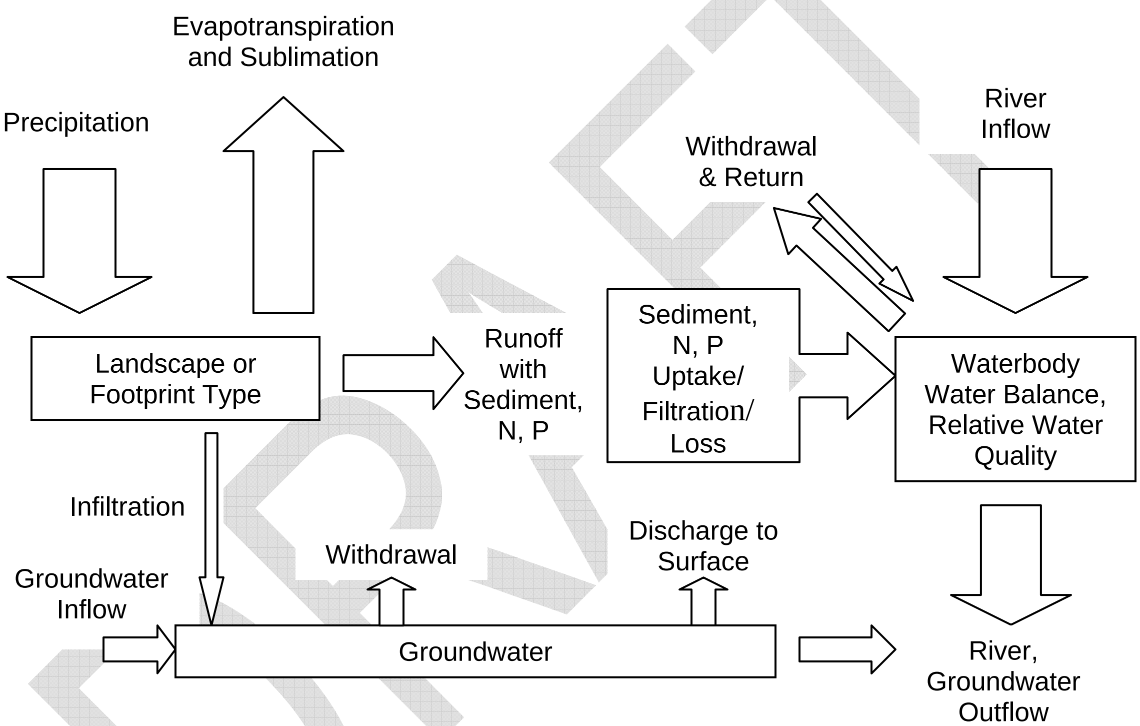

Figure 3. Hydrology and water quality pathways modeled in ALCES.

ALCES is intended to simulate broad, strategic level patterns and provides annual net water balance estimates for the entire study area. This approach does not capture seasonal fluctuations in discharge, nor differences between watersheds in the study area. For example, the SES study area is considered to be a water source area because of its location in the headwaters of the South Saskatchewan basin. Water withdrawal for human use is generally restricted to the eastern third of the study area, but this withdrawal is averaged over the entire study area.

Regional water inputs and outputs are calculated using the following parameters:

- Monthly mean precipitation onto the study area (+/- variance);
- Monthly mean temperature in study area (+/- variance);
- Annual water volume being carried into the region in mainstream rivers and groundwater (zero in the SES study area);
- Annual input to mainstem rivers from glacier melt (zero in the SES study area);
- Mean groundwater discharge into stream channels and landscape types (zero in the SES study area due to lack of data);
- Mean water volume being carried out of the region in river channels and groundwater;
- Mean sublimation, absorption, and evapotranspiration from each landscape and footprint type;
- Mean net groundwater, surface water, and reservoir withdrawal per capita or production unit for each land use (domestic human, livestock, irrigation, and industrial);
- Minimum export requirements from region;
- Initial shallow, medium, and deep aquifer volumes (unknown in this study area);
- Shallow, medium and deep aquifer transit times (unknown in this study area).

Because natural climatic variability causes surface and groundwater availability to vary from year to year, ALCES© has been designed to generate stochastic simulations that help define the range of natural variability (RNV). These simulations are informed by climatic mean and variance input parameters.

3.1.1.1 Water Quantity Management Objective

A range of natural variability (RNV)-based water quantity objective was adopted for the SES Pilot in recognition of the importance of natural variation on annual runoff and instream flows. This approach is consistent with instream flow management guidelines that are based on natural flow regimes.

The SES Pilot water quantity objective was: maintain net annual water balance in the study area within 25% of the estimated minimum historical value defined by the estimated 100 year range of natural variability.

3.1.2 Water Quality

Aquatic health can be measured using chemical, physical, and biological criteria (North/South 2007). Water quality can be variously defined, but most definitions involve considerations of physical elements (e.g., sediment, temperature), biological inputs (e.g., organic carbon), nutrients, metals, and ions (e.g., nitrogen, phosphorus, chloride), and chemicals (e.g., pesticides, trace organics). Water quality may change over time due to changes in landscape and land use features such as forest area/type, road density, percent of landscape that is agricultural or urban, and livestock density (e.g., Cooke and Prepas 1998; Carignan et al. 2000; Beaudry 2004; Croke and Hairsine 2006; Cows and Fish nd).

ALCES© simulates changes to three water quality parameters - sediment, nitrogen, and phosphorus - that were agreed to be negatively linearly related, in a basic manner, to overall water quality. This approach was developed at an ALCES Water Quality workshop held in June 2003, with participants from the Alberta government (Al Sosiak, Wendell Koning, Pat Kinnear), academia (Dr. David Schindler and Dr. Bill Donahue (UA)), and the ALCES Group (Dr. Brad Stelfox, Dr. Dan Farr). When considered alone, or combined into a Relative Water Quality Index, these parameters provide a measure of relative changes in the regional export of these parameters from the study area over time. Sediment and nutrients were also used as aquatic health indicators in a recent provincial Water for Life assessment (North/South 2007). As stated in this assessment, "These indices are not intended to replace the conventional process of analyzing and interpreting water quality data in detail; rather, they should be utilized as qualitative and complementary assessment tools.

Regional sediment, nitrogen, and phosphorus inputs and outputs are calculated based on water quantity simulations and coefficients defining the rates (kg/ha/yr) at which nitrogen, phosphorus, and sediment are transported from various landscape and footprint types (Figure 2). Coefficients used here were derived for the Southern Alberta Landscapes initiative (AENV 2007) based on the most representative values available in the literature (Table 2).

Note that previous ALCES simulations of the Relative Water Quality Index did not provide empirical information on anticipated water quality changes because they did not account for attenuation of these exports prior to reaching waterbodies (i.e., not all sediment lost from fields reaches lakes or streams because the distance to the nearest waterbody varies and vegetation filtering results in nutrient uptake and sediment deposition; Corley et al. 1999). Because AENV representatives identified water quality as the desired management objective for the SES Pilot Project, ALCES was modified to account for this attenuation by including delivery coefficients for each landscape and footprint type (Table 7). These were based on the most representative values available in the literature or derived through simulations of background water quality.

Table 7. Mean surface runoff, erosion, and nutrient output coefficients for each SES landscape and footprint type.

ALCES Landscape/ Footprint Type		**ET and Sublimation** (% of incoming precip.)	**Infiltration** (% of incoming precip.)	**Runoff** (% of incoming precipitation)	**Nitrogen Runoff** (tonnes/ ha/yr)	**Nitrogen Delivery Coefficent** (% of runoff)	**Phosphorus Runoff** (tonnes/ ha/yr)	**Phosphorus Delivery Coefficent** (% of runoff)	**Sediment Runoff** (tonnes/ ha/yr)	**Sediment Delivery Coefficent** (% of runoff)
Landscape Type	Hardwood Forest	0.77	0.11	0.12	0.0025	0.03	0.0002	0.004	0.24	0.03
	Mixedwood Forest	0.77	0.11	0.12	0.0025	0.03	0.0002	0.004	0.24	0.03
	White Spruce Forest	0.77	0.11	0.12	0.0025	0.03	0.0002	0.004	0.24	0.03
	Pine Forest	0.77	0.11	0.12	0.0025	0.03	0.0002	0.004	0.24	0.03
	Spruce Fir Forest	0.77	0.11	0.12	0.0025	0.03	0.0002	0.004	0.24	0.03
	Prairie Treed/Riparian	0.77	0.11	0.12	0.0025	0.6	0.0002	0.2	0.24	0.6
	Mixed Grassland	0.77	0.11	0.12	0.00106	0.03	0.00017	0.17	0.02404	0.03
	Fescue Grassland	0.77	0.11	0.12	0.00124	0.03	0.00021	0.21	0.02404	0.03
	Fescue Parkland	0.77	0.11	0.12	0.00065	0.03	0.00011	0.11	0.0625	0.03
	Grassland Shrub	0.77	0.11	0.12	0.00065	0.03	0.00011	0.11	0.0625	0.03

Table 7 (cont.). Mean surface runoff, erosion, and nutrient output coefficients for each SES landscape and footprint type.

ALCES Landscape/ Footprint Type		**ET and Sublimation** (% of incoming precip.)	**Infiltration** (% of incoming precip.)	**Runoff** (% of incoming precipitation)	**Nitrogen Runoff** (tonnes/ ha/yr)	**Nitrogen Delivery Coefficent** (% of runoff)	**Phosphorus Runoff** (tonnes/ ha/yr)	**Phosphorus Delivery Coefficent** (% of runoff)	**Sediment Runoff** (tonnes/ ha/yr)	**Sediment Delivery Coefficent** (% of runoff)
Landscape Type (cont.)	Forest Shrub	0.77	0.11	0.12	0.0025	0.03	0.0002	0.2	0.25	0.03
	Lotic Water	0.1	0.2	0.7	0	1	0	0.25	0	1
	Lentic Water	0.1	0.2	0.7	0	1	0	0.25	0	1
	Reservoir	0.1	0.2	0.7	0	1	0	0.25	0	1
	Cereal Crop	0.8	0	0.2	0.006	0.6	0.00097	0.1	1.44	0.03
	Oilseeds & Pulses	0.8	0	0.2	0.0123	0.6	0.0038	0.1	1.44	0.03
	Forage Crop	0.8	0	0.2	0.004	0.3	0.00033	0.05	0.77	0.03
	Tame Grassland	0.8	0	0.2	0.0051	0.3	0.00075	0.05	1.44	0.03
	Rock/Ice	0.2	0.2	0.6	0.00275	0.5	0.00005	0.1	0.25	0.5
	Badlands	0.15	0.35	0.5	0.00005	0.5	0.00004	0.1	1	0.5
Footprint Type	Major Road	0.05	0	0.95	0.005	1	0.0035	3.5	2	1
	Minor Road	0.1	0.02	0.88	0.005	1	0.0035		2	1
	Wind Turbine	0.14	0.06	0.8	0.005	0.2	0.0035	3.5	2	0.2

Table 7 (cont.). Mean surface runoff, erosion, and nutrient output coefficients for each SES landscape and footprint type.

ALCES Landscape/ Footprint Type		**ET and Sublimation** (% of incoming precip.)	**Infiltration** (% of incoming precip.)	**Runoff** (% of incoming precipitation)	**Nitrogen Runoff** (tonnes/ ha/yr)	**Nitrogen Delivery Coefficent** (% of runoff)	**Phosphorus Runoff** (tonnes/ ha/yr)	**Phosphorus Delivery Coefficent** (% of runoff)	**Sediment Runoff** (tonnes/ ha/yr)	**Sediment Delivery Coefficent** (% of runoff)
Footprint Type (cont.)	Inblock Road	0.1	0.02	0.88	0.005	1	0.0035	1.5	2	1
	Gravel Pit/Coal Mine	0.35	0.05	0.6	0.0086	0.1	0.0015	0.75	0.869	0.1
	Transmission Line	0.77	0.06	0.17	0.0051	0.2	0.00075	250	2	0.2
	Feedlot	0.1	0	0.9	1	0.2	0.25	7.95	2	0.2
	Industrial/ Recreational	0.1	0	0.9	0.00225	0.2	0.00795	0.19	0.869	0.2
	Agricultural Residence	0.78	0.02	0.2	0.00152	0.2	0.00019	0.22	0.209	0.8
	Town/City	0.05	0	0.95	0.0103	0.8	0.00022	0.19	0.209	0.2
	Acreage	0.78	0.02	0.2	0.00152	0.2	0.00019	0.75	0.209	0.2
	Seismic Line	0.68	0.02	0.3	0.0051	0.2	0.00075	7.95	2	0.2
	Wellsite	0.7	0	0.3	0.00225	0.2	0.00795	0.75	0.869	0.2
	Pipeline	0.7	0	0.3	0.0051	0.2	0.00075	0	0.457	0.2
	Canal	0.1	0.2	0.7	0	1	0	0.2	2	1

3.1.2.1 Water Quality Management Objective

The water quality management objective identified for the SES Pilot Project was to maintain water quality within Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life (AENV 1999). As noted below, chronic values were used because these are most comparable to the annual average outputs simulated by ALCES:

1. Total Suspended Solids: <10 mg/L above background (estimated to be 33.4 mg/L as an annual average)
2. Total Nitrogen (Inorganic and Organic): 1 mg/L (chronic)
3. Total Phosphorus (Inorganic and Organic): 0.05 mg/L (chronic)

3.1.3 Grizzly Bear Habitat

ALCES© simulates changes in grizzly bear habitat effectiveness and mortality risk using Resource Selection Function (RSF) coefficients developed for the Southern Alberta Sustainability Strategy initiative (Nielsen and Boyce 2003). These were based on habitat selection and mortality equations developed with data from the Foothills Model Forest and East Slopes Grizzly Bear Study (Nielsen et al. 2004; Nielsen 2005). Model inputs include:

- Habitat selection coefficient for used landscape and footprint types;
- Mortality coefficient for each used landscape and footprint types;
- Combined exposure coefficient for used landscape and footprint types;

Individual coefficients express the probability of grizzly bear use (or death) for each landscape type, based on analysis of actual bear telemetry locations. Exposure reflects overall mortality risk when habitat is considered (i.e., exposure is reduced in habitat types that have lower selection probability, and increased in habitat types that have higher selection probability [attractive sinks]).

3.1.3.1 Grizzly Bear Management Objective

The draft Alberta Grizzly Bear Recovery Plan (Alberta Grizzly Bear Recovery Team 2005) established a goal of maintaining a self-sustaining population of grizzly bears over the long term. Southern Foothills Study simulations indicated that grizzly bear exposure risk is currently high (current RSF exposure rating is 1.25X higher than the predisturbance rating of 1), and increasing in the study area, which suggests that population persistence is at risk.

Reversal of this trend over time was considered to be a reasonable management objective, more specifically: Reduce grizzly bear RSF exposure rating by 50% over the next 50 years (to 1.125) to reduce risk of grizzly bear population declines.

3.1.4 Land Use (Anthropogenic) Edge

Land use edge is created when linear corridors and sites are cleared or disturbed. These edges can fragment habitat, create movement barriers or filters, contribute to invasive species expansion, and increase mortality or predation rates. Edge density (frequently referred to as access density) is considered to be the most useful landscape indicator because it integrates so many ecological impacts of roads, human use, and vehicles (Thomas *et al.* 1979 and 1988; Lyon 1983 and 1984; McLellan and Shackleton 1988; Mace and Manley 1993; Reijnen and Foppen 1994; Forman and Hersperger 1996; Jalkotzy *et al.* 1997; Trombulak and Frissell 2000; Anderson *et al.* 2002; MLAP 2002; Forman *et al.* 2003; Bayne *et al.* 2005a, b; Nielsen et al. 2007).

.Existing edge and cleared area data for each landscape and footprint type are incorporated into the ALCES© model to characterize current conditions. Past and future changes to land use edge are simulated based on these relationships or user-defined relationships between land use features and the edge they create. Model inputs include:

- Number [length] of land use features related to unit of production or number of other related features;
- Land use feature area or width;
- Land use feature lifespan and reclamation rate; and
- Land use feature overlap with existing features.

3.1.4.1 Edge Management Objective

Results of the Southern Foothills Study (SALTS 2007) indicated that edge density is currently about 1.2 km/km^2; this density is associated with moderate risk of adverse impacts on ecological function (USDA Forest Service 1996). This is also at the management target proposed for grizzly bears (Alberta Grizzly Bear Recovery Team 2005).

The edge management objective adopted for the SES Pilot was: total edge in any year to be no higher than the current value (1.2 km/km^2) to reduce further direct degradation of native vegetation and associated species.

4. ALCES SIMULATIONS

The following ALCES© simulations were completed to evaluate the effect of land management on selected ecological, economic, and natural capital indicators:

1. **Business as Usual**: 50 year future scenario with land use based on industrial business development projections, historic annual average population growth rates, average reclamation rates, conventional seismic exploration methods, no deliberate infrastructure sharing, and natural landscape variability.
2. **Management for Ecological Objectives**: Preliminary work for the Southern Foothills Study indicated that a "Business as Usual" approach is unlikely to satisfy societal demands for indicator performance. As such, Management for Ecological Objectives simulations explored the changes to 'Best Management Practices' (hereafter referred to as Best Practices) and/or the amount of each land use required to achieve the pre-defined land management objectives. Because no single solution exists, multiple land use/natural variability combinations were systematically evaluated using factorial experiments to understand the combined measures needed to achieve management objectives. Two factorial experiments were completed. One evaluated the influence of Best Practices on indicator performance, while the other evaluated the effect of limiting future land use and restoring existing footprints

4.1 MANAGEMENT FOR OBJECTIVE SIMULATION METHODS

A factorial experiment is used to evaluate the effect of multiple factors on a variable of interest as well as the effects of interactions between factors. With this approach, the influence of two or more factors, each with discrete possible values or "levels", is evaluated by testing the effect of all possible combinations of these levels across all such factors. The outcomes from the experiments are then analyzed using statistical procedures such as analysis of variance or regression to estimate the strength of the relationship between each factor and the response variable of interest.

Factorial experiments completed for this project assessed the relationship between land use options (i.e., Best Practices and land use amount) and the status of SES indicators at year 50. As an example, all possible combinations of ten Best Practices options were simulated at two levels (each one off, or each one at the maximum benefit defined in the Southern Foothills Study), for a total of 1,024 scenarios. Simulation results were then summarized using multiple regression, with SES indicator status at year 50 as the dependent variable and land use options as the covariates. Linear regression models were used because exploratory simulations indicated linear relationships between the amount of a land use and indicator performance, and between the degree of best practice implementation and indicator performance.

Multiple linear regression models were fit by minimizing the residual sum of squares using procedure ‘lm’ in the statistical software ‘R’. Land use variables with a statistical significance below 95% were deemed to have a negligible influence on outcomes and were excluded from further consideration.

This approach provides a numerical rating of the effect of each best practice or land management option in comparison to all other options, so that the ‘best’ option or combination of options can be easily identified. Details of each factorial simulation experiment are described below.

4.1.1 Best Management Practices

Sector-specific Best Practices developed for the Southern Foothills Study in conjunction with industry representatives were used in these simulations. Best practice modifiers considered in the scenario included: increasing number of wells per pad; reclaiming wells and roads to reduce nutrient and sediment runoff; reducing septic system nutrient runoff; reducing feedlot nutrient runoff; reducing cropland nutrient and sediment runoff; using access management to reduce grizzly bear mortality; using access management to reduce sediment runoff from off highway vehicle use; reducing irrigation water use; reducing cutblock nutrient runoff; reducing nutrient and sediment runoff from riparian grazing; reclaiming inblock roads to reduce nutrient and sediment runoff; pulse reclamation to reduce nutrient runoff and edge; and increasing rural residence contagion to reduce edge and runoff. The Southern Foothills Study also defined the maximum likely benefit for each best practice relative to current standard practices, based on cost and feasibility considerations (Table 8).

Table 8. Assumed maximum likely benefits from best practices relative to current standard practices (from Southern Foothills Study, SALTS 2007).

Practice	Effect
Cutblock buffer strips	30-70% reduction in nutrient runoff
Residence contagion	
Cattle grazing system	
Feedlot nutrient management	50% reduction in nutrient runoff
Cropland runoff management	45-55% reduction in nutrient and sediment runoff
Separate cattle from streams	50% reduction in nutrient and sediment runoff
Septic management	40-60% reduction in nutrient runoff
OHV runoff management	50% reduction in nutrient runoff
Reduced irrigation	60% reduction in water use
Well and access road reclamation	Reduce footprint lifespan from 35 to 10 years
Multiple wells per pad	Increase wells per pad from 1 to 2
Inblock road reclamation	Reduce inblock road lifespan from 25 to 2 years
Access management	Reduce grizzly mortality caused by access by 50%

4.1.2 Land Use Amount

The land use amount factorial experiment assessed the effect of reducing the amount of each of five land uses (energy, agriculture, forestry, transportation, and settlements). Three land use amount levels were included: 100%, representing the Business as Usual scenario; 66% of Business as Usual; and 33% of Business as Usual.

Different assumptions were used in the factorial experiment for land uses with permanent (agriculture, settlements, and transportation) and transient (energy and forestry) footprints to ensure that all land uses were simulated in an equivalent manner. For land uses with permanent footprints, the initial amount of land use and its future rate of growth were both manipulated to control the amount of the land use. In the 66% agriculture scenario for example, one third of the existing cropland was reclaimed at the start of the simulation and the rate of growth in cropland was also reduced by one third. For land uses with transient footprints, on the other hand, only the future growth of land use was manipulated. In the 66.7% energy scenario for example, future energy development was reduced by one third and existing energy footprint was restored at rates as previously defined (i.e., BAU reclamation rates). Table 9 provides an explanation of the land use variables manipulated in the simulations to control the amount of each land use type.

Table 9. Land use variables manipulated in the land use amount factorial experiment to control the amount of each land use type.

Land use	Land use variables included in factorial experiment
Energy	Number of new exploratory wells per year, which also influences the rate of growth in seismic lines, access roads, and pipelines.
Forestry	Annual timber harvest, which also influences the rate of growth in inblock roads and landings.
Agriculture	Area of cropland at year 0 and cropland growth rate. Livestock population at year 0 and livestock population growth rate.
Settlements	Settlement area at year 0 and settlement area growth rate. Human population at year 0 and human population growth rate. Tourism activity days at year 0 and tourism activity day growth rate.
Transportation	Length of major and minor roads at year 0 and major and minor road growth rate. Length of transmission lines at year 0 and transmission line growth rate.

In addition to land use amount, best practices were also included as a factor in this factorial experiment. The purpose of including best practices was to assess the combined influence to indicators of reducing the amount of land use and implementing best practices. For the purpose of the land use amount factorial experiment, best practices were either all turned off or all implemented at 100%. This is in contrast to the best practice factorial experiment where best practices were individually turned on and off.

Exploratory simulations indicated that the area of industrial footprint was an important driver for most ecological indicators. As a result, an aggressive ‘pulse reclamation’ program was also included as a factor in the land use amount factorial experiment. The pulse reclamation scenario, which was either turned on or off in the factorial experiment, reclaimed 15% of existing seismic lines, minor roads, and inblock roads every 5 years.

The resulting factorial experiment included: five land use factors (energy, agriculture, forestry, transportation, and settlements) each at three levels (100%, 66.7% or 33.3%); a best practice factor at two levels (all best practices on or off); and a pulse reclamation factor at two levels (pulse reclamation on or off). This created a total of 972 scenarios.

Multiple linear regression models were fit for the status of each ecological land management indicator and genuine progress indicator (GPI, GDP, ESP) at year 50 with the amount of each land use, best practice implementation rate, and pulse reclamation rate as covariates.

4.2 INCORPORATING EGS IN ALCES

4.2.1 Gross Domestic Product

Current GDP values were calculated on a per hectare basis (Section 2.2.1.1 above). This static valuation approach is not transferable to future projections because it does not accommodate ongoing changes in landscape and land use conditions. For example, per hectare valuations would suggest that well sites are contributing to GDP, even after they have been suspended and production is no longer occurring. Because ALCES is able to track annual commodity production associated with each footprint, GDP estimates were derived on a commodity basis.

4.2.2 Ecosystem Service Product

Four of the 17 ecosystem services or functions were selected to estimate ESP using ALCES for this pilot project:

1. water quality;
2. water supply;
3. biotic carbon; and
4. recreation and tourism (natural landscapes).

These were selected because: of their perceived ecological value to human populations in the region who benefit from Natures’ capital; these four ecosystem services also comprise the majority (84%) of estimated present ESP economic value; and sufficient data were available for them to derive values for all landscape and footprint types. Other types of ecosystem services not evaluated in this project include, for example, soil formation, climate regulation, disease regulation, and spiritual and aesthetic values.

As with GDP, ESP values for water quality, water supply, and biotic carbon were tracked on a commodity, rather than hectare basis.

4.2.3 Genuine Progress Indicator

GPI was calculated each year in ALCES by adding total GDP and ESP so that relative ‘progress’ could be quantified under various land management scenarios.

4.3 SIMULATION RESULTS

4.3.1 Business as Usual

Graphic outputs from Business as Usual (BAU) simulations are presented as blue lines for each indicator in Figure 4. In these and subsequent simulation graphics, the land management objective (target) for that indicator is displayed as a dashed line for reference purposes. In each graphic, all indicators except water quantity meet the target when they are below the dashed line (desirable conditions), and exceed the target when they are above the dashed line (undesirable conditions). Because the water quantity target is a minimum rather than maximum value, it is acceptable when above the dashed line, and unacceptable when below the dashed line. Water quantity Best Practices simulations are provided on the same chart for easy comparison. The relative benefit of adopting Best Practices relative to BAU can be seen by how far the Best Practices line is below the BAU simulation for the same point in time.

The Business as Usual simulations predicted that the performance of ecological land management indicators will decrease over the next 50 years and that, with the exception of water quantity, management objectives will not be achieved. Note that these graphics are intended to provide a ‘proof of concept’, rather than accurate predictions of future indicator status in the SES pilot study area.

4.3.2 Best Management Practices

Best Practices improved the performance of all ecological land management indicators, although the improvement was insufficient to achieve indicator targets with the exception of nitrogen (Figure 4).

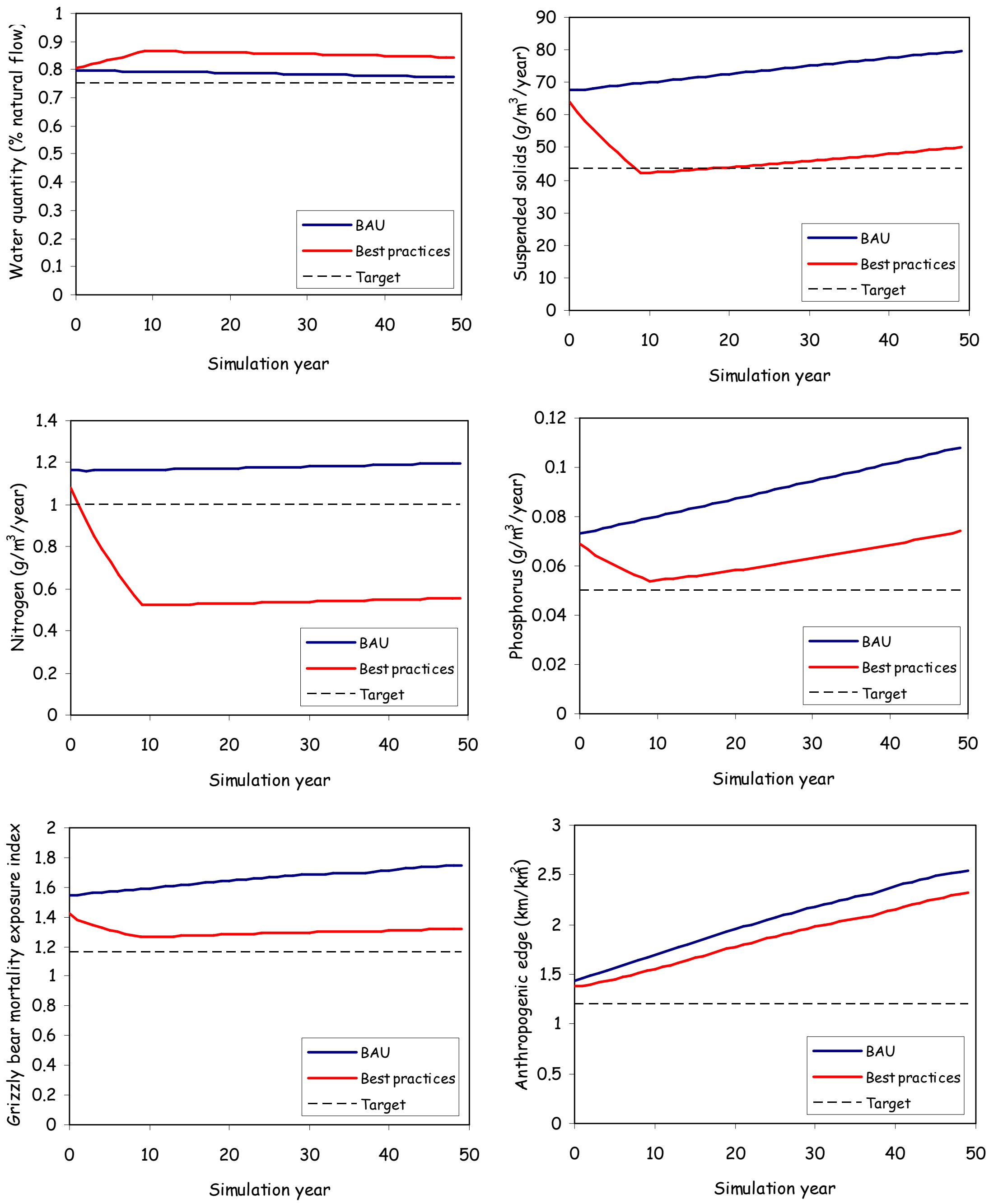

Figure 4. Simulated ecological land management indicator status in response to Business as Usual (BAU) and Best Practices scenarios. (Management targets set for each indicator are shown as dashed lines).

Results from the best practice factorial experiment provide further insight into the influence of the individual Best Practices. Indicator projections were summarized by modeling the effect of Best Practices on indicator performance using the main effects regression model:

$$y = a_0 + a_1x_1 + \ldots + a_{10}x_{10} \qquad \text{(Equation 1)}$$

where:

y = indicator status at year 50

$x_{1\text{-}10}$ = the degree of implementation (0-1) of Best Practices 1 to 10.

a_0 = indicator status at year 50 if all Best Practices are not implemented

$a_{1\text{-}10}$ = the effect to indicator status of implementing Best Practices 1 to 10 at 100%.

The models explained greater than 95% of the variation in the indicators across the simulations (Table 10). Due to the high R^2, it was deemed unnecessary to include interaction terms in the regression models. This implies that the effect of each best practice is additive and not conditional on the degree to which other Best Practices are implemented.

Table 10. Coefficients of determination (R^2) for multiple linear regressions relating Best Practices to simulated indicator status at year 50.

Water quantity	**Suspended solids**	**Nitrogen**	**Phosphorus**	**Grizzly mortality exposure index**	**Anthropogenic edge density**
1.0000	0.9938	0.9533	0.9733	0.9875	0.9893

Best practice model coefficients for each ecological land management indicator are listed in Table 11 and displayed visually in Figure 5. The relative influence of each Best Practice varied depending on the indicator of interest (Figure 5).

As discussed previously, the intercept term can be interpreted as the indicator's status in the absence of Best Practices. Best Practice regression coefficients can be interpreted as that practice's influence on indicator status as a result of implementing the Best Practices at 100%. The effect to an indicator of implementing Best Practices at y% can be estimated by multiplying the appropriate best practice coefficients by y%. This interpretation of the models assumes a linear relationship between best practice implementation rate and indicator performance. The validity of this assumption was confirmed by exploratory simulations that demonstrated linear relationships between the implementation rate (0%, 50% and 100%) of individual Best Practices and indicator performance.

Table 11. Coefficients from multiple linear regression models for the affects of Best Practices on ecological land management indicators. (Blank entries indicate that the significance of coefficients was less than 95%).

	Water quantity	Suspended solids	Nitrogen	Phosphorus	Grizzly exposure index	Anthropogenic edge
Intercept	0.7731	78.4476	1.1485	0.1062	1.7259	2.5373
Reduced irrigation	0.0723	-4.1985	-0.0546	-0.0059		
Cropland runoff management		-3.6946	-0.2508	-0.0059		
Separation of cattle from streams		-16.8331	-0.2805	-0.0063		
Feedlot runoff management			-0.0254	-0.0064		
Septic runoff management			-0.0291	-0.0007		
OHV runoff management		-0.7691				
Well and access road reclamation	-0.0006	-1.2544		-0.0030	-0.0057	-0.0480
Multiple wells per pad	-0.0004	-0.8276		-0.0023	-0.0072	-0.0588
Inblock road reclamation	-0.0007	-1.8506		-0.0034	-0.1227	-0.1199
Access management					-0.2923	

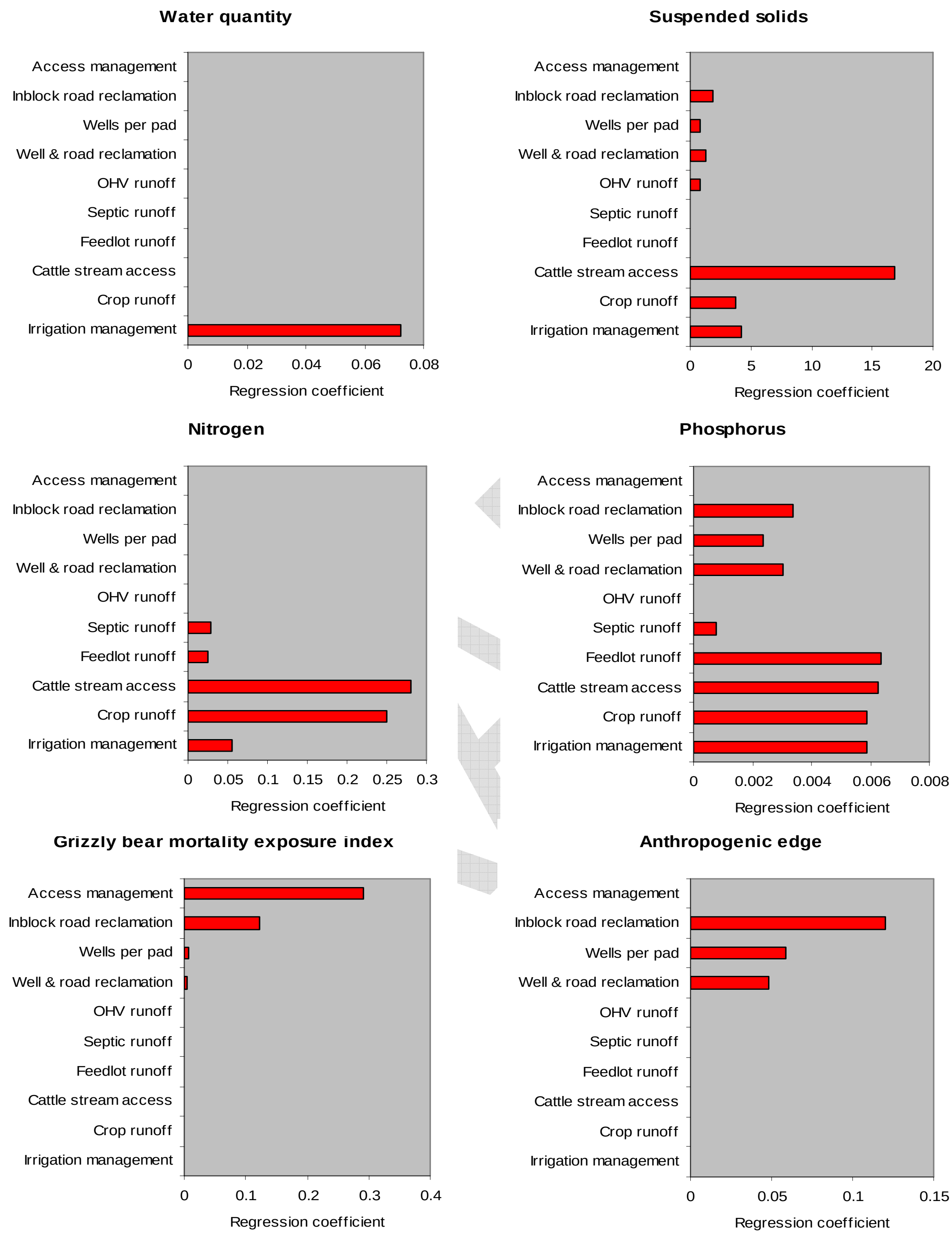

Figure 5. Coefficients from multiple linear regression models for the affects of Best Practices on ecological land management indicators.

4.3.3 Land Use Amount

Results from the land use amount factorial experiment were summarized by modeling the affect of land use amount, Best Practices, and pulse reclamation on ecological land management indicator and genuine progress indicator performance using the model:

$$y = b_0 + b_1Ag + b_2En + b_3Fo + b_4Se + b_5Tr + b_6Bp + b_7Pr + + b_8BpPr + b_9AgBp + b_{10}EnBp + b_{11}FoBp + b_{12}SeBp + b_{13}TrBp + b_{14}AgPr + b_{15}EnPr + b_{16}FoPr + b_{17}SePr + b_{18}TrPr \qquad \text{(Equation 2)}$$

where:

y = indicator status at year 50

Ag, En, Fo, Se, Tr = the amount of agriculture, forestry, energy, transportation, and settlements, respectively, where 1 represents 100% of the BAU scenario

Bp = best practice implementation rate, where 1 represents 100% implementation of the full suite of Best Practices (table 2)

Pr = pulse reclamation, where 1 represents reclamation of 15% of seismic lines, minor roads, and inblock roads every 5 years

b_0 = intercept term, which can be interpreted as indicator status at year 50 if all land uses are turned off

b_{1-5} = land use main effect coefficients, which can be interpreted as the effect to indicator status of implementing a land use at 100% of the BAU scenario

b_6 = best practice main effect coefficient, which can be interpreted as the effect to indicator status of implementing Best Practices if all land uses are turned off

b_7 = pulse reclamation main effect coefficient, which can be interpreted as the effect to indicator status of implementing pulse reclamation if all land uses are turned off

b_8 = Best Practices/pulse reclamation interaction coefficient, which can be interpreted as the effect to indicator status of implementing Best Practices when pulse reclamation is also implemented

b_{9-13} = Best Practices/land use interaction coefficients, which can be interpreted as the effect to indicator status of implementing Best Practices if a land use is implemented at 100% of the BAU scenario.

b14-18 = pulse reclamation/land use interaction coefficient, which can be interpreted as the effect to indicator status of implementing pulse reclamation if a land use is implemented at 100% of the BAU scenario.

The interaction terms (AgBp, AgPr, etc.) were included because they substantially improved model fit, indicating that the influence of Best Practices and pulse reclamation on indicator status is dependent on the amount of land use that is occurring in the region.

4.3.4 Land Management Objectives

The regression models (equation 2) explained greater than 99% of the variation in the ecological land management indicators across the simulations (Table 12); this means that they provide good reference on how to most effectively achieve management objectives, independent of cost. Model coefficients for each ecological land management indicator are presented in Table 13. Water quantity was not included in the land use amount factorial experiment because exploratory simulations demonstrated that water quantity targets could be achieved without Best Practices or reducing land use amount (Figure 4).

Table 12. Coefficients of determination (R^2) for multiple linear regressions relating land use amount, Best Practices, and pulse reclamation to simulated indicator status at year 50.

Suspended solids	Nitrogen	Phosphorus	Grizzly mortality exposure index	Anthropogenic edge density
0.9994	0.9997	0.9982	0.9919	0.9996

Table 13. Coefficients from multiple linear regression models for the affect of land use amount, Best Practices, and pulse reclamation on ecological land management indicators. Coefficients refer to equation 2. Blank entries indicate that the significance of coefficients was less than 95%.

	Suspended solids	Nitrogen	Phosphorus	Grizzly mortality exposure	Anthropogenic edge density
b_0	34.1096	0.3869	0.0037	1.0598	0.1012
b_1	12.9597	0.8368	0.0364	0.1257	0.0082
b_2	3.3851	-0.0043	0.0074	0.2420	0.8100
b_3	1.7028		0.0032	0.0913	0.2450
b_4	1.9186		0.0126	0.0188	0.2214
b_5	25.5366	-0.0094	0.0444	0.1523	1.1420
b_6	-16.0907	-0.0663	-0.0009	-0.0716	-0.0531
b_7	-2.4024	0.0000	-0.0043	-0.0380	-0.0645
b_8	0.0972	-0.0202	0.0036	0.1541	0.0974
b_9	-11.3960	-0.6493	-0.0256	-0.0437	
b_{10}	-1.4784	0.0092	-0.0044	-0.0951	-0.0806
b_{11}	-1.2842		-0.0024	-0.0689	-0.0740
b_{12}	1.2286	0.0101		-0.0088	
b_{13}		0.0406		-0.0671	
b_{14}		0.0134		-0.0255	
b_{15}	-0.5650		-0.0019	-0.1546	-0.5670
b_{16}	-0.0364		-0.0011	-0.0383	-0.0364
b_{17}	-0.0251			-0.0070	-0.0200
b_{18}	-0.3691	-0.0089	-0.0254	-0.0619	-0.0596

The implications of the multiple regression models are shown graphically in Figures 6 and 7. For each ecological indicator, two charts are provided. The left-hand chart displays the status of an indicator at year 50 assuming BAU status without Best Practices or pulse reclamation. BAU indicator status is broken into land uses to communicate the portion of an indicator's status that is associated with each land use. These portions are equal to coefficients b_1 to b_5 in Table 13.

The effect of reducing the amount of a land use by a specified amount (say x%) is equivalent to reducing the portion of an indicator's status that is associated with that land use by the specific amount (x%). As such, the chart can be used to visually assess the types of land use reductions that would be needed to achieve predefined targets. The portion of an indicator's status that is independent of the amount of land use is also identified. This portion is equal to coefficient b_0 (Table 13).

The right-hand chart displays the status of indicators at year 50 assuming that Best Practices and pulse reclamation are implemented. The chart is equivalent to the left-hand chart except that dashed boxes show the improvement in indicator performance (i.e., reduction in indicator status) achieved by implementing Best Practices and pulse reclamation. The chart can be used to visually assess the types of land use reductions that would be needed to achieve an indicator's target if Best Practices and pulse reclamation are also used.

Simulation results such as those presented in Figures 6 and 7 can be used to understand the importance of each land use for the indicator being considered, and relative importance of different land uses for that indicator. For example, Figure 6 shows that the transportation network and energy development play a dominant role in the exposure of grizzly bears to mortality and the increase in anthropogenic edge. Best Practices and pulse reclamation are able to virtually eliminate the impacts of these land uses to grizzly bear, thereby reducing grizzly bear mortality exposure to within the management target. For anthropogenic edge, Best Practices are largely ineffective. Pulse reclamation is able to substantially reduce the contribution of energy development to anthropogenic edge, but is not able to reduce the contribution of the transportation network. As a result, a reduction in land use is needed to achieve the edge target, most importantly reductions to the simulated transportation network.

Agriculture and the transportation network play a dominant role in the degradation of water quality (Figure 7). Implementing Best Practices reduces the contribution of agriculture to nitrogen runoff enough to achieve the management target. Best Practices also reduce the contributions of agriculture and the transportation network to phosphorus runoff, although the reduction is insufficient to achieve the target. The phosphorus management target is achieved, however, when pulse reclamation is also implemented. For suspended solids, Best Practices and pulse reclamation are able to achieve a large reduction in agricultural impact but are sufficient to achieve the management target because of the ongoing influence of the existing transportation network. To achieve the target for suspended solids, the transportation network would need to be reduced.

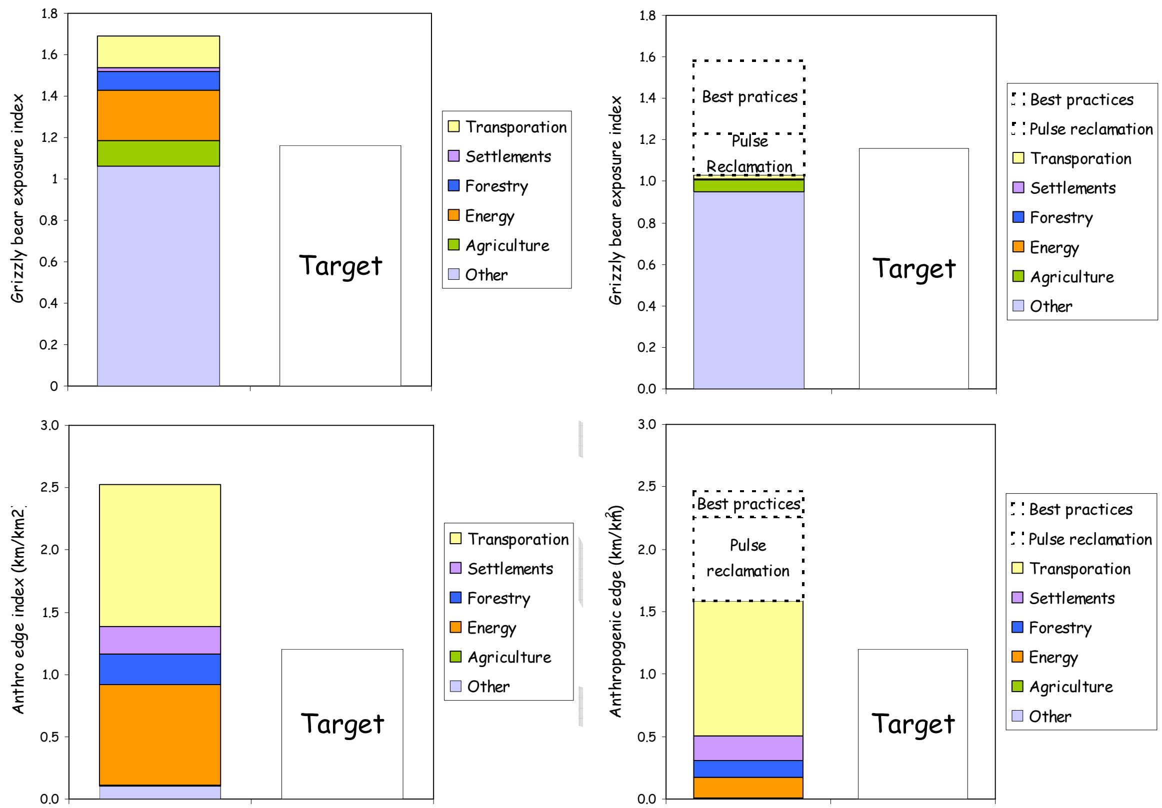

Figure 6. Contributions of land uses, Best Practices, and pulse reclamation to grizzly bear mortality exposure and anthropogenic edge density at year 50. (The charts are based on coefficients of regression models that summarize results from the land use amount factorial experiment. See text for details.)

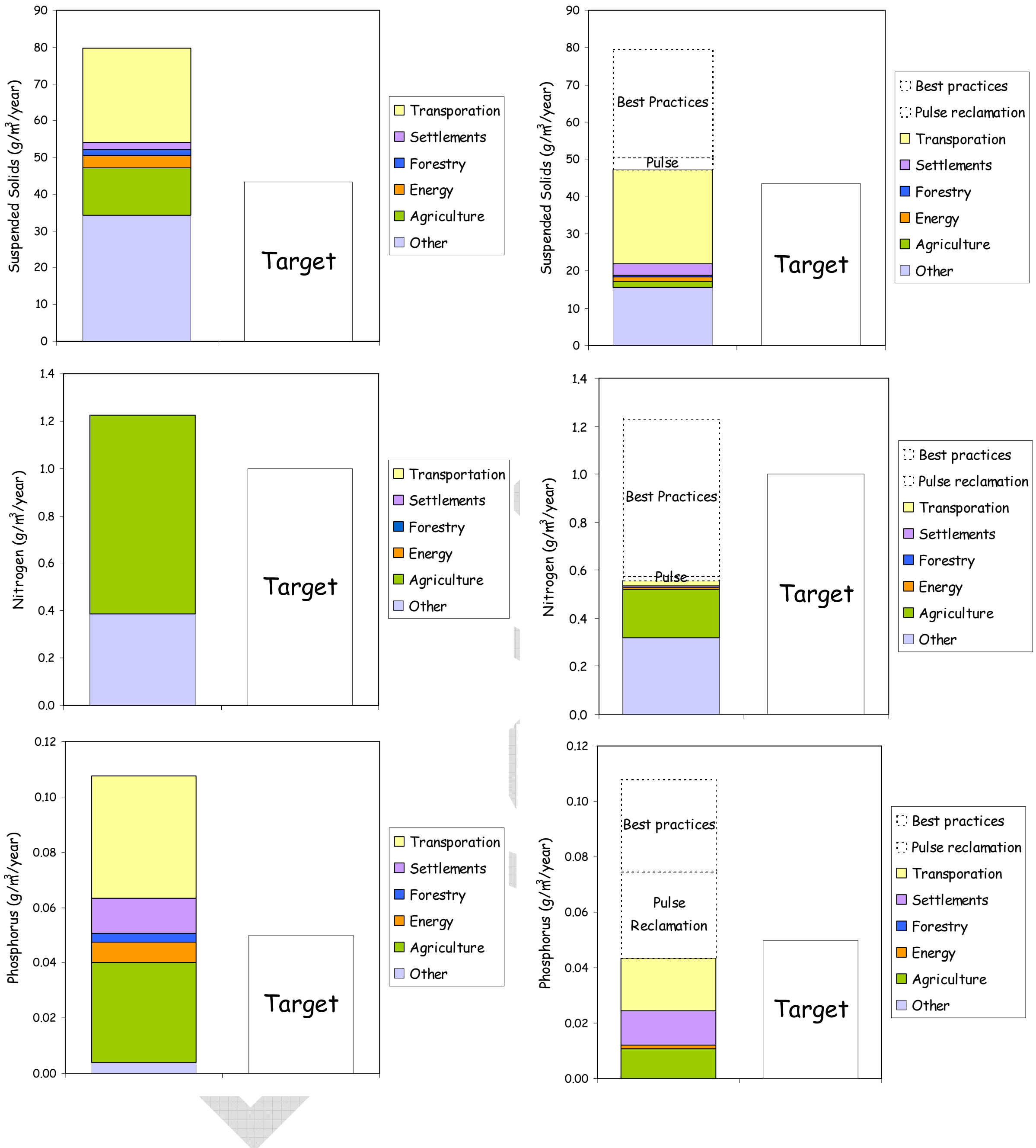

Figure 7. Contributions of land uses, Best Practices, and pulse reclamation to suspended solids, nitrogen, and phosphorus status at year 50. (The charts are based on coefficients of regression models that summarize results from the land use amount factorial experiment. See text for details.)

4.3.5 Genuine Progress Indicator

Simulation of the Business as Usual scenario demonstrated an increase in the Genuine Progress Indicator over time (Figure 8). The increase was due to a substantial rise in gross domestic product (GDP) that exceeded a small reduction in ecological services product (ESP).

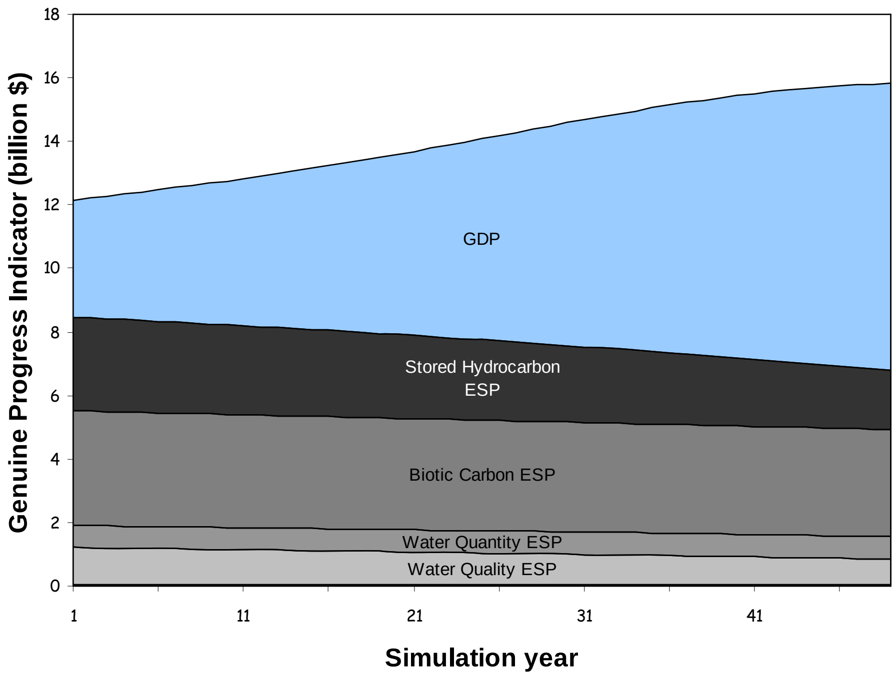

Figure 8. Simulated Genuine Progress performance in response to the business as usual scenario. The contributions of gross domestic product (GDP) and various ecological services products (ESP) to true economic performance are identified.

Regression models that summarized results from the land use amount factorial experiment accounted for > 99.9% of the variation (Table 14) in genuine progress indicators across the 972 simulations. Model coefficients are listed in Table 15 and presented visually in figures 9-11.

Table 14. Coefficients of determination (R^2) for multiple linear regressions relating land use amount, Best Practices, and pulse reclamation to simulated genuine progress indicator status at year 50.

Genuine Progress Indicator	Gross domestic product	Ecological services product
0.9999	0.9999	0.9991

Table 15. Coefficients from multiple linear regression models for the affect of land use amount, Best Practices, and pulse reclamation on genuine progress indicators. (Coefficients refer to equation 3. Blank entries indicate that the significance of coefficients was less than 95%).

	True economic performance	Gross domestic product	Ecological services product
b_0	1.04E+10	6.93E+07	1.03E+10
b_1	-1.81E+09	2.57E+08	-2.06E+09
b_2	1.96E+09	2.76E+09	-7.92E+08
b_3	-1.51E+08		-1.54E+08
b_4	5.90E+09	5.93E+09	-2.88E+07
b_5	-4.02E+08		-3.98E+08
b_6	3.05E+08		3.06E+08
b_7			
b_8	-3.72E+07		-3.76E+07
b_9	9.03E+08		9.03E+08
b_{10}	2.09E+07		2.06E+07
b_{11}	2.31E+07		2.31E+07
b_{12}	3.24E+07		3.24E+07
b_{13}			0.00E+00
b_{14}	1.22E+08		1.19E+08
b_{15}	2.23E+07		1.98E+07
b_{16}			
b_{17}			9.26E+06
b_{18}	1.91E+08		1.87E+08

The bars presented for each land use in Figures 9 through 11 can be interpreted as the contribution of each land use to the status of the Genuine Progress Indicator at year 50. These represent coefficients b_{1-5} in equation 2 (Table 15).

Land use contributions to GDP were dominated by settlements (service sector or non-resource contributions) and energy (Figure 9).

All land uses with the exception of settlements had noticeable negative effects on ESP, as shown by bars with negative values in Figure 10. The Best Practice and pulse reclamation bars indicate that ESP can be increased by improving current practices. The shorter height of bars for Best Practice and pulse reclamation as compared to Business as Usual, Best Practices and pulse reclamation indicates that these improved practices were not able to completely offset the negative effect of existing land use on ESP.

In Figure 11, the best practice and pulse reclamation bars indicate the increase in GPI achieved by implementing Best Practices and pulse reclamation.

For agriculture, transportation, and forestry, negative effects to ESP exceeded positive contributions to GDP, resulting in negative contributions to the combined GPI. Implementing Best Practices and pulse reclamation improved the effect of some land uses to genuine progress indicators, as represented by coefficients b_{9-19}. A portion of the negative contribution of agriculture to ESP, for example, could be offset by implementing Best Practices and pulse reclamation (Figure 10). As shown by the shorter height of bars for best practice and pulse reclamation as compared to business as usual, Best Practices and pulse reclamation were not able to completely offset the negative effect of agriculture and transportation to GPI.

The intercept term (b_0) presented in Table 15 represents the overall economic performance that would occur in the absence of major land uses in the study area. With respect to Gross Domestic Product (Figure 9), this is shown as the "other" category which represents the contributions of land uses not specified in the regression models, most notably mining. With respect to Ecological Services Product (Figure 10), this is shown as the "ecosystem" category which represents the value of ecological services in the absence of land use. With respect to the Genuine Progress Indicator (Figure 11), this is shown as the "ecosystem" category which represents the contribution of ecosystem services to true economic performance. It is apparent from the simulation results that the contribution of ecological services to a Genuine Progress Indicator exceeds that of land use (Figure 10).

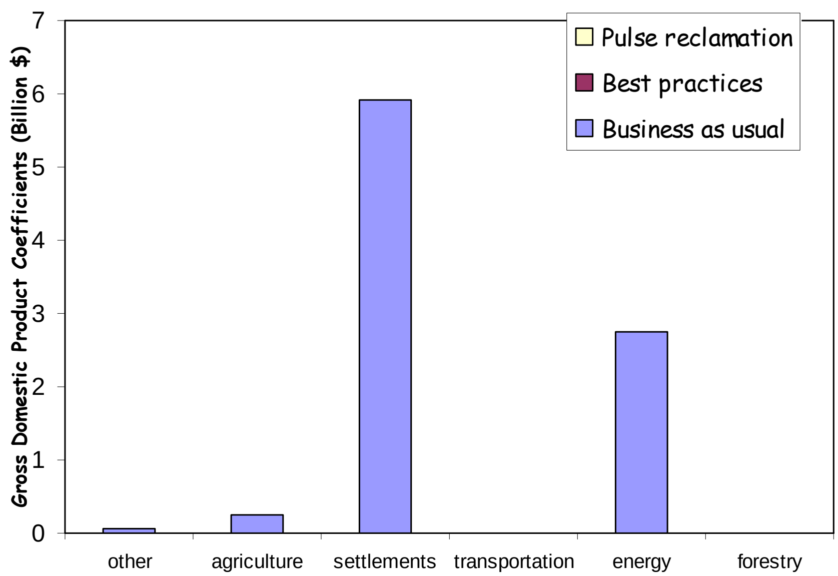

Figure 9. Contributions of land uses to Gross Domestic Product at year 50. (The charts are based on coefficients from regression models that summarize results from the land use amount factorial experiment. See text for details.)

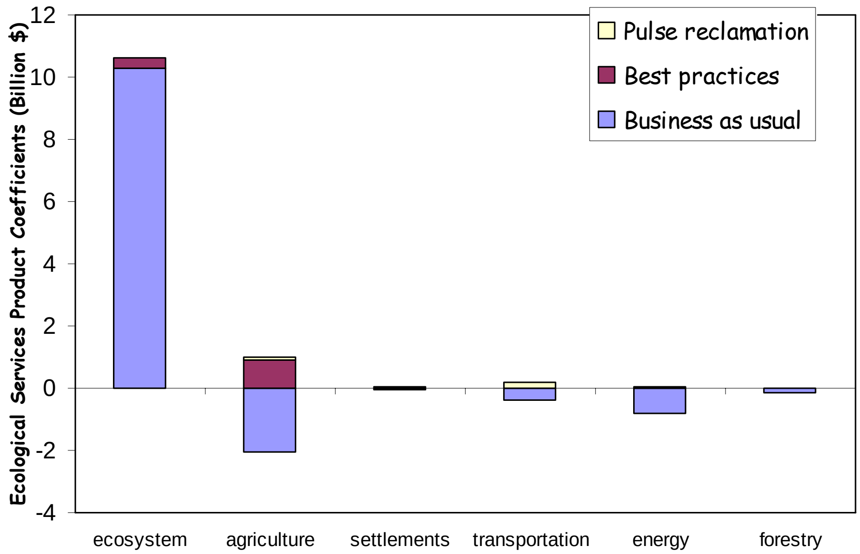

Figure 10. The positive contribution of ecosystem services ("ecosystem") and negative contributions of land uses to Ecological Services Product (ESP) at simulation year 50. (The charts are based on coefficients from regression models that summarize results from the land use amount factorial experiment. See text for details.)

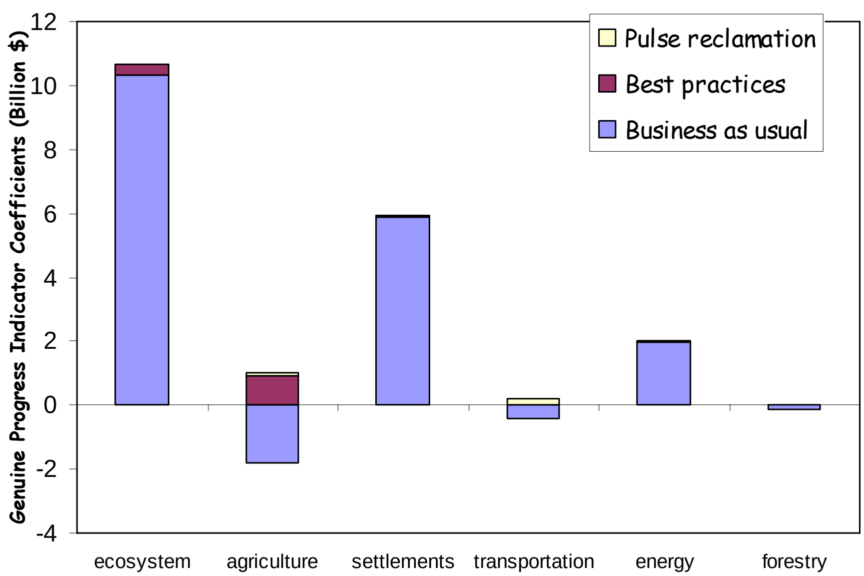

Figure 11. The contribution of ecosystem services ("ecosystem") and land uses to true economic performance (TEP) at simulation year 50. (The charts are based on coefficients from regression models that summarize results from the land use amount factorial experiment. See text for details.)

5. CONCLUSIONS

Classical economic indicators, such as the Gross Domestic Product (GDP) and national income accounts, ignore the value of ecological goods and services and natural capital values. Natural capital accounting helps resource managers take stock of their natural assets and the natural values that they provide, including ecosystem goods and services.

The primary goal of the SES Pilot ecological goods and services component was to construct a preliminary natural capital account for the SES study area incorporating: a) the market value of natural capital assets (e.g. timber, oil, gas and agricultural land) as measured in terms of GDP; b) the non-market Ecosystem Service Product (ESP) value of ecosystem services; and c) the combined value, or Genuine Progress Indicator (GPI).

The SES Pilot developed estimates of key Ecosystem Service Product (ESP) values for the southern east slopes. In particular, values for water quality (water supply/filtration) and water quantity (water regulation) were derived to reflect treatment and replacement costs, respectively. The estimated water supply/filtration service value of $1,135 million for 2006 was the most significant ESP value in the SES study area.

The SES Pilot also demonstrated that the ALCES© model could be modified to:

- simulate annual changes in GDP, ESP, and GPI concurrently with biophysical indicators so that projected trade-offs can be more directly compared.
- illustrate how different combinations of land uses, operating at different intensities and deploying alternative technologies, influence trade-offs between economic and ecological indicator performance and ultimately achieve pre-defined management outcomes.
- incorporate an ‘optimization’ approach that narrows all possible land use and management options to a subset of the most reasonable solutions for further evaluation. Although this factorial experiment approach is challenging to explain in non-technical language, it provides a rigorous, transparent and defensible approach to ‘optimizing’ solutions that achieve desired land management outcomes.

Several areas warranting further work were identified in this pilot project. These ultimately relate to the need to develop consistent and accepted assumptions for future scenarios modeling.

- Wherever possible, Government of Alberta-endorsed values and coefficients for commodities, ecological services, and pollutant loading and delivery should be used for regional simulations conducted for the Land Use Framework.
- It was not possible to estimate values for each ecosystem service because of data limitations or the absence of methodologies for analyzing various ecosystem functions. Further work to estimate these values should be considered.

- The current project did not consider the incremental cost of best practices or alternative land management options. Further work to estimate these costs should be considered.

It is important to note that the land management objectives and simulation results provided in the SES Pilot do not reflect government direction nor the "correct" landscape/land use combination for the SES Pilot study area. However, they do demonstrate the value of this approach, and how it might be applied through the Land Use Framework being developed by the Government of Alberta.

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