Scope of Work

Title: **A Landscape Analysis and Monitoring Program for Waterton-Glacier International Peace Park and the Greater Crown of the Continent Ecosystem. Phase I**

Background:

Project Summary:

An ecological health monitoring program for the Crown of the Continent Ecosystem faces unique challenges posed by an international and inter-provincial border and multiple management jurisdictions. The project is intended to (i) evaluate the suitability of existing geospatial data sets for providing baseline information on habitats and human footprints, (ii) fill in missing or unreliable information through remote sensing, and (iii) develop the tools and monitoring strategies necessary for analyzing changes in baseline conditions through time. The team represents a unique partnership between the University of Calgary, the National Parks Service, and all participating agencies within the Crown Managers Partnership, and will address many of the issues and questions that confront resource conservation efforts across the entire Great Northern Landscape.

Need for the Project:

Increasing concerns regarding the impacts of climate change, shifting patterns of land use and land cover, and altered ecological processes (fire, insects, disease, flooding, etc) on biodiversity and ecosystem functioning have led to the establishment of numerous mapping and monitoring programs operating at the regional (Yan et al. 2007; Jones et al. 2009; Wang et al. 2009), national (Homer et al. 2007; Zhang et al. 2007; Wulder et al. 2008a), and international (DeFries and Townshend 1994; Potapov et al. 2008; Pekkarinen et al. 2009) levels. While parks, monuments, and other protected areas remain the cornerstone of modern conservation strategies, our current understanding of biotic functioning acknowledges that the health of ecosystems even within parks' boundaries is influenced strongly by changes in the surrounding landscapes (Newmark 1985; Salwasser et al. 1987; Hansen and DeFries 2007). As a result, we have seen a growing emphasis on monitoring programs aimed at multi-jurisdictional areas surrounding core parks. For example, Wang et al. (2009) described a multi-scale protocol for detecting and monitoring land-cover change for ten segments of the Appalachian National Scenic Trail, including areas in and around eight park units from Maine to Pennsylvania. Similarly, Jones et al. (2009) described a conceptual model for monitoring land-use changes in the Greater Yellowstone Ecosystem. International programs for monitoring multi-jurisdictional landscapes can be found around the Wolong Nature Reserve in China (Vina et al. 2007) and the Calakmul Biosphere Reserve in Mexico (Vester et al. 2007), among others.

The Crown Managers Partnership is a multi-agency and university collaboration, initiated in 2001, that seeks to demonstrate leadership in addressing environmental management issues across the Crown. The (CMP's) Ecological Health Subcommittee is working in partnership with the National Parks Service's Rocky Mountain Monitoring Network (ROMN) and researchers at the University of Calgary (UofC) to develop a

Figure 1: The Crown of the Continent

monitoring program designed to track changes in landscapes across the Crown of the Continent Ecosystem (CCE). The program is intended to support the long-term health of the CCE and provide a scientifically credible foundation for managers within the CMP to engage in natural resource protection activities. The CMP has six indicators of ecological health (EH) and is strategically developing the landscape monitoring program to provide a baseline and trend monitoring protocol by which the remaining EH indicators can be measured. The CCE covers 72,000 square kilometers of complex and ecologically diverse landscapes in western Canada and the United States, including one state – Montana – and two provinces – Alberta and British Columbia (Figure 1). The region contains the headwaters of three major river systems draining each of North America's ocean basins – the Missouri (Atlantic), Columbia (Pacific), and Saskatchewan (Arctic) – and represents a key segment of North America's mountain ecosystem. The CCE is internationally recognized for its beauty and biological diversity, and contains landscapes ranging from alpine to grasslands across relatively short distances.

Our monitoring strategy will focus on the development and acquisition of geospatial datasets from remote sensing and other GIS sources designed to track changes in habitats and human footprint consistently and reliably across the CCE. While our work will certainly be informed by monitoring protocols elsewhere (e.g. Fancy et al. 2009; Kennedy et al. 2009; Crabtree et al. 2009; and other works cited previously), the challenges posed by the CCE are unique. Most pressing among these is the presence of the US-Canada international border, which complicates a variety of issues surrounding data acquisition and integration. Our efforts will address many of the questions that confront resource conservation efforts across the entire Great Northern Landscape, and the project will set valuable precedents in this respect.

Objectives:

The objective of the Crown of the Continent Landscape Monitoring Program is to develop and implement a long-term monitoring program for the CCE. The program will be designed to characterize trends in resource conditions, with a focus on various elements of habitat (land cover, vegetation structure and dynamics) and land use (settlements, agriculture, and industrial footprints) using raster and vector data models, as appropriate (Linke et al. 2009a). In addition to providing tools for tracking management efforts, our work also will support a variety of research and conservation initiatives through the production of spatially-explicit geospatial layers that are accurate and consistent at the scale of the CCE. These layers will lay the foundation for international conservation projects across multi-jurisdictional lands that are beyond the reach of current information resources. With respect to the objectives of the LCC, this project will provide a methodology to acquire landscape-level baseline and trend information that can be: 1) evaluated against the range of climate scenarios for the Crown, 2) monitor impacts and vulnerabilities in the face of climate change, and 3) assist managers with determining and implementing strategies for increasing resiliency in the face of climate change.

Methodology:

Jones et al. (2009) outlined a conceptual framework for monitoring land use and land cover around parks, and we will adopt a modified version of their approach for the CCE.

A. Monitoring indicators for the CCE. While the CMP intends to pursue a variety of indicators of ecological health in the long run, including biodiversity, water quality, exotics, and air quality, our initial efforts will revolve around landscapes. Four categories of landscape indicators have been identified as having the potential to influence key elements of ecosystem functioning within the CCE: (i) *land cover*, including the physiognomic categories of vegetated

(herb, shrub, forest) and non-vegetated (barren, water, ice/snow) surfaces; (ii) *vegetation structure*, including the two-dimensional variability of overstorey crown closure and species composition, each measured on a continuous scale; (iii) *vegetation dynamics*, including start- and end-of-growing-season, time and rate of maximum green-up, and overall measures of net primary productivity; and (iv) *human footprint*, including roads, pipelines, cut blocks, well sites, agricultural areas, and urban/built-up areas.

B. Quantifying monitoring indicators. We will use two main categories of data for quantifying the landscape indicators that make up the core of the CCE's monitoring program: (i) existing GIS layers, and (ii) remote sensing. There is a large number of existing GIS layers produced by state, provincial, and federal jurisdictions within the CCE, and cooperative efforts amongst personnel at the UofC, CMP, and ROMN over the past six months have focused on data-mining exercises designed to compile as much trans-boundary information as possible. The work has resulted in a set of base GIS layers on roads, geo-administration, hydrology, land cover, and disturbances. However, the quality of these data layers remains to be assessed, and their suitability for reliable landscape monitoring is unknown. The presence of the international boundary within the CCE presents unique challenges in this respect, and an important element of the proposed project will involve a critical evaluation of existing data sets. For example, land cover on the US side is mapped by the United States Geological Survey's National Land Cover (NLC) data set (Homer et al. 2004; 2007), while the Canadian land base is covered in part by the Canadian Forest Service's Earth Observation for Sustainable Development (EOSD) project (Wulder et al. 2008b; 2008c). However, the update frequency of the EOSD map has not yet been established, the NLCD products contain differences in classification methods that may hinder their capacity for monitoring, and the local accuracy of both data sets is unknown. Other information layers (state and provincial roads layers, for example) contain jurisdictional inconsistencies, are subject to restrictive data-access limitations (Canadian industrial data sets) or are simply unavailable across the full extent of the CCE (USGS Phenology products). It seems clear that we will have to develop and retain a significant capacity for 'filling in' missing or unreliable information through remote sensing.

Remote sensing from satellite and airborne platforms has the capacity to map and monitor large numbers of ecologically relevant attributes in an accurate and spatially explicit manner, including elements of land cover, vegetation structure and dynamics, and overall productivity (McDermid et al. 2009). Linke and McDermid (in press) articulated a conceptual model for multi-temporal landscape monitoring that involves the backdating and/or updating of existing reference maps with dynamic objects stored in geodatabase: a so-called *disturbance inventory*. With this approach, final maps are only altered in regions of confirmed change, so that spurious changes caused by differential errors in classification quality, geometric registration, scene illumination, resolution, and object delineation (Linke et al. 2009b) are avoided. We will develop base maps for each of the monitoring indicators for which no suitable pre-existing GIS alternatives exist, and then develop strategies for monitoring changes in these indicators using Linke and McDermid's basic approach. This work will be carried out by a project technician and graduate students at the UofC, and will include specific efforts to develop software tools for assisting automated or semi-automated work flow. Significant field campaigns will be required to collect calibration/validation data for remote sensing-based reference maps.

C. **Analyzing and interpreting monitoring data.** The ultimate purpose of the proposed monitoring program is to produce information products that are useful to managers within the CCE. ROMN has established, and will continue to develop, geospatial analysis and investigative techniques designed to provide measures of ecological health. The effort is part of the National Parks Service's Vital Signs Inventory and Monitoring Program, and includes measures of

landscape condition (or status) and change (trend) using metrics of landscape structure/configuration, composition, and function. We will use ecologically meaningful reporting units that will vary in scale across watersheds, geopolitical boundaries, ecoregions, and the entire CCE. Specific monitoring objectives include determining annual, or as the data becomes available, the status and trends of selected metrics of landscape composition, structure, and function for multiple reporting units within the CCE. Select metrics will be analyzed over time for landscape change and trend analyses. Core analytical methodologies will use well recognized tools such as FragStats, ArcGIS 9.3 Hydrology Toolset, and Landscape Disturbance Indexes. Data processing, spatial analyses, and summaries will occur almost exclusively in ArcGIS 9.3, Microsoft Office Suite, and a yet-to-be-identified statistical software package for trend analyses.

Key cooperators for this work include the UofC, which will house the graduate students performing the bulk of the remote sensing work, and a dedicated project technician. ROMN will handle data management duties and contribute analysis services surrounding landscape metrics and other elements of the NPS' Vital Signs program. The CMP will lead the collaborative elements of the project, including the coordination of workshops and meetings, and facilitate communication with the various management agencies within the CCE.

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