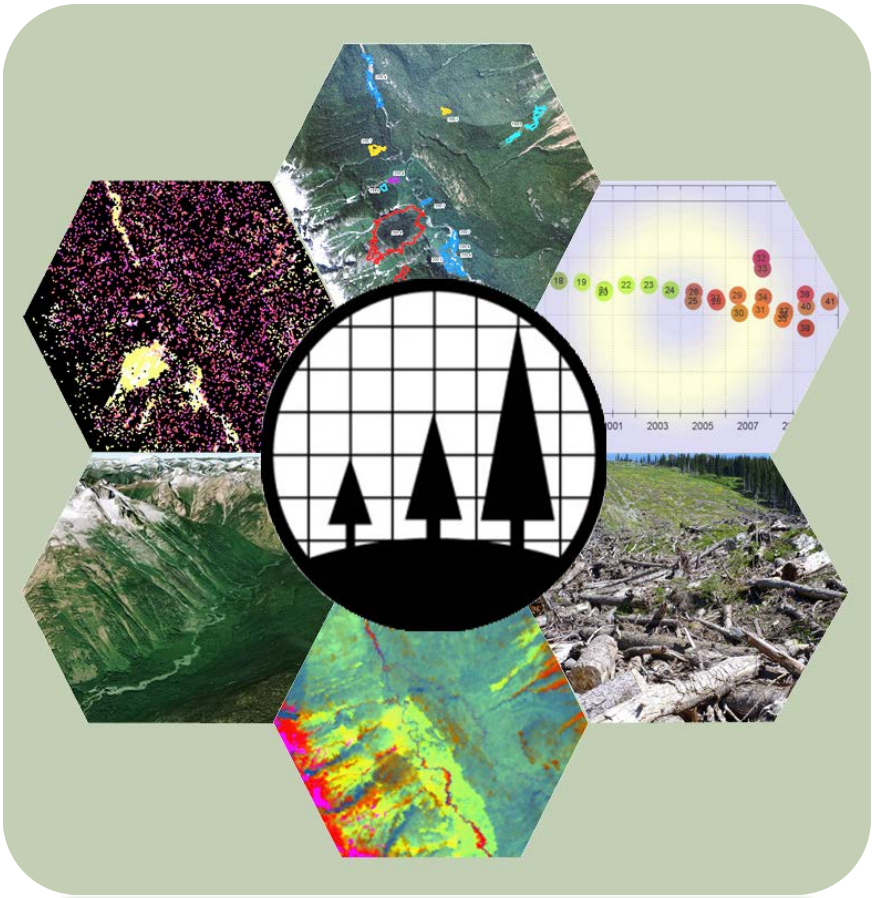
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Protocol for Landsat-based Monitoring of Landscape Dynamics in North Coast and Cascades Network Parks

Version 2

Natural Resource Report NPS/NCCN/NRR—2012/601



ON THE COVER
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NCCN Landscape Dynamics Graphic Identity in center created by Michael Liang

Protocol for Landsat-based Monitoring of Landscape Dynamics in North Coast and Cascades Network Parks

Version 2

Natural Resource Report NPS/NCCN/NRR—2012/601

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Executive Summary

Landscape dynamics refers to a large suite of ecological and geomorphological processes occurring across broad spatial scales. As part of Vital Signs Monitoring, the North Coast and Cascades Network (NCCN) of the National Park Service developed a protocol for monitoring landscape dynamics using remote sensing. Protocol implementation involves cooperative work with the Laboratory for Applications of Remote Sensing in Ecology (LARSE) at Oregon State University, leveraging their use of Landsat remotely sensed imagery to detect landscape change. LARSE has developed a set of algorithms called LandTrendr (Landsat-based Detection of Trends in Disturbance and Recovery). The core goal of this protocol is to detect and map eight types of landscape change due to both natural and anthropogenic causes in the NCCN parks and surrounding study areas using annual LandTrendr data.

LandTrendr has come to refer to the suite of change-detection algorithms which tracks the spectral trajectory of Landsat pixels through time. The main steps in the LandTrendr process include processing Landsat imagery, then smoothing the spectral index signature of each pixel into coherent segments describing periods of stability or change. The primary outputs from LandTrendr are the year of change onset, the duration of change, and the magnitude of the change.

LandTrendr outputs are processed into patches based on the year of onset and duration of change, resulting in a polygon layer with a minimum patch size of nine-pixels or 0.8 ha (2.5 acres) representing landscape changes of less than 4 years in duration. A Random Forests classification model is then applied so that the change polygons are labeled by their change type. The eight change types of interest are: Avalanches, Clearings, Development, Fires, Mass Movements, Progressive Defoliation, Riparian, and Tree Toppling. Field and office validation of the labeled results is conducted to determine the accuracy of the Random Forest classification.

For each park in the NCCN, data analysis and reporting will occur every three years and trends will be reported every 10 years. With the development of the Landscape Dynamics Monitoring Protocol, NCCN represents one of the first natural resource management agencies in the country to use the dense Landsat time-series data for monitoring.

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Acronyms

ArcGIS™ - A group of geographic information system (GIS) software products produced by ESRI

ASTER - Advanced Spaceborne Thermal Emission and Reflection Radiometer

EBLA - Ebey's Landing National Historic Reserve

ESRI - Environmental Systems Research Group

ETM+ - Enhanced Thematic Mapper

GIS - Geographic Information System

I&M - Inventory and Monitoring

Landsat - A global land-imaging project consisting of a series of satellites that routinely gather land imagery from space

LandTrendr - Landsat-based Detection of Trends in Disturbance and Recovery

LARSE - Laboratory for Applications of Remote Sensing in Ecology

LDMP - Landscape Dynamics Monitoring Protocol

LEWI - Lewis and Clark National Historical Park

MMU - minimum mapping unit

MODIS - Moderate Resolution Imaging Spectroradiometer

MORA - Mount Rainier National Park

NAIP - National Agricultural Imagery Program

NCCN - North Coast and Cascades Network

NOCA - North Cascades National Park Service Complex

NPP - National Polar-orbiting Partnership

NPS - National Park Service

OLYM - Olympic National Park

RF - Random Forests or randomForest

SAJH - San Juan Island National Historical Park

SPOT - Systeme Pour l'Observation de La Terre

TC - Tasseled Cap

TM - Thematic Mapper

VIIRS - Visible & Infrared Imaging Radiometer Suit

1. Background and Objectives

A. Rationale

Landscape dynamics refers to a large suite of ecological and geomorphological processes occurring across broad spatial scales. As part of the National Park Service's larger goal of developing a long-term monitoring program in response to the Natural Resource Challenge of 2000, the North Coast and Cascades Network (NCCN) determined that monitoring landscape dynamics was necessary in order to track the health of park ecosystems (Weber et al. 2005). The products of a long-term Landscape Dynamics monitoring program were determined to be valuable to park managers. While landscape dynamics could encompass a broad range of changes on the landscape, for the purposes of current monitoring, the focus is on changes that affect park resources in a way that could influence planning and budgeting.

One of the primary goals of the NPS Inventory and Monitoring program is to "monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments" (http://science.nature.nps.gov/im/index.cfm). Natural change processes are considered "park resources and values" subject to management provisions of the Organic Act of 1916 and further refined in the NPS General Authorities Act of 1978. These "park resources and values" are described in section 1.4 of the Management Policies (National Park Service 2006) as including,

> "The park's scenery, natural and historic objects, and wildlife, and the processes and conditions that sustain them, including, to the extent present in the park: *the ecological, biological and physical processes that created the park and continue to act upon it*; scenic features; natural visibility, both in daytime and at night; natural landscapes…"

Although mentioned in NPS management policies, the dynamics of natural landscape processes are generally not well documented within the national parks of the NCCN. Therefore, the first aim of the Landscape Dynamics Monitoring Protocol (LDMP) is to provide park managers with baseline information on the, type, location, frequency and severity of landscape changes expected within the parks. The LDMP is unique among other NCCN monitoring efforts in that it takes advantage of a long record of data, from 1985 to present, to determine these baseline conditions. These baseline conditions then create a reference point against which park managers can compare the landscape changes that occurred during the same time span outside the park boundaries, which are also monitored by the protocol, and can also continue monitoring landscape dynamics inside the park boundaries.

A second aim of the LDMP with respect to meeting management needs is to provide information that will allow the complex relationships between climate and landscape dynamics in the NCCN to be better understood. In the coming decades, the frequency, magnitude and distribution of landscape changes within both natural and altered environments are expected to respond to changing temperature and precipitation regimes (Dale et al. 2001). Temperatures are projected to rise between 0.11 and 1.8 degrees C (0.2 and 1.0 degrees F) per decade. Projected changes in the total amount of precipitation are small; however, some models predict greater variation in the seasonal cycle, with more precipitation falling as rain rather than snow in the early winter, and less summer precipitation (Mote and Salathé 2010). Increased temperatures coupled with shifts

in the timing of precipitation could impact landscape dynamics in NCCN parks in a variety of ways. Examples of potential climate warming-induced landscape changes include: more frequent and more severe flooding (Mantua et al. 2010) caused by the increasing frequency of rain-on-snow events, more avalanches, tree toppling events in response to winter storms due to increasing winter soil moisture or tree icing, or expanding areas of insect damage or an increase in the severity of wildland fires due to decreasing summer soil moisture causing drought stress (Littell et al. 2010).

Individual landscape change events such as tree toppling events, landslides, floods and fires can have significant impact on visitor experiences and park facilities. The Landscape Dynamics Monitoring Protocol is not designed to inform park managers about specific events that require an immediate management response. Park managers will already know about an avalanche that has blocked a park road, or a large wildfire. However, the LDMP will provide important and previously lacking knowledge about trends in the size, frequency or severity of these events. This information provided by the protocol can be used to improve the manner in which park managers allocate funding and maintain existing or locate new park facilities, as well as feed into adaptive management strategies for park resources in the face of climate change.

Outside the parks, landscape change occurs due to exogenous factors that are tied to land management practices and economic factors which, for the most part, are beyond the direct control of the park managers. Nevertheless, these changes can have significant impacts on ecosystem function and processes within the park boundaries. Park managers can use information about landscape dynamics inside and outside of their jurisdiction to inform other land managers and the public about the effects these land practices might have on park resources and how the impacts of various land management practices change over time. The information can also be used to plan for potential impacts and work with other agencies to plan mitigation efforts or influence policy.

In addition to providing managers with direct information about the dynamics of park resources, the LDMP will provide a landscape context for changes documented by the other NCCN vital signs (see http://science.nature.nps.gov/im/units/NCCN/ for further information). The results from landscape monitoring will likely aid in the interpretation of detected trends in these vital signs. For example, if a Long-Term Forest Monitoring plot (Acker et al. 2010) experiences significant tree mortality, the products from the LDMP protocol can provide landscape-scale information on areas with similar conditions where such mortality might be expected in the future. Similarly, trends detected by the Elk (Griffin et al. 2011 and 2012) or the Fish Assemblages (Brenkman and Connolly 2008) Monitoring Protocols can be correlated with the park areas affected by vegetation change due to progressive defoliation or tree toppling events, landslides, or riparian change.

In addition, the LDMP will provide both a trigger and a mechanism for updating two of the NCCN's major inventories: the Landform Inventory and the Vegetation Inventory. The LDMP will provide information on the location and extent of changes that are relevant to the Landform Inventory by providing information for the two geomorphic categories that are currently documented in the Inventory, mass movements and changes in riparian corridors. Similarly, Landscape Dynamics results can also be used to indicate areas within the Vegetation Inventory maps that have undergone reduction or removal of vegetation cover.

Finally, the LDMP products will serve as a trigger for site visits by park and network employees when natural, cultural or visitor resources are shown to be affected by a landscape change event, especially in remote areas that might not be frequently or otherwise easily accessed. The information on the type, size, and magnitude of the event provided by the protocol to the park and network staff will help them determine whether or not a site visit is warranted.

B. Background and History

Monitoring landscape-level change requires the use of a method with a resolution that captures broad spatial and temporal scales. To develop the Landscape Dynamics Monitoring Protocol, NCCN has engaged in cooperative work with the Laboratory for Applications of Remote Sensing in Ecology (LARSE) at Oregon State University, leveraging their extensive experience with landscape level remote sensing applications to document change in the Pacific Northwest. LARSE, led by Dr. Robert Kennedy and Dr. Warren Cohen, utilizes the Landsat platform as their primary remote sensing tool. The spectral and spatial characteristics of Landsat Thematic Mapper (TM) and Landsat Enhanced Thematic Mapper (ETM+) make it appropriate and useful for park-wide monitoring of diverse land cover types. With a pixel size of 30 meters, TM and ETM+ images capture adequate spatial detail for many landscape processes. The spectral character of the sensor allows discrimination of vegetated from non-vegetated surfaces, hardwoods from conifers and structurally complex canopies from more uniform canopies (Cohen and Spies 1992, Cohen and Goward 2004).

Protocol V1

Development of the first version of the NCCN landscape dynamics protocol began with a workshop in 2002. During this workshop, a comprehensive list of monitoring goals was created. Based on the size of the areas to be monitored and budget considerations, Landsat TM and ETM+ data were recommended as a viable tool to meet NCCN goals. Only monitoring goals that were considered achievable using Landsat were retained from this process (Table 1).

Table 1. The original North Coast and Cascades Network landscape change monitoring goals grouped by change interval needed for detection (from Kennedy et al. 2007a).

Landscape Change Agent
Type 1: Monitor Yearly
Avalanche chute clearing
Landslides
Fire
Insect/disease defoliation in forest
Riparian disturbance
Clearcuts
Rural development
Windthrow
Type 2: Monitor Every 10 Years
Alpine tree encroachment
Hardwood/conifer forest composition
Forest structure

LARSE developed an annual monitoring protocol that used a variation on a simple two date change detection method (Kennedy et al. 2007a). After geometric and radiometric corrections were made, a baseline image was transformed using the tasseled cap (TC) algorithm (Crist and Cicone 1984). The TC transformation compresses the six non-thermal bands of Landsat TM or ETM+ imagery into three spectral axes, corresponding to the brightness, greenness, and wetness components of a pixel's spectral signal. Using an unsupervised classification, the baseline TC image was classified into 9 physiognomic classes including water, conifer forest, broadleaf vegetation, bare soil, and snow. The spectral signatures derived from the nine physiognomic classes were then used for calculating the probability of membership (POM) in each of the classes for pixels in two images in a chosen change interval. The difference in POM values between the pixels from the two dates was then recorded into an n-dimensional output. Some of the benefits of this approach, relative to a simple two date change detection, were that it allowed fuzzy membership in classes and that the probability of membership in all classes was retained for all pixels. It was also designed to allow for varying change detection thresholds, so that change of different magnitudes might be better monitored at different threshold levels.

The next step in the analysis was to translate the N-dimensional POM image into a product that could undergo validation. Differences in POM were collapsed into 15 change classes that could be interpreted directly from the TC images. The change classes encompassed broad transitions of pixels within and between physiognomic classes, for example vegetation to water, or conifer forest to broadleaf, or a generalized decrease in vegetation. The target landscape change to be monitored was indirectly linked to the change classes through interpretation of the change in physiognomic class. For example, windthrow could cause decreases in the broadleaf class, the conifer class and/or the mixed vegetation class. Ascribing the agent of change required analysis not only of the change class but also the location of the altered pixel on the landscape. Interpretation of the change relied on the TC images, aerial photography and additional ancillary data. A protocol for going from broad change classes to specific change agent categories was never developed, a major omission in the original protocol.

Validation involved the process of determining how accurately the change classes were detected and labeled. The change classes were validated using 1.5 km boxes randomly placed throughout the study area. Each pixel within the box was labeled as either "no change" or one of the 15 change classes. The interpreter then used both the tassel cap images and the differenced image to confirm the change. Interpretation was greatly facilitated by being able to see the conditions before and after the change, which was generally only possible with repeat high resolution aerial photography. Therefore, a significant cost of the first version of the Protocol was to purchase aerial photography for the NCCN parks approximately every seven years.

The protocol was to be implemented annually in each of the parks. The first version of the protocol included highly detailed image processing, change detection and validation SOPs. However, it did not include an SOP for labeling the landscape change by type.

Protocol Implementation

Between 2005 and 2008, the NCCN implemented the Landsat-based monitoring protocol at MORA, NOCA and OLYM. A detailed description of the results of this first implementation can be found in Antonova et al. (2010). Challenges arose from applying the change detection methodology described above. Although landscape changes of interest to the monitoring

program were detected by the method, the results were overwhelmed by false and or non-target change brought about by annual changes in cloud cover, shadows associated with cloud cover and topography, and phenology. It became obvious that it would be very difficult to develop a pair of Landsat scenes for each park each year that would minimize the effects of differences in sun angle, phenology, and cloud cover. Additionally, implementation revealed that the validation of change classes, because it relied on human interpretation of satellite imagery that has undergone statistical modification, measured how well the interpreter mimicked the computer algorithm more than how well the algorithm mapped real change. An additional challenge of the validation process was to achieve consistent application of the method among the staff performing the interpretation. Finally, a methodology for labeling change agents was not developed in the first version of the protocol.

Assessment of Other Monitoring Platforms

Concurrent with the first implementation of the protocol, new developments in the field of remote sensing technology were taking place (Melesse et al. 2007). Numerous new satellite platforms were being introduced and tested for various natural resource applications by other agencies and other networks in the NPS (Reed et al. 2009, Bayer and Schei 2009). With Landsat ETM+ developing problems, NCCN evaluated a number of these instruments keeping in mind that the key to any monitoring system is consistency over time. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), a more modern instrument than Landsat, was considered an attractive alternative. ASTER was not selected because the data have to be requested and availability has been unreliable at times. Moreover, there was no follow-on planned for this particular instrument. Similarly, after researching the potential use of Moderate Resolution Imaging Spectroradiometer (MODIS), it became apparent that the National Polar-orbiting Partnership's Visible & Infrared Imaging Radiometer Suit (NPP VIIRS), the instrument designed to continue its legacy, varied in design specifications enough from MODIS that any monitoring program designed to utilize its data would likely need to be re-developed.

In contrast, the Landsat mission had stable, consistent, historical imagery that could be maximally utilized. The Landsat system also remained the only system with a commitment from the federal government for future maintenance. The Landsat Data Continuity Mission (LDCM, Landsat 8) is in pre-launch development, with the expectation and funding to proceed to launch in early 2013 (Behrens 2011). Therefore, we concluded that Landsat was more stable and consistent over time, and provided the only long-term data stream that was both historical and likely to continue into the future. As with any long-term monitoring project that relies on use of a specific technology, there will always be a chance that this technology will at some point become unavailable, either because it is no longer functioning or supported. Should that become the case, new methods will have to be developed using other available sources of remotely-sensed data, such as Systeme Pour l'Observation de La Terre (SPOT) or MODIS or ASTER that will mimic the current information provided by Landsat.

Development of New Techniques

In the meantime, advancements in change detection methods were emerging from LARSE. In 2009, the Landsat archive was released to the public free of charge. The availability of these scenes facilitated the development of a method that uses multiple Landsat images. LARSE developed a set of algorithms called LandTrendr (Landsat-based Detection of Trends in Disturbance and Recovery) that allowed users to trace spectral changes in each pixel through the

time-series of images (Kennedy et al. 2007b). Shortly thereafter, LARSE made significant improvements to the image processing and the change detection steps (Kennedy et al. 2010) as well as developed a new tool called TimeSync, which greatly facilitated the validation process (Cohen et al. 2010). One of the major advantages of the LandTrendr algorithm is that it can accept multiple images per year so that pixels associated with clouds, cloud shadows and defects in one image can be replaced by unaffected pixels from another image from that same year. . This means that LandTrendr can make use of Landsat ETM+ data, which are still high quality in non-gap areas, allowing continued monitoring until the upcoming Landsat Data Continuity Mission is launched.

LandTrendr traces the spectral trajectory of each pixel through the stack of imagery and breaks the trajectory into a series of segments. The segments are defined by vertices that represent changes in spectral state that surpass a predefined threshold for change (Figure 1). Variations brought about by sensor drift, phenology or other artifacts are smoothed in a process of statistical line-fitting. The primary outputs from LandTrendr are the year at which the change occurred, the duration of change, and the magnitude of the change (Figure 1). LandTrendr has been applied to research applications in the Pacific Northwest, including mapping of change for the Northwest Forest Plan (Moeur et al. 2005) and estimation of forest biomass (Powell et al. 2010). LandTrendr and associated products will be discussed in detail in the methods section below.

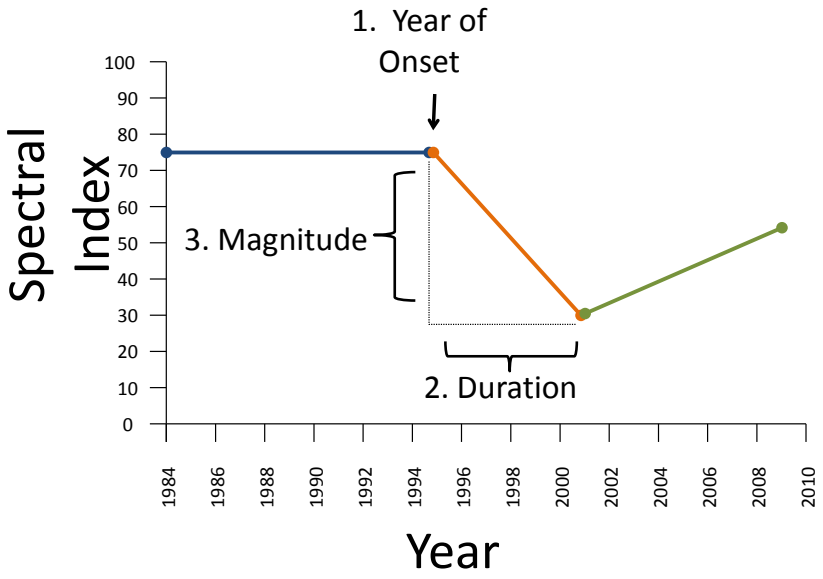


Figure 1. An idealized LandTrendr trajectory tracing a Landsat pixel through periods of stability, change and recovery. The period from 1984 to 1994 is a stable segment. A change event begins in 1994 and lasts until 2001, causing a 40% reduction in the spectral index. The change is followed by a recovery period from 2001 to 2010.

Study Area Development and Modification

The study area boundaries for each park were developed to integrate ecological features with constraints of the Landsat imagery. First, a 16km (10 m) buffer was established around each of the parks' boundaries. These were expanded in several cases to include entire watershed boundaries and to include wildlife and hydrographic considerations. For example, the entire

Olympic Peninsula was included in the analysis for the Olympic National Park, and the Chilliwack and Upper Skagit watersheds in British Columbia were included within the study area of the North Cascades National Park. The 16 km buffer was truncated in several places to accommodate the geometry of the available Landsat imagery.

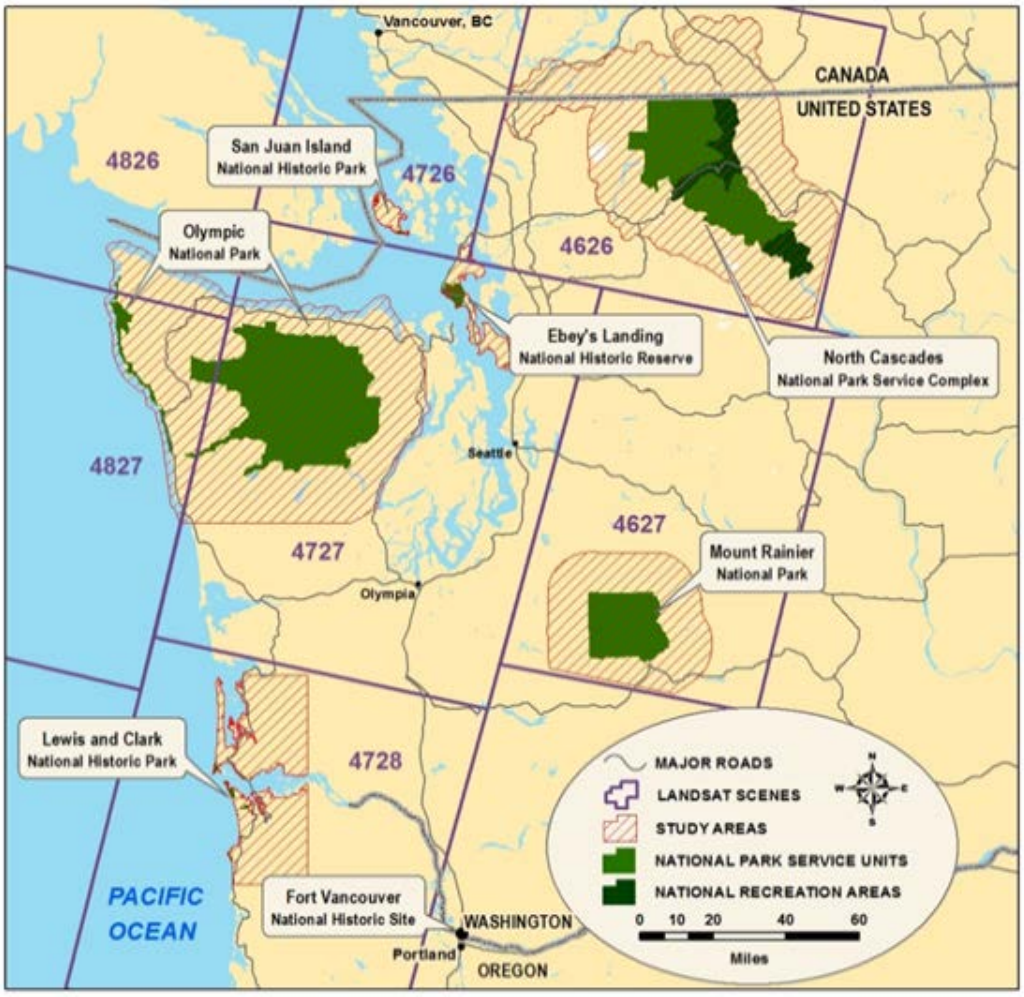


Figure 2. NCCN parks, study areas, and Landsat scene boundaries.

Updated Monitoring Goals

Updating the Landscape Dynamics monitoring protocol has allowed the NCCN to evaluate the agents of change originally proposed for monitoring (Table 1) with respect to the LandTrendr method. Using inputs from NCCN staff, as well as information gathered in the field, some of the change categories were updated in order to better reflect evolving understanding of change processes and to reflect current terminology. Table 2 shows the updated list of change categories. In some cases the new label represents inherent uncertainty about the proximate cause of change, especially in cases where there are interactions among change types. For example, LandTrendr detects a circular patch in the forest where all the trees are laying on the ground. The cause of this event is likely wind, but it is impossible to determine if the trees were first affected by root rot, causing them to be more vulnerable to windthrow. The label "Tree Toppling" incorporates the underlying uncertainty about the processes but still describes the final outcome. **Appendix**

A: Descriptions of the Landscape Change Categories provides detailed descriptions and pictures of each of the change types that will be monitored.

Table 2. Landscape change types monitored by the NCCN.

Landscape Change Types	
Current Label	**Previous Label**
Avalanche	Avalanche chute clearing
Clearing	Clearcuts
Development	Rural Development
Fire	Fire
Mass Movement	Landslides
Progressive Defoliation	Insect/disease defoliation in forest
Riparian	Riparian change
Tree Toppling	Windthrow

C. Measurable Objectives

The primary objectives of this protocol are:

1. Detect and map landscape changes for EBLA, LEWI, MORA, NOCA, OLYM, and SAJH, that are larger than 0.8 ha (2 acres) in size and are a result of an avalanche, clearing, development, fire, mass movement, progressive defoliation, tree toppling, or riparian flooding. Detection and mapping of changes will occur annually within a 16 km (10 mile) buffer around park boundaries. Reporting will occur at 3 and 10-year intervals.

2. Determine trends in the size, magnitude, location, and spatial distribution of each landscape change category.

2. Methods

The core goal of this protocol is to detect and map landscape changes in the NCCN parks and surrounding study areas. In this section the overall workflow of the protocol and its anticipated products are described in detail (Figure 3). The overall workflow can be divided into two major parts. The first part is carried out by the LARSE and includes downloading and processing Landsat imagery, running LandTrendr, filtering by magnitude to create a layer of the greatest change in the stack, and delivering results to the NCCN. The second part is done by the NPS and involves filtering results by duration, using a minimum mapping unit to generate Rapid Change polygons, labeling the polygons by change type, performing validation, and generating summary statistics and reports. This document contains SOPs for the parts of the protocol performed by NPS.

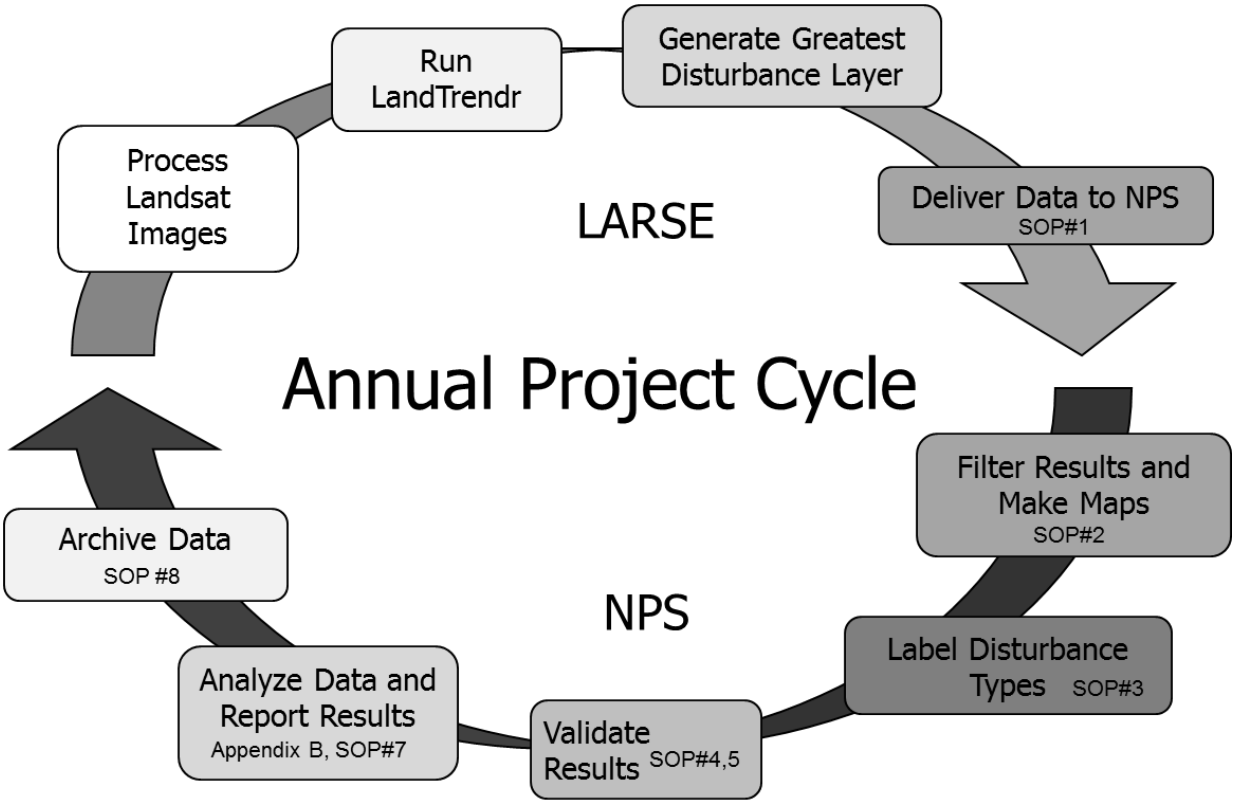


Figure 3. The annual project cycle. The upper arrow tracks project phases performed by LARSE, the lower arrow tracks NPS processing steps and associated Standard Operating Procedures (SOPs).

A. Landsat Image Processing

Image Selection and Acquisition

The first priority for image selection is to acquire good images as close as possible to the median Julian date (approximately mid-July) of the whole stack. A consistent date minimizes noise related to annual changes in sun angle, which cause topographic shadows, and vegetation phenology.

Topographic shadows and phenological variability in source imagery potentially exert a confounding effect on the year-to-year spectral signal and their effect must be reduced as much as possible. This had been a consideration in two-date change detection as well, but with only two dates of imagery, avoiding clouds was considered more important. Because LandTrendr uses a dense temporal stack of imagery, a clouded pixel in one image can be replaced by a non-clouded pixel from an earlier or a later image, making the penalty for clouds relatively low. Therefore, more prominence can be given to stabilizing the phenological and topographic signal.

Dense temporal stacks of images also allow the use of Landsat ETM+ images, which have striping or gaps on their edges after a sensor malfunction in 2003. Affected pixels can be replaced by pixels from images adjacent in time, much as with clouded pixels. Appropriate images are selected and downloaded from the USGS's GLOVIS website (http://glovis.usgs.gov).

Cloud Screening

The first step in image processing is to screen out the clouds and cloud shadows that can confound change detection. The LARSE builds on cloud- and shadow-identification routines built into the Vegetation Change Tracker (VCT), a software package designed to quickly map forest disturbance with Landsat imagery (Huang et al. 2010). The cloud-masking in VCT is robust and fast, allowing a quick first run of cloud mapping. For all further steps, pixels are considered "clear" when they are not labeled cloud, cloud edge, shadow, shadow edge, or snow according to the VCT algorithm. Occasionally, the VCT approach will not sufficiently detect thin cirrus clouds or smoke. In these cases, an expert interpreter determines a brightness value above which the pixel is considered a cloud or the temperature value below which it would be considered a cloud.

Atmospheric Correction and Normalization

Atmospheric correction of satellite images is a critical image-processing step in which the influence of Earth's atmosphere is removed or greatly reduced. The goal of this processing step is to generate images that are spectrally similar to each other by reducing variability in reflectance values associated with atmospheric scattering due to aerosols, and solar angle at the time of acquisition. LARSE uses the standard Dark Object Subtraction (DOS) correction to account for additive noise caused by aerosols (Kennedy et al. 2007b) combined with the cosine estimation of atmospheric transmittance (COST) to correct for solar angle (Chavez 1996) The DOS method assumes that for objects or surfaces which absorb all incoming light, such as water, dense forests, or shadows, the real reflectance should be zero. Any measured reflectance would therefore be a result of atmospheric scattering (Schroeder et al. 2006). For each image, the difference between zero and measured reflectance of dark objects is subtracted from every pixel. Lastly, a multiplicative correction using a first approximation of atmospheric transmission based on the cosine of the sun's zenith angle at the time of image acquisition is applied.

Although the COST is useful, by itself it is not sufficient for comparison across images. The COST process is approximate and leaves some atmospheric effects uncorrected. The magnitude of that uncorrected portion differs for each image, and thus if it were applied separately to all of the images, these residual errors would introduce noise in the change detection. Thus, a critical step after COST correction of a single reference image is a normalization process intended to align all images to a single COST-corrected reference image.

Radiometric normalization uses statistical methods to adjust raw image values by normalizing the image based on stable, unchanging pixels in the imagery. Typical stable pixels within a scene range from dark, invariant shadows, to stable vegetation, to bright non-vegetated surfaces such as rocks or sand. LARSE uses an automated approach for detection of stable targets, multiple alteration detection calibration (MADCAL) because the manual process of finding stable targets is time consuming (Schroeder et al. 2006). Additionally, LARSE has modified the standard MADCAL to allow for the normalization of many images in a stack. While the standard MADCAL routines derive relationships between images using a single 1,000 by 1,000 pixel subset, the LARSE modification utilizes a random sample of pixels from the entire image to better capture the full range of conditions across the landscape (i.e. typical image size is approximately 7,000 by 8,000 pixels). To avoid the effects of clouds, this random sample is drawn from pixels that were labeled as clear in the prior cloud-masking step.

From that point, the relative normalization process can proceed quickly without significant human intervention. The COST reference image is compared to each input image in the stack. The normalization coefficients are calculated by performing a linear regression on each Landsat band using randomly selected pixels from both images.

After all image processing is complete, the user now has a stack of corrected and normalized Landsat images upon which further analysis is based (Figure 4).

B. LandTrendr-Based Change Detection

LandTrendr is a combination of change detection and results-processing algorithms. The acronym has come to refer to the larger process of detecting and mapping change. LandTrendr evaluates one spectral index at a time. The core LandTrendr algorithms follow the trajectory of a spectral index of an image pixel through the time series of Landsat images. Statistical line fitting techniques are used to draw a smooth trajectory through the series of values of the spectral index of a pixel. Primary outputs from LandTrendr are the years in which major changes occurred, the duration of the change and the magnitude of change in the spectral index used.

Spectral Index

Landsat satellite data comes in 7 bands, with each band representing some portion of the visible to near infrared spectrum. Spectral indices are a useful tool for reducing the complexity of multispectral space. Although any spectral index could be used, the normalized burn ratio (NBR) index has been determined by LARSE to be one of the most useful for detecting change, and is the index used for this protocol (Key and Benson 2004). NBR is defined as the difference between near infrared (Band 4) and middle infrared (Band 7) reflectance divided by their sum.

$$NBR = (R_4 - R_7) / (R_4 + R_7)$$

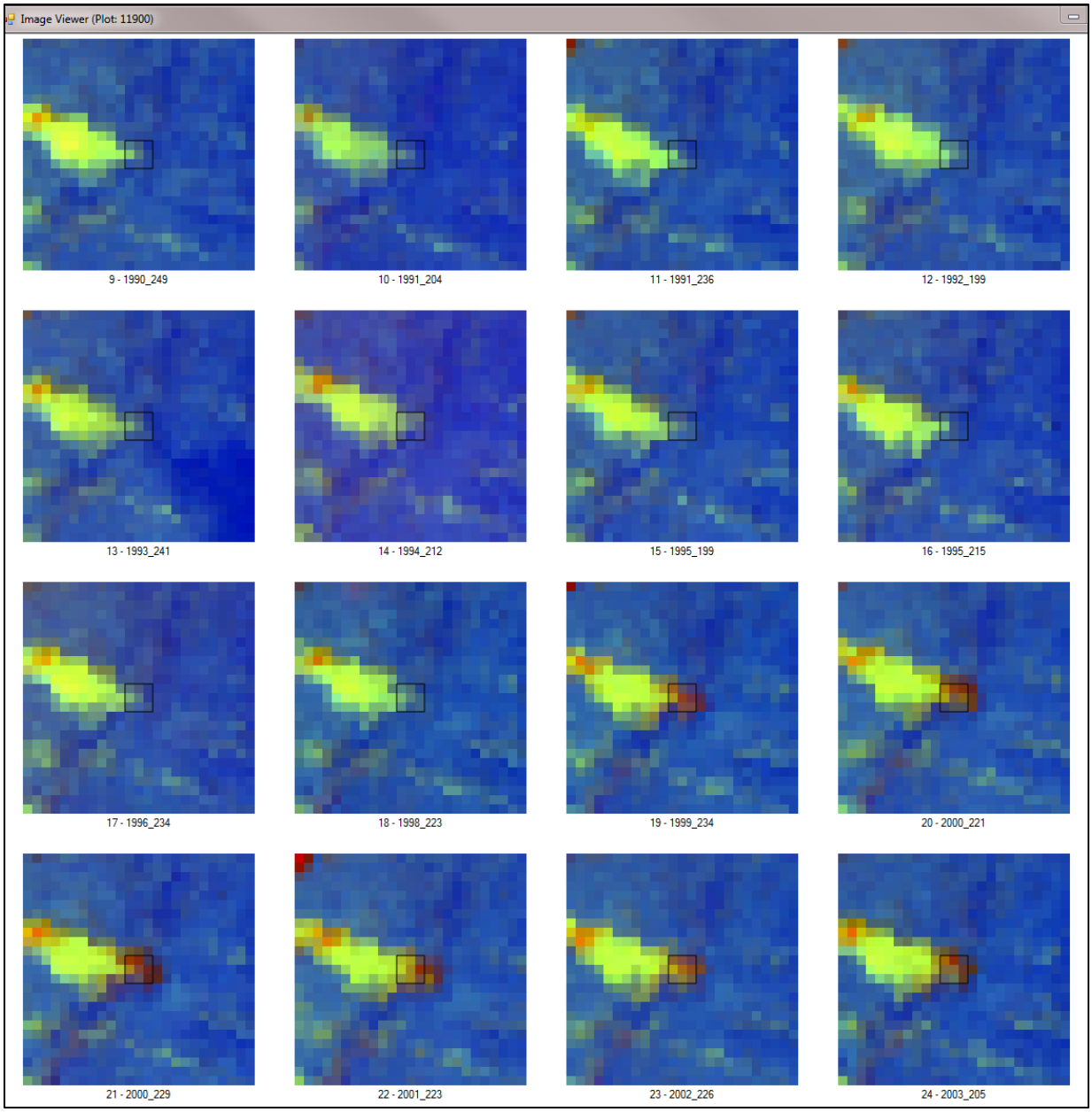


Figure 4. A subset of series of image chips from 1990 to 2003 for an area at North Cascades National Park Complex prior to and after an avalanche in 1999.

NBR is most useful for characterizing vegetated systems because vegetation has low reflectance in Band 7 and high reflectance in Band 4. The wide range of values allows for detection of subtle difference in vegetation types and condition (Cohen and Goward 2004). NBR has been used in national parks as a means of observing fire severity (van Wagtendonk et al. 2004), and has been used by LARSE in various change detection applications (Kennedy et al. 2010, Cohen et al. 2010). NBR has been shown to be more sensitive than the wetness index for detecting lower intensity changes (Cohen et al. 2010).

Segmentation

Even after efforts to normalize images in the time series, residual year-to-year variations remain in each pixel's temporal history. These variations are caused by the random effect of image acquisition date and can include: phenological differences, sun angle variations, and residual atmospheric effects. These noise effects can confound change detection, and therefore it is necessary to identify the underlying temporal progression of each pixel's spectral history. LARSE's LandTrendr process is built on an approach to achieve this simplification through the fitting of straight line-segments through each spectral trajectory. This temporal segmentation process simplifies each pixel's spectral history to its salient shape. The resultant segments can then be evaluated to determine when the spectral values are increasing, decreasing or stable.

Segmentation is described in detail in Kennedy et al. (2010), and is summarized here. For each pixel, the NBR values are extracted for each year in the stack (Figure 5). If there are multiple images supplied for a given year in the stack, the algorithm chooses the best one based first on masking (clouded pixels are not chosen) and then the date (pixels from the image closest to the median date for all images in the stack are preferred).

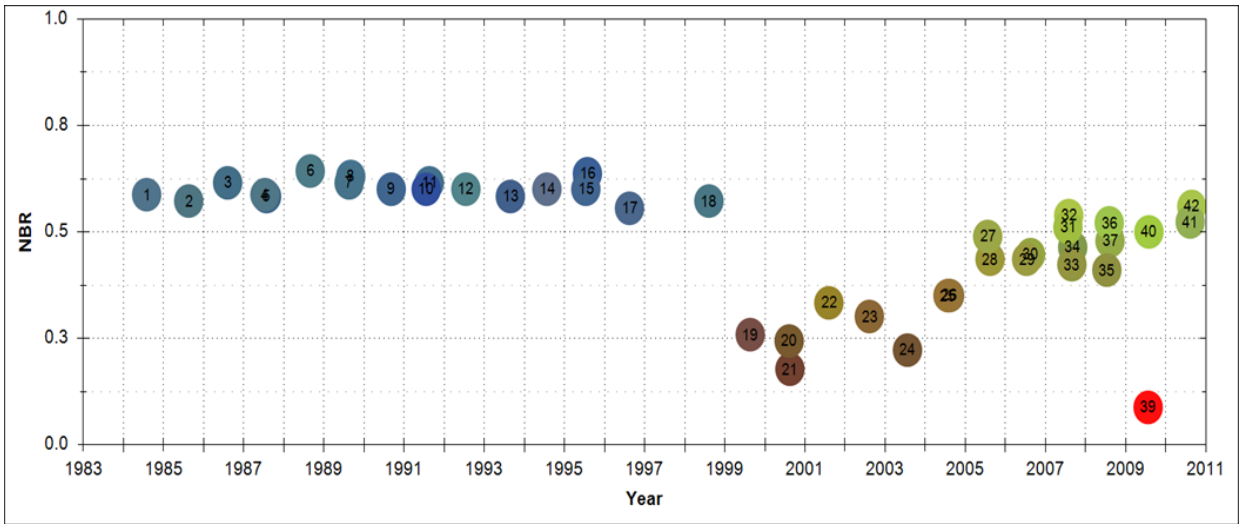


Figure 5. Extracted NBR (Normalized Burn Ratio) values from the Landsat stack for the focus area shown in Figure 4. The numbers in each circle correlate to the ordered sequence of Landsat image chips in the stack. The colors reflect landcover type; dark blues represent conifer forest, browns represent exposed soil following an avalanche, and greens depict vegetation recovery. The red circle in 2010 indicates missing data due to cloud cover.

The first LandTrendr algorithm identifies years that appear to represent turning points – either upward or downward – in the overall trajectory. These turning points are referred to as vertex years in the trajectory, since they describe vertices between two sequential segments (Figure 6). Selection of these candidate vertex years is a critical step that is achieved using one of several different approaches. One approach is to evaluate slope change with and without each vertex. Another approach analyzes the deviation of the point from the longer-term, straight line trend. Priority for retention as a vertex can also be given to years that precede or follow large changes, assuming that change signals have a consistent directional character. Once a target number of candidate vertex years is chosen, a second set of algorithms then identifies the most parsimonious path through the vertex years (the x-axis) to describe variation in the signal (y-

axis). These fitting algorithms are used again later. A third algorithm then identifies and removes the vertex whose removal caused the least penalty to overall description of variance, and then the second set of algorithms is reapplied to the smaller set of potential vertices. This vertex removal and trajectory recalculation is repeated until only one segment (with two endpoints) remains (Figure 6). Finally, another algorithm is used to determine which number of segments represented the best overall description of the trajectory.

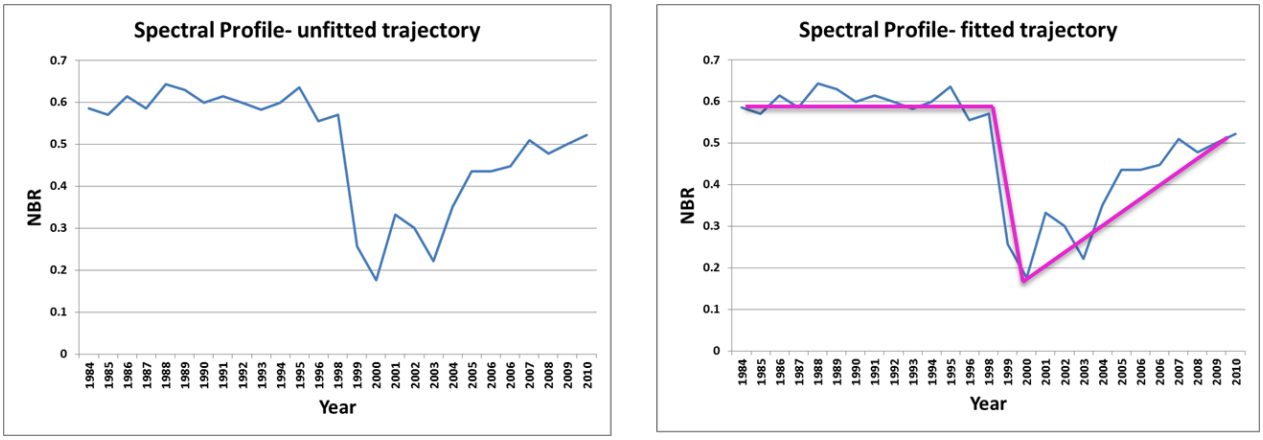


Figure 6. The left panel shows the spectral profile of an unfitted trajectory for the avalanche area shown in Figures 4 and 5. The pink fitted trajectory in the right panel shows the smoothing effect of LandTrendr's line fitting algorithm.

The decision points for all of these steps are controlled by a set of segmentation control parameters, which again are detailed in Kennedy et al. (2010). Based on comparison with validation points across the west-side Pacific Northwest forests, LARSE identified a stable set of segmentation parameters used in all forest-related efforts in the region, and these are used for this protocol (Table 3).

Table 3. The LandTrendr segmentation parameters used in this protocol.

Parameter	Value	Description
Kernelsize	1	Size in pixels of the fundamental analysis. Each pixel is handled separately.
Pval	0.05	Statistical *p*-value of goodness-of-fit test needed for a fitted trajectory to be considered good. Higher values allow noisier trajectories.
Max_segments	6	Maximum number of segments into which to divide a given trajectory
Recovery_threshold	0.25	A noise filtering parameter that prevents segments with unrealistically fast recovery to be considered valid.
Despike_val	0.9	Used to filter year-to-year spikes or dips; this value allows moderate filtering.
Distweightfactor	2	A parameter used to give preference to vertices that lie near change events; this allows capture of more subtle change effects.
Vertexcountovershoot	3	The initial regression-based detection of potential vertices can overshoot (max_segments+1) vertices by this value; angle-based culling is used to return to the desired number of vertices if overshoot occurs. This parameter allows better capture of subtle changes by allowing initial discovery of more vertices than necessary.
Bestmodelproportion	0.75	Allows more complicated segmentation results to be selected as best even if not strictly the highest-scoring model.

Outputs

The vertex years and vertex values of this "best description" of the trajectory provide the basis for all further mapping. The vertex years and the values of the spectral index at those vertex years are written to output files for later processing. In addition to the vertices at the endpoints of segments, the fitted values at each year along the segment are also written to a "fitted value" image that has as many layers as there were years in the input image data.

LandTrendr algorithms also have the potential to characterize change for spectral indices other than NBR. Rather than using the other indices to both identify vertices and then fit the time series data, the first step is skipped and the other indices are forced to fit to the vertices found using NBR. These "fit-to-vertices" images allow for a richer description of change in a manner that constrains all other spectral indices used for visualizing or validating results to move in unison with NBR. For this protocol, the tasseled-cap spectral indices (brightness, greenness, and wetness) were fit to the NBR temporal segmentation.

Filtering Results

The LandTrendr outputs at this point are information rich and must be processed to filter out unwanted information. The fitted image could itself be used to display spatial patterns in the trajectories of pixels across an image and compared visually with other datasets to understand if a particular known phenomenon is being captured by the segmentation process. However, the information is not summarized in a manner that can be interpreted quickly or quantitatively. In order to make use of the data, rule-based approaches must be applied to the vertex data to distill the information into simpler forms that can be mapped easily. In essence, the most salient or distinctive features are extracted from a given trajectory while ignoring the noise in the signal. This requires a sequence of processing steps.

Filtering by Magnitude

One drawback of the segmentation approach is its potential susceptibility to "overfitting," whereby an undesirable small noise event is captured as a meaningful segment. Relative to a simple two-date change detection used in Protocol V1, these "false positive" signals are greatly reduced in frequency, but they still occur. Therefore, in the LandTrendr processing flow, a thresholding process is used to remove segment information that is indistinguishable from noise from the maps.

The thresholding process is based on an estimate of percent vegetative cover. Percent vegetative cover is estimated using statistical models which link photointerpreted percent vegetative cover with NBR. In this process a random sample of pixels is chosen from across a Landsat scene, and at each pixel an analyst visually estimates percent vegetative cover from air photos, based on experience and information from plot data. These photointerpreted estimates of cover are then linked to the pixel values of the NBR index, and a regression is used to estimate the relationship between NBR and percent cover. LARSE applies this percent cover model to the fitted vertex values in a trajectory segmentation. Any segments whose starting and ending vertices were closer in percent cover to each other than the 10% percent cover threshold would be considered "no-change."

Once percent cover estimates are related to the NBR index used for segmentation, filtering is applied differentially to change processes. For segments associated with a change event, the pre-

disturbance cover and the relative magnitude of change are considered in the filtering process. Change segments that began in conditions having too little vegetation are considered noise, as are change segments whose magnitude of cover change is too small. The change-magnitude criterion is adjusted relative to the duration of the change process: short-duration change segments are more likely to be identified through overfitting, and therefore require a greater magnitude of change to be considered meaningful than are segments that persist across many years of data. This threshold can be calculated either directly or relative to the starting cover estimate; for all change filtering tested here, the relative cover change is used.

After the filtering steps described above are completed, LARSE delivers the two primary layers to NCCN (**SOP 1: Acquiring LandTrendr Data and Scenes**). One layer contains an image with pixels containing information about the change of greatest magnitude for the processed time period for the pixel's location. This image consists of bands that identify the onset year of the greatest disturbance, and its magnitude and duration. The second layer contains information about the pixel's spectral trajectory, including the values of three bands of tasseled cap transformation prior, during and after the change. From this point in the protocol forward, NCCN carries out the remaining steps (Figure 3).

Mapping

Filtering to Distinguish Rapid Change (**SOP 2: Filtering LandTrendr Results**)
NCCN uses ArcGIS models to filter the Greatest Disturbance layer based on duration of change. Currently, only Rapid changes are separated. The Rapid layer is filtered to only contain pixels with a change segment of **less than or equal to** four years in duration (Figure 7).

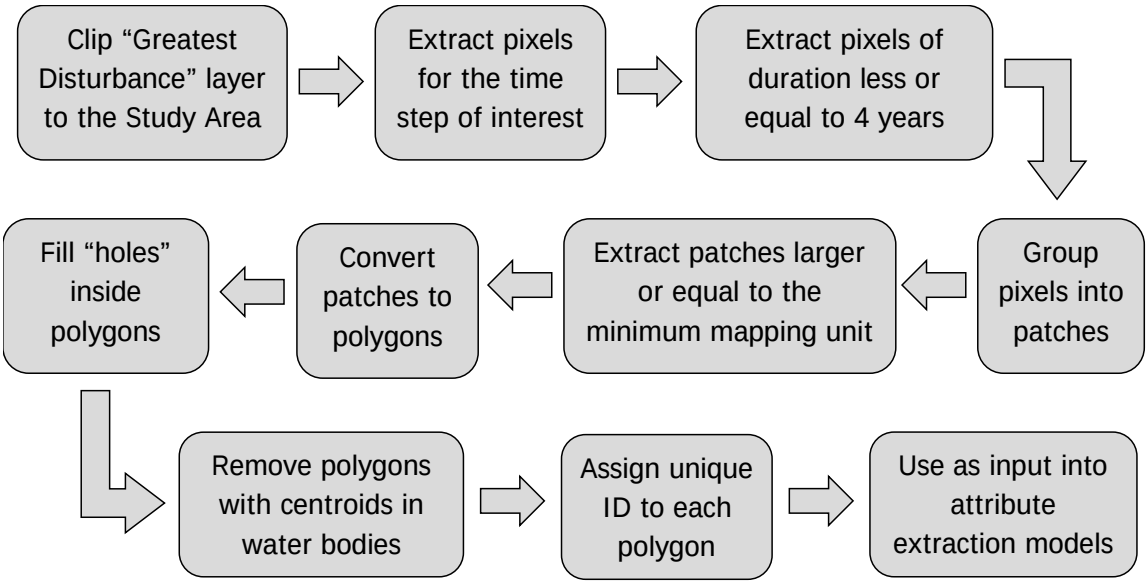


Figure 7. Processing steps to filter Rapid change and create polygons.

Patch Creation
At this point the LandTrendr change detection results are still at the pixel level. The next processing step groups pixels into patches of meaningful change that can be linked to the change types of interest to the NCCN. Although landscape changes are detected at the scale of one pixel,

monitoring change at the one-pixel scale is not feasible. First, monitoring at the finest scale of the Landsat pixels greatly increases the noise in the data. Second, it is much more challenging to validate results at that scale due to the relatively coarse resolution of the aerial photography used for validation. The minimum mapping unit (MMU) is the smallest number of pixels joined together to create a landscape change patch. During the development stage of the protocol, various sizes of the MMU were tested to determine which one would achieve a tolerable balance between detecting enough of the changes of interest and validating the changes detected. A nine-pixel MMU - approximately 0.8 ha (2.5 acres) was selected as the optimal size for the NCCN monitoring.

ArcGIS tools are used to filter change pixels into patches equal or greater to the MMU (Figure 8). For Rapid change, it is assumed that adjacent pixels which have the same year of onset are part of the same landscape change event. Therefore, patches are defined as groups of adjacent pixels, using an 8-neighbor rule, in which the year of change onset is the same for every pixel. The 8 neighbor rule allows all 8 pixels surrounding a target pixel to be evaluated for inclusion in a polygon, rather than just the 4 pixels in the cardinal directions. The final ArcGIS tool used assigns each patch a unique ID and creates a final polygon feature class layer, which is used as input in the subsequent processing steps.

C. Labeling Landscape Change Type

A main objective of this protocol is not only to know the year, location and magnitude of landscape changes, but also to identify and label each change with a type (Table 2). One approach is to manually label each polygon using aerial photography. Manual labeling is currently being used successfully by the Great Lakes Network (Kirschbaum and Gafvert 2010). The 1985 to 2010 results for North Cascades study area provide an estimate of the number of polygons to be processed each year as the protocol is implemented in the future. There are 14,123 total polygons, an average of 550 ± 330 polygons per year. The number of detected polygons varies considerably between inside and outside the park boundary. There are approximately 2,013 polygons found inside the park boundary, resulting in about 81 polygons inside and 484 polygons outside a year, on average, to be labeled.

Because the initial time step in the analysis included 25 years of polygons for multiple parks, manual labeling of the approximately 14,000 polygons per park was not feasible. Instead, a method for automatically labeling the polygons by change type was developed using an ensemble classification algorithm called Random Forests (RF) (Breiman 2001). Applying the RF model gives us the option to speed up the labeling process by classifying the polygons into predetermined categories representing changes of interest to NCCN.

Change Type Model Development

The first step in developing the change type model was to create training data for map classification. Each polygon in the training dataset was attributed with its change type using aerial photography that showed the location prior to and after the onset of change. A separate change type model for each park was developed due to differences in prevailing types and their characteristics. For example, the glacial outflows at MORA are an example of a mass movement that is not found in other parks.

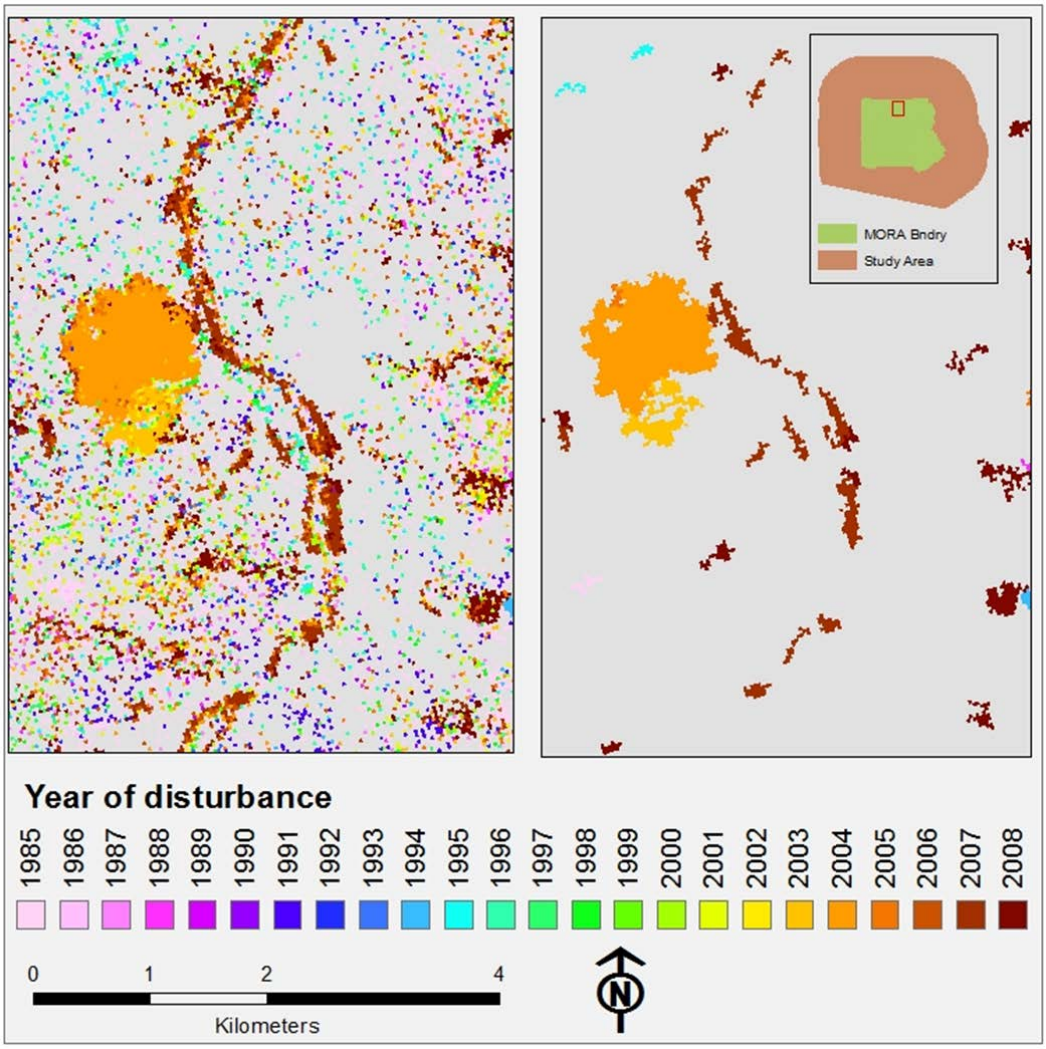


Figure 8. Filtering results reduces noise by generating coherent landscape change patches. The image on the left shows every Rapid change pixel detected by LandTrendr. The pixels have been color-coded by year. The image on the right shows what remains after the filtering program has been run.

Although the change types are not distributed equally among the parks, an equal number of samples in each change category were selected to avoid large error rates for changes that are rare but of high interest to the network. The RF statistical method optimizes the overall model error rate by keeping the error rate low for larger classes and letting the error rate go up for the smaller classes (Breiman 2001). This effect can be reduced by using an equal number of samples in each category and by weighting the sample size of categories for which a larger sample size cannot be found.

The resulting sample distribution for NOCA is shown in Table 4. Because the "Tree Toppling" category of change is rarely found at NOCA, only 11 samples were found in the study area from 1985 to 2010. On the other hand, "Clearing" category is widespread in the study area, including areas inside the park boundary along the power lines and road reroutes in the Stehekin Valley. A

larger sample size is used for this category to adequately model its variability, which is considered to be more important than having an equal sample size.

The "Annual Variability" category was included in the model to accommodate landscape changes that are not the focus of this protocol. These changes are usually found in subalpine areas and are related to changes in snow cover, topographic shadows, and vegetation phenology that were not removed during the image filtering process. The goal is not to monitor annual variability as a change type, but rather to let the RF attribution process remove it from the results.

Table 4. The sample size by type of the NOCA Random Forest training dataset.

Change Type	Sample Size
Annual Variability	45
Agricultural	44
Avalanche	45
Clearing	97
Development	46
Fire	45
Mass Movement	45
Progressive Defoliation	45
Riparian	45
Tree Toppling	11

For each of the attributed polygons in the training dataset, explanatory variables were extracted from Landsat spectral data and auxiliary GIS datasets using a series of ArcGIS™ tools. The extracted variables were appended to the change polygon layer's table. The variables were chosen to capture spectral characteristics of each patch that relate to the state of the landcover prior to and after the change and the magnitude and duration of spectral change, position of the patch on the landscape relative to the valley floor, its proximity to hydrologic features, and its shape.

Table 5 lists all the variables extracted by the ArcGIS™ tools. Thickness, Major Axis, Minor Axis, and Orientation attributes were calculated using the "Zonal Geometry as Table" tool from the Spatial Analyst/Zonal toolbox in ArcGIS™. Largest Area and Compactness attributes were calculated using a method developed by Maceachren (1985). Landscape position variables such as elevation, slope, and aspect were derived using Surface tools in the Spatial Analyst Toolbox. Topographic Convergence Index and Topographic Position Index, two moisture indices, as well as Landform and Slope Position variables, were calculated using Topography Tools for ArcGIS 9.3.1 developed by Thomas Dilts and based on work by Jeff Jenness (Jenness 2006, Dilts 2010). Distance and Direction to Stream attributes were calculated using the Euclidian Distance tool in the Spatial Analyst/Distance toolbox.

The spectral variables associated with different aspects of the Tasseled Cap and NBR indices were extracted from the LandTrendr grid layers provided by LARSE.

Table 5. Variable names and definitions used as input into randomForest.

Variable Name	Type	Definition
Compctnss	Geometric	Compactness of the patch
Paratio	Geometric	Standardized perimeter to area ratio
MajorAxis	Geometric	Length of the major axis of a patch (meters)
MinorAxis	Geometric	Length of the minor axis of a patch (meters)
Orientation	Geometric	Angle between the x-axis and the major axis of the patch
Thickness	Geometric	The radius of the largest circle that can be drawn within a patch (number of pixels)
Aspect	Landscape	Majority aspect class for a patch (Flat, N, NE, etc)
DirStream	Landscape	Majority direction to nearest stream class for a patch (N, NE, etc)
DistStream	Landscape	Distance to nearest stream (meters)
Eastness	Landscape	Mean value of sine transformation of aspect for a patch
IsInside	Landscape	Change patch centroid is inside or outside park boundary
Landform	Landscape	Landform on which patch found (class)
MaxElev	Landscape	Maximum elevation within a change patch (meters)
MaxSlope	Landscape	Maximum slope within a patch (degrees)
MeanElev	Landscape	Mean elevation within a change patch (meters)
MeanSlope	Landscape	Mean slope of a change patch (degrees)
MinElev	Landscape	Minimum elevation within a change patch (meters)
MinSlope	Landscape	Minimum slope within change patch (meters)
Northness	Landscape	Mean value of cosine transformation of aspect for a patch
SPI2000	Landscape	Majority slope position class within a patch (SPI generated using 2000-m radius roaming window)
SPI500	Landscape	Majority slope position class within a patch (SPI generated using 500-m radius roaming window)
stdDistStr	Landscape	Standard deviation of the distance to nearest stream (meters)
TCI_mean	Landscape	Mean Topographic Convergence Index (local wetness) for a patch
TCI_stdev	Landscape	Standard deviation of the Topographic Convergence Index (local wetness) for a patch
TPI2000_mean	Landscape	Mean standardized Topographic Position Index for a patch (TPI generated using 2000-m radius roaming window)
TPI2000_std	Landscape	Standard deviation of the standardized Topographic Position Index for a patch (TPI generated using 2000-m radius roaming window)
TPI500_mean	Landscape	Mean standardized Topographic Position Index for a patch (TPI generated using 500-m radius roaming window)
TPI500_std	Landscape	Standard deviation of the standardized Topographic Position Index for a patch (TPI generated using 500-m radius roaming window)
BrightMag	Spectral	Mean brightness magnitude of change segment
GreenMag	Spectral	Mean greenness magnitude of change segment
Mag	Spectral	Mean magnitude of change segment in terms of percent cover
PostBrightMag	Spectral	Mean change in brightness for segment following change
PostBright	Spectral	Mean brightness value for the vertex just after change
PostGreen	Spectral	Mean greenness value for the vertex just after change
PostGreenMag	Spectral	Mean change in greenness for the segment following change
PostWet	Spectral	Mean wetness value for the vertex just after change
PostWetMag	Spectral	Mean change in wetness for the segment following change
PreBright	Spectral	Mean brightness for the vertex just prior to change
PreGreen	Spectral	Mean greenness for the vertex just prior to change

Table 5. Variable names and definitions used as input into randomForest (continued).

Variable Name	Type	Definition
PreNBR	Spectral	Mean NBR value just prior to change
PreWet	Spectral	Mean wetness for the vertex just prior to change
stdBrightMag	Spectral	Standard deviation (across pixels in a patch) of change in brightness for the change segment
stdGreenMag	Spectral	Standard deviation of change in greenness for the change segment
stdMag	Spectral	Standard deviation (NBR units) of magnitude of change segment
stdPostBrightMag	Spectral	Standard deviation of change in brightness for the segment following change
stdPostBright	Spectral	Standard deviation of brightness for the vertex just after change
stdPostGreenMag	Spectral	Standard deviation of change in greenness for the segment following change
stdPostGreen	Spectral	Standard deviation of greenness for the vertex just after change
stdPostWetMag	Spectral	Standard deviation of change in wetness for the segment following change
stdPostWet	Spectral	Standard deviation of wetness for the vertex just after change
stdPreBright	Spectral	Standard deviation of the brightness value for the vertex just prior to change
stdPreGreen	Spectral	Standard deviation of the greenness value for the vertex just prior to change
stdPreNBR	Spectral	Standard deviation of the Normalized Burn Ratio (NBR) value for the vertex just prior to change
stdPreWet	Spectral	Standard deviation of the wetness value for the vertex just prior to change
stdWetMag	Spectral	Standard deviation of change in wetness for the change segment
WetMag	Spectral	Mean wetness magnitude of change segment
Dur	Time	Mean duration of change segment across all pixels in a patch (years)
stdDur	Time	Standard deviation of duration of change segment (years)
Year1	Time	Year change initiated

Random Forests

Random Forests (RF) (Breiman 2001) is an ensemble classification method that greatly expands the relatively simple concept of classification and regression trees (CART). The RF classification grows many classification or regression trees. It is implemented using the randomForest package (Liaw and Weiner 2002) in R version 2.13.1 (R Development Core Team 2011). The number of bootstrap iterations, which is the number of trees in the forest, is controlled by the operator, and in this case was 5000. To grow each tree, RF first takes a random subset of the training data. As RF grows each tree, it only uses a random subset of two thirds of the predictor variables for each split or node in the tree (Breiman 2001). Random Forests combines the trees into a single prediction- in other words, the tree which occurred with the most frequency, or has the vote majority, represents the best classification model. Strengths of the RF approach include its insensitivity to distributional assumptions and its ability to incorporate complex interactions among independent variables (Breiman 2001, Cutler et al. 2007).

Although RF has strong predictive capabilities, its outputs can be difficult to interpret. Unlike a CART, RF does not provide a rule-set but rather predicts an outcome based on a simple vote majority. RF excels at identifying important independent variables (Evans and Cushman 2009) and provides measures of variable importance.

After attributes were extracted, the Random Forests was run for the training data. The best performing model based on different combinations of variables, overall classification and individual change category classification accuracies was selected. The final model was saved and applied to the change polygons across the whole landscape. **SOP 3: Labeling Landscape**

Change Types includes the R script used to apply the RF classification to the study area as well as a more detailed explanation of the change type labeling process.

D. Validation

Validation is the process of determining how well the change detection method captures and labels change. Underpinning this protocol are two layers of validation. The first layer is overall validation of the LandTrendr method and its ability to detect and map change. This validation has been performed by LARSE (Cohen et al. 2010). The second layer is validation of the change category labels assigned by the randomForest attribution model. Figure 9 depicts both types of validation.

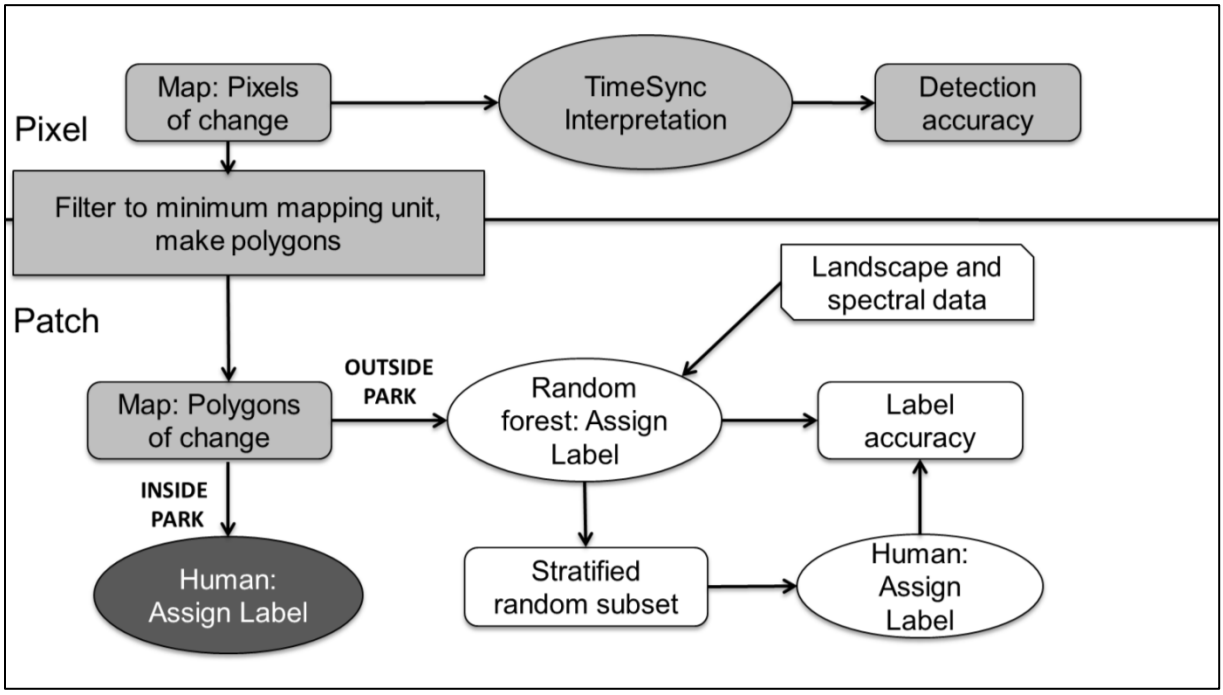


Figure 9. Schematic of the two layers of validation underpinning the protocol. Pixel level results above the line have been validated by LARSE. Patch level results are validated by the NCCN during protocol implementation. Changes inside park boundaries are labeled by hand in the office and validated with field visits. Changes outside park boundaries are labeled by the RF model and validated in the office using a random subset of changes stratified by change type.

LandTrendr Validation

Cohen et al. (2010) present a thorough examination of LandTrendr validation issues. There are two primary challenges with validating a long time series of data: 1) there are three types of LandTrendr outputs that need to be validated, including vertices (years), intensity and duration; and 2) reference datasets (e.g. plot data or aerial photographs) with matching variables are extremely rare. Because comparison with field or aerial photo data is virtually impossible, validation relies on comparing automated vs. human interpretation of change using Landsat images.

LARSE has developed an application called TimeSync to aid the human interpretation aspect of the validation process. TimeSync facilitates visualization of the time series of Landsat images

and validation data collection. The TimeSync application consists of four components: an image chip window, a trajectory window, Google Earth (http://earth.google.com/), and a Microsoft® Access database. The Access database is populated with coordinates for locations that need to be validated. TimeSync displays each location at the same time as the entire stack of corresponding image chips. TimeSync also displays the spectral trajectory (using NBR or Wetness spectral index) of a user-defined set of pixels around the central pixel in each image chip (Figure 4). By providing the interpreter with both spatial and temporal depth, detection of subtle events is vastly improved relative to single- or two-date interpretation, and ephemeral non-informative changes are easily ignored.

Cohen et al. (2010) used TimeSync to validate LandTrendr results over forested areas in Oregon and Washington. In this validation exercise, interpreters compared trajectories they created by hand using the time series with trajectories that LandTrendr generated. They compared the dates of change initiation, number of segments, and whether or not the change was a disturbance or recovery. Disagreements in the form of false positives (detecting a change when none occurred-commission) and false negatives (change occurred but was not detected-omission) were also evaluated.

When compared to manual change detection using TimeSync using the NBR index, LandTrendr had a slight tendency toward omission, with rates of omission varying with intensity of change. Intensity is defined as the percent cover loss relative to the pixel's starting cover value. In contrast, LandTrendr, when using the same NBR index, overestimated the number of recovery and stable segments relative to TimeSync. LandTrendr omitted 10% of all high intensity (76-100 % cover loss) TimeSync-identified changes. Omission rates increased to 22% for medium (36-75 % cover loss) and 56% for low intensity (1-35 % cover loss) changes. The assumption is that the error rates for NCCN use of LandTrendr are comparable.

Change Type Validation

The second layer of validation assesses how accurately the RF model classifies change types. The RF-generated error matrix that is produced by the statistical package during the model development stage was used as one assessment of the labeling accuracy (Table 6). Field validation was also performed on a larger sample of changes. Areas of the park were selected for accessibility and variety of polygon types. Hand held GPS with pre-loaded polygon boundaries were used to navigate to individual landscape change event. Landscape change type was assigned to the polygon based on field observation of land cover inside the polygon and consideration of its position on the landscape. The RF classification results were better than the results generated by the field validation exercise.

Table 6. Accuracy assessment matrix for RF-derived labels for NOCA training polygons used in model generation.

ACTUAL/PREDICTED	Agriculture	Annual Variability	Avalanche	Clearing	Development	Fire	Tree Toppling	Progressive Defoliation	Mass Movement	Riparian	Error
Agricultural	**38**	0	0	0	5	0	0	0	0	1	0.136
Annual Variability	0	**42**	2	0	0	0	1	1	0	0	0.087
Avalanche	0	1	**31**	5	0	0	0	2	6	0	0.311
Clearing	0	1	1	**90**	3	1	0	0	0	1	0.072
Development	2	0	0	6	**38**	0	0	0	0	0	0.174
Fire	0	0	1	0	0	**43**	0	0	1	0	0.044
Tree Toppling	0	0	2	0	0	0	**7**	2	0	0	0.364
Progressive Defoliation	0	0	1	1	0	0	0	**43**	0	0	0.044
Mass Movement	0	1	6	1	0	0	0	1	**33**	3	0.267
Riparian	1	0	1	1	1	0	0	0	6	**35**	0.222

Field validation proved to be problematic, because this protocol involves assessment of large areas inside and outside park boundaries and because landscape change events occurred in areas that were difficult to access. Due to these considerations, changes were also evaluated in the office using aerial photography in Google Earth in conjunction with the TimeSync application. This approach had advantages over field validation because it allowed assessment of the change's spectral characteristics alongside visual evaluation. Older changes could also be identified using a time series of aerial photos accessible through Google Earth's "time" toolbar. Landscape change polygons were assessed in the GIS lab using software and techniques described above. A random subset of change polygons from NOCA, which added up to approximately 10% of polygons found inside and 20% of polygons found outside the park boundary was assessed. Each polygon was assigned a change type label that corresponded to one of the natural or anthropogenic processes of interest to NCCN or to factors included under the "Annual Variability" label. The GIS-lab labels were compared to the labels generated by the RF model.

To summarize, the combination of aerial photos and TimeSync had its advantages over field validation because: 1) it provided different perspectives, both visual and spectral of the landscape change polygons, 2) it allowed viewing of the entire polygon in all cases, 3) older changes could be viewed on their corresponding older aerial photos, and 4) there was no doubt about the location and boundaries of the change polygons, which was not the case on the ground due to irregular polygon shapes combined with typical GPS position error. The "Unknown" label was used less frequently in the lab compared to the field. Based on this experience, a combination of office and field validation was chosen for this protocol. Because the entire landscape change polygon could be viewed using an aerial photo, a polygon-based accuracy assessment approach, rather than the minimum mapping unit-based approach recommended by the NPS accuracy assessment guidelines (Lea and Curtis 2010), was chosen as the preferred approach.

E. Summary of Change Type Labeling and Validation Methods

In the future, new annual data will be created for each park every three years (see section **3.C: Recommended Reporting Schedule**), significantly reducing the number of landscape change events to be analyzed in each year. The assignment of change type labels will proceed in the following manner:

1. Run the RF change type labeling model for the areas outside of park boundary.

2. Manually assign a change type to every polygon inside the park boundary using aerial photography and TimeSync application.

3. Field-validate a random subset of landscape change events inside the park boundary.

This approach will provide higher confidence in the change type labeling inside the parks, which is of the most interest to NCCN park management.

For the first three years of each park's analysis, a validation study for areas outside the park boundary will be implemented. Outside the park boundary, within each landscape change category, we will manually assign a change type to 30 randomly chosen polygons (Lea and Curtis 2010). When NOCA change polygons were validated during the protocol development, it was determined that some landscape changes can be represented by multiple polygons. This is especially true for narrow, long landscape change events such as avalanches and debris flows. In order to avoid validating the same landscape change event multiple times, within each change category, we will generate an oversample of additional 10 polygons. If, during the validation of the first 30 samples, two or more of polygons come from the same event, only one sample representing the event will be retained and additional samples will be drawn from the oversample. If fewer than 30 polygons are labeled by the RF model for a particular change type, all instances of this change type will be validated using the aerial photography method. Validation results will be summarized in a confusion matrix (**SOP 4: Office Validation**). Once the error rate stabilizes, the validation for areas outside the park boundaries will no longer be performed.

The entire set of change polygons within the park boundary will be validated in the office. Additional field validation will occur for a random subset of polygons. The field validation will be performed by the Landscape Dynamics field crew (GIS Specialist and an intern) with additional help from the network field staff. The number of polygons selected for field validation from each change category will depend on the types of changes that occurred during the analysis time window and the location of the polygons. All polygons within change categories with fewer than five instances will be field-validated. A random subset consisting of a minimum of five polygons and a maximum of 10% of available polygons in each remaining category, except Fire, will be field-validated. Fire is omitted because the parks will likely have field documentation of any fire greater than the MMU which occurs within park boundaries. This information will be used in lieu of a separate field visit. For the categories with more than five instances, the pool of polygons available for random selection will first be restricted to those within 0.5 km of a trail or a road. Second, all selected polygons will be assessed using GIS for accessibility. Any polygons located on or requiring travel across terrain steeper than 35 degrees or that require crossing of a large stream will be removed from the sample. If required, additional samples will be generated

and assessed for accessibility to replace discarded samples. The field validation results for randomly selected polygons will be compared to the office validation results and summarized in a confusion matrix. The field validation procedures are described in (**SOP 5: Field Validation**).

In addition to the randomly selected samples, there will likely be other polygons that could be opportunistically validated in the field. Once the field itineraries are established, the crew will determine if there are any additional polygons that could be validated while en route to the randomly selected polygons. Special preference will be given to any change polygons that could potentially represent an error after office validation. NPS staff and visitors also frequently report and document landscape changes. For example, the major storm events at MORA in 2006 and OLYM in 2007 created a wealth of photos and data for specific landscape change events that were linked to change polygons generated by the LandTrendr. All these observations will be used in combination with the targeted field validation to increase the robustness of the office accuracy assessment methods. The combination of the office and field validation described above, that include both randomly selected and incidental observations, will give the network the best possible attributed dataset.

3. Data Analysis, Reporting and Information Management

This section describes the procedures for data analysis, reporting and management. Data will be summarized as tables, graphs and maps. Additional details and context for the data management section of this chapter are provided in the NCCN Data Management Plan (Boetsch et al. 2009), which describes the overall information management strategy for the network. The NCCN website (http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) contains guidance documents on various information management topics (e.g., report development, GIS development).

A. Recommended Reporting Schedule

A schedule for analysis and reporting that creates an achievable and steady workflow for the NCCN GIS Specialist and for LARSE staff was developed. The schedule is tied to the timing of freely available aerial photography produced by the National Agricultural Imagery Program (NAIP). In order to perform validation in the office, high resolution, frequent aerial photography is needed for the areas of interest. NAIP is committed to providing 1-meter resolution true color digital orthophotography for the entire United States every three years. In Washington State the schedule has been 2006, 2009 and 2011.

During the first three years of protocol implementation, the time series from 1985 to the present will be analyzed and reported on. Starting in 2014 one to three parks per year will be analyzed. The reporting for any given park will occur every three years.

B. Data Analysis: Status and Trends

This section describes and provides examples of the types of data summaries which will be generated every three years for each park in the NCCN. The goal of these standard summaries and maps is to provide enough information to park natural resource managers to quickly view and interpret landscape changes occurring inside the analysis area as well as develop future research questions. Maps will provide general overviews of landscape changes for the entire area of analysis by year, magnitude or change type. General overview maps for each of the study areas will be complemented by maps of individual areas or watersheds. Examples of tables and maps can be viewed in **Appendix B: Example Report Format Template**.

Metrics for Status

In each reporting cycle, the location and magnitude of changes that have occurred during the three previous years will be documented. This provides resource managers a snapshot of current changes by which they can evaluate whether particular areas of the park are being affected.

Three metrics will be tracked for each year:

1. Total area affected by change
2. Number of change events
3. Top 10 changes (rank by a combined score of area and magnitude)

Table 7. NCCN reporting schedule overview.

Dates of analysis	Year																	
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
	NAIP		NAIP			NAIP			NAIP			NAIP			NAIP			NAIP
1985-2009				NOCA														
1985-2010					MORA, OLYM													
1985-2011						LEWI, SAJH, EBLA												
2010-2012							NOCA, MORA											
2011-2013								OLYM										
2012-2014									LEWI, SAJH, EBLA									
2013-2015										NOCA, MORA								
2014-2016											OLYM							
2015-2017												LEWI, SAJH, EBLA						
2016-2018													NOCA, MORA					
2017-2019														OLYM				
2018-2020															LEWI, SAJH, EBLA			
2019-2021+10 yr report																NOCA, MORA		
2020-2022 +10 yr report																	OLYM	
2021-2023 +10 yr report																		LEWI, SAJH, EBLA

Each of these will be summarized across gradients including:

1. Inside vs. outside the park
2. Change type
3. Elevation
4. Vegetation type (when new vegetation maps are available)

The smallest area that can be detected is defined by the minimum mapping unit of analysis (0.8 ha or 2 acres). Therefore, smaller-area changes will not be included in these overall summaries.

Reporting Uncertainty

There are two sources of potential error in the labeled change polygons that will be reported under this protocol: pixel-level detection errors and patch-level labeling errors.

At the pixel scale, the change maps derived from LandTrendr have errors of omission (real changes that were missed in the map) and commission (stable areas falsely mapped as changed). Errors of omission and commission can be estimated by randomly distributing validation samples and using TimeSync to validate whether the algorithm captured a real or false change as demonstrated by the LandTrendr developed for landscapes in Washington and Oregon by LARSE (Cohen et al. 2010). Results of the validation are shown in Table 8. These error rates can be expressed as ratios relative to the mapped area to put estimated sideboards on the areas missed (by intensity category) or falsely included.

Table 8. LandTrendr (NBR) omission by intensity and commission rates as assessed using TimeSync validation tool for the Pacific Northwest region (Cohen et al. 2010).

LandTrendr (NBR)		
Intensity	**Error of omission**	**Error of commission**
Low (0-35% cover removed)	0.56	
Medium (35-65% cover removed)	0.22	0.13
High (65-100% cover removed)	0.10	

Labeling error structure at the polygon level is slightly more complex. Inside the parks, where all polygons will be directly validated, algorithm error will not be an issue. For the polygons outside the park that are not directly validated, however, the Random Forest prediction likely will have errors, with some polygons mislabeled as belonging to other classes. These mismatches will be captured in the error matrix derived from polygon-level validation of the Random Forest model predictions, and can be used to provide sideboards on the primary landscape change rates reported by category as follows. The primary estimate of the number of polygons for each class will simply be those values reported in the map. Estimates of lower and upper bounds on that estimate will be inferred from the error matrix, where predicted labels (from the algorithm) are tallied against actual labels (from the interpreters). For a given class, the proportion of predicted labels that are from a different actual class represents the algorithm's tendency to over-predict that class; this proportion will be used to downscale the primary estimate to provide a likely lower-bound on that class. Conversely, the proportion of actual labels in that class that were predicted as belonging to other classes represents the algorithm's tendency to under-predict that class; this proportion will be used to upscale the primary estimate to provide a likely upper-

bound on the class. Because these maps are census-based, the upper and lower bounds cannot be considered standard errors in the sense appropriate for sample-based estimates. They are likely to represent a conservative estimate of error for each class label, and will provide a straightforward means of judging which class labels are robust and which are more uncertain.

Separately, the error matrix from the polygon-level validation will be used to report the overall labeling error and the *Kappa* statistic. The *Kappa* statistic is a quantitative assessment of the error matrix, which measures the difference between the observed agreement between the two maps (modeled vs. interpreted) and the agreement that might be contributed solely by chance matching of the two maps. **SOP 4: Office Validation** describes steps for generating the error matrix and associated statistics.

Methods for Long-Term Trend Analysis

Where the triennial reporting schedule above provides a view of recent landscape changes, it does not provide a means to assess trends and drivers of change. Those must be determined through long-term analysis. Such long-term analysis is facilitated by the use of a time series of consistent data that goes back to 1985 in this protocol. An analysis of trends from 1985 to the present will be first conducted when the protocol starts in 2012, followed by another one in 2019. In each long-term analysis, the core questions are:

- Has the total area disturbed per year in the study areas significantly increased, decreased or stayed the same over time?

- Has the number, average size or distribution of the change types changed significantly over time?

Analysis will use generalized least square regression and other statistical techniques (to be tested), that will take into account the impacts of serial autocorrelation in the change rates. Because they are driven by stochastic phenomena, landscape change processes are anticipated to vary substantially from year-to-year for the relatively small areas represented by each park. This variation could make trend analysis at the yearly time-step challenging. Therefore, standard moving- and fixed-window averaging techniques will be explored.

Weather events or patterns are likely to exert strong control over many natural types of landscape change, including flood-related riparian changes, avalanches, windthrow, and fire. These weather events vary annually and will likely change in response to broader climate oscillations such as El Nino Southern Oscillation and Pacific Decadal Oscillation. Thus, in addition to evaluating trends spanning the entire record, residuals from those trends will be assessed to determine if they provide information on weather-related drivers of landscape change. This will involve addressing the following core question:

- Which years in the time series have above or below average area, numbers or intensity of landscape changes?

For the years with above average number or area of landscape changes, weather patterns in those years will be evaluated as possible causal agents. Snow depth and seasonal extent, temperature maximum and minimum values, as well as mean precipitation and deviation from mean will all

be assessed, incorporating data from the NCCN Climate Monitoring Protocol (Lofgren et al. 2010). Different landscape changes are likely to result from different weather conditions (Mantua et al. 2010, Mote and Salathé 2010).

It is likely that changes associated with Development and Clearing categories respond to non-environmental forcing, such as the price of wood or population growth. Therefore they would be excluded from this analysis, although it might be interesting to relate them to economic or policy variables.

C. Data Reporting

The annual status and periodic trend reports will be published in the NPS Natural Resource Report series. The NCCN Annual Accomplishment Report and associated data tables is another primary outlet for reporting results from this protocol.

Report Format with Examples of Summary Tables and Figures

Annual reports and trend analysis reports will use the NPS Natural Resource Publications template, a pre-formatted Microsoft Word template document based on current NPS formatting standards (http://www.nature.nps.gov/publications/NRPM/index.cfm). Annual reports will be produced using the Natural Resource Technical Report (NRTR) series template. Each "annual" report will present monitoring results from 1-3 parks and cover a three year period (Table 6). The sections of the report will include Introduction, Methods, Results and Summary/Conclusions. **Appendix B: Example Report Format Template** provides a sample report template populated with examples of the summary tables and figures derived from NOCA data from 2007-2009 in order to mimic the anticipated three year time step.

Resource Condition Summary Tables

The "connect the dots" table is one of the main reporting metrics for the NCCN each year. The following table outlines the data generated by this protocol, which will be listed in the table for a given park. It is important to note that for the purposes of NCCN Vital Sign reporting, which occurs in October of each year, new results will not be reported for each park in each year. Following implementation of the protocol, the measures listed in Table 9 will be reported. The reference conditions will be calculated for each park during the first report, generating reference data from 1985 to 2009. Conditions for portions of the study area outside the park will be calculated for a 5 year time period based on the assumption that outside the park landscape change is driven by economic rather than environmental factors.

Table 9. Example of Natural Resource Condition Summary Table for NOCA.

Priority Resource or Value (Vital Sign)	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source
Landscape Dynamics	Total area affected by high intensity, rapid landscape change (ha)	Inside park boundary in 2009		Total area in 2009 is within 1 standard deviation of the 1985-2009 average[1]	Average of 249.64 ± 243.6 ha calculated from the LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by high intensity, rapid landscape change (ha)	Outside park boundary in 2009		Area in 2009 below the 2005-2009 average[1]	Average of 2296.96 ± 1045.1 ha calculated from the LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Avalanches	Inside park boundary in 2009		Area in 2009 is more than 2 standard deviations greater than the 1985-2009 average[1]	Average of 23.17 ± 42.78 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Fire	Inside park boundary in 2009		Area in 2009 below the 1985-2009 average[1]	Average of 158.09 ± 206.87 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Mass Movements	Inside park boundary in 2009		Area in 2009 below the 1985-2009 average[1]	Average of 10.83 ± 27.06 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by rapid Progressive Defoliation	Inside park boundary in 2009		Area in 2009 below the 1985-2009 average[1]	Average of 42.15 ± 76.4 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Riparian changes	Inside park boundary in 2009		Area in 2009 below the 1985-2009 average[1]	Average of 3.17 ± 9.64 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Tree Toppling	Inside park boundary in 2009		Area in 2009 below the 1985-2009 average[1]	Average of 1.06 ± 2.49 ha calculated from LandTrendr 1985-2009 image stack[1]
Landscape Dynamics	Total area affected by Development	Outside park boundary in 2009		Area in 2009 below the latest 5-year average (2005-2009)[1]	Estimated average of 120.6 ± 48.9 ha calculated from LandTrendr 2005-2009 image stack [1]
Landscape Dynamics	Total area affected by Clearing	Outside park boundary in 2009		Area in 2009 below the latest 5-year average (2005-2009)[1]	Estimated average of 542.1 ± 255.0 ha calculated from LandTrendr 2005-2009 image stack[1]

References: [1] Antonova, N., C. Copass, and S. Clary. In development. Landsat-based Monitoring of Landscape Dynamics in North Cascades National Park: 1985-2009. Natural Resource Report NPS/20XX/NRR—20XX/XXX. National Park Service, Fort Collins, Colorado.

D. Project Information Management Overview

Project information management may be best understood as an ongoing or cyclic process. Specific yearly information management tasks for this project and their timing are described in **Appendix C: Yearly Project Task List**. Readers may also refer to each respective chapter section for additional guidance and instructions.

The stages of this cycle are described in greater depth in later sections of this chapter, but can be briefly summarized as follows:

- *Preparation* – Coordination with LARSE for upcoming annual cycle
- *Data acquisition* – Delivery of LandTrendr results from LARSE
- *Data processing* – Polygon filtering, attribution, labeling, and validation
- *Quality review* – Data are reviewed for structural integrity, completeness and logical consistency
- *Metadata* – Documentation of the year's data and results of the quality review
- *Data certification* – Data are certified as complete for the period of record
- *Data delivery* – Certified data and metadata are delivered for archiving
- *Data analysis* – Data are summarized and analyzed
- *Product development* – Reports, maps, and other information delivery products are developed
- *Product delivery* – Deliver reports and other products for posting and archiving
- *Posting & distribution* – Distribute products as planned and/or post to NPS clearinghouses
- *Archiving & records management* – Review analog and digital files for retention (or destruction) according to NPS Director's Order 19. Retained files are renamed and stored as needed
- *Annual close-out* – Review and document needed improvements to project procedures or infrastructure, complete administrative reports, and develop work plans for the coming year

Project Workspace Setup

A section of the networked file server is reserved for this project, and access privileges are established so that project staff members have access to needed files within this workspace. In addition to workspace on the network file server, the GIS Specialist's workstation will serve as a repository for intermediate GIS products and Landsat and LandTrendr imagery. Workspace structure, naming conventions, and additional details are provided in **SOP 6: Project Workspace and Records Management**.

E. Overview of Database Design

Two relational databases are maintained by this project. The Data Manager is responsible for the development and maintenance of a customized relational database, which maintains a list of landscape change polygons identified by the project with their associated attributes and information about validation results. A separate ArcGIS™ file geodatabase contains landscape change polygons with limited attributes retained for mapping and report purposes. The GIS Specialist is responsible for development and maintenance of the project geodatabase.

The design of both databases is consistent with NPS I&M and NCCN standards. The database schemas are documented in **Appendix D: NCCN Landscape Dynamics Protocol Database Documentation**. The tabular database is divided into two components: one for storing data in a series of related tables composed of fields and records (i.e., the "back-end database"), and a second that acts as a portal or user interface through which data may be entered, viewed, edited, error-checked, summarized and exported (i.e., the "front-end application"). By splitting the database into front-and back-end components, multiple users may interact with the data simultaneously, and user interface updates can be implemented without service disruptions. The back-end database is implemented in Microsoft SQL Server to take advantage of the automated backup and transaction logging capabilities of this enterprise database software. The front-end application is implemented in Microsoft Access™. It contains the forms, queries, and formatted report objects for interacting with the data in the back-end. Its features and functionality are customized using Visual Basic for Applications (VBA) programming code. The application has separate forms for data entry, browsing and editing data, for completing the annual quality review, and for summarizing and exporting data to other software (e.g., for analysis and graphics production). The database resides on a network server that is backed up regularly to an off-site location.

F. Management of Reference Data

Two categories of reference data are maintained by this project. The first category includes layers delivered to NCCN by LARSE. Because of the size of the image data files, this category of data set will be maintained on the GIS Specialist's workstation. The workstation was specifically purchased for this project and includes sufficient storage space to accommodate multiple years of imagery and Redundant Array of Independent Disks (RAID) technology to increase storage reliability. Table 10 lists several types of images provided by LARSE for each scene and their purpose.

The second category includes base GIS data for each park that are used in the filtering and attribute extraction models. These data are located in an ArcGIS™ file geodatabase and stored on the GIS Specialist's workstation. A second copy of the file geodatabase will reside on the network file server at OLYM that is backed up regularly to an off-site file server at MORA. Refer to Table 2.1 for a list of raster datasets included in this geodatabase. In addition to raster data, the geodatabase includes vector layers depicting park boundary, study area boundary and water bodies within the study area.

Table 10. Types and sizes of images and LandTrendr data from LARSE.

Image type	Number and Size of Data Layers[1]	Description
Yearly image data	Six layers reflected, one or two layers thermal, for one or more images per year (~850 MB/image)	MADCAL-normalized Landsat images for each year used in TimeSync
Yearly Tasseled-cap data	Three layers, for one or more images per year (~400 MB/image)	MADCAL-normalized Landsat images for each year transformed to tasseled-cap brightness, greenness and wetness used in TimeSync
Source NBR stack	One layer per year, from 1985 to current	Time-series stack of NBR-calculated values based on MADCAL-normalized values
Fitted NBR stack	One layer per year, from 1985 to current	Time-series stack of NBR-values after LandTrendr segmentation
Greatest Disturbance	Eight layers (~900MB)	Derived landscape change map layer with information on timing and magnitude of change in units of cover and NBR – used in filtering and attribute extraction
Greatest Disturbance, pre-change tasseled-cap values	Twelve layers (~1.4 GB)	Tasseled-cap values for pre- and post-change segments and vertices - used in attribute extraction

[1] The size of each file is a function of the number of layers and the size of each layer; the size of each layer depends on study area of each park, but can be as large as 80 Mb for an entire scene footprint.

G. Data Processing

The LandTrendr results, in the form of raster layers, and park base layers are the primary inputs into the data processing workflow. Subsequent processing steps create interim products as the results are passed from one processing or filtering step to the next. A naming convention for each of these interim products will be developed. See SOP 2 through 5 for details on how these products are generated.

Lastly, the final labeled LandTrendr polygons are used to generate maps and data summaries as used in the reports. Data summaries for the reports will be generated using validated data contained in the project database. Maps will be generated using park landscape change polygons located in the master geodatabase for the project, which will be updated following each analysis time step. The GIS Specialist will use queries within the feature class containing the landscape change polygons to isolate polygons of interest and symbolize them to fit the purpose of the map.

H. Regular Data Backups

Automatic database backups are scheduled in the SQL Server database management system to help prevent data loss in case of user error, drive failure, or database file corruption. Full backups are scheduled on a weekly basis, with daily transactional backups to enable restore operations to a point in time within a moving eight-week window. Weekly backups and transaction files are retained for eight weeks to conserve drive space. Full monthly backups are stored for at least one year after data have been certified. Snapshot backup copies of certified data, made at the time of certification, are retained indefinitely.

Reference image data will be stored on a drive with RAID capabilities. A copy of the image data will also be maintained by LARSE. Final GIS products will be copied to the network server that is subject to regular backups.

I. Data Entry

Data Entry During Office Validation

During the office validation, data will be entered directly into the project database application, found in the project workspace. The front-end can be considered "disposable" because it does not contain any data, but rather acts as a pointer to the data that reside in the back-end working database. Whenever updates to the front-end application are made available by the Data Manager, an updated front-end database should be copied from the project workspace to the workstation hard drive.

The data entry forms in the front-end application will be patterned to follow the steps of validation process, including identification of the landscape change category, determination of certainty and alternative categories. Built-in quality assurance components, such as pick lists and validation rules to test for missing data or illogical combinations, will be included in the forms. A number of fields related to the timing and the identity of person entering the data will be recorded automatically by the database based on login information.

Data Entry from Field Forms

Following validation in the field, data recorded on field form shown in Figure 5.1 will be entered into the front-end project database application using a data entry form patterned after the field form. Occasionally, the Project Lead or the GIS Specialist will receive field forms from other network and park employees who will have documented landscape changes while working on other projects. These will be entered into the project database in a similar manner.

J. Data Verification

As data are being entered, the person doing the data entry should visually review them to make sure that the data on screen match the field forms. This should be done for each record prior to moving to the next form for data entry. At regular intervals the GIS Specialist should inspect the data being entered to check for completeness and perhaps identify avoidable errors. The GIS Specialist may also periodically run the quality assurance tools that are built into the front-end database application to check for logical inconsistencies and data outliers (this step is described in greater detail in **Section K, Data Quality Review** and also in **SOP 7: Data Quality Review and Certification**).

K. Data Quality Review

After the data have been entered and processed, they need to be reviewed for structural integrity, completeness and logical consistency. The front-end database application facilitates this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The GIS Specialist may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed, in which case a description of the resulting errors and why edits were not made is documented and included in the metadata and certification report.

Data Edits After Certification

It is not efficient to log all changes in the database until after data are reviewed and certified. Prior to certification, daily backups of the database provide a crude means of restoring data to the previous day's state. After certification, all edits to certified records are tracked in an edit log

(refer to **Appendix D: NCCN Landscape Dynamics Monitoring Protocol Database Documentation**) so that future data users will be aware of changes made after certification. In case future users need to restore data to the certified version, a separate, read-only copy of the original, certified data for each year in the project workspace is retained.

L. Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, condition and other characteristics of a given data set. Additionally, metadata provide the means to catalog and search among data sets, thus making them available to a broad range of potential data users. Metadata for all NCCN monitoring data will conform to Federal Geographic Data Committee (FGDC) guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

At the conclusion of the annual analysis (according to the schedule in **Appendix C: Yearly Project Task List**), the Project Lead will be responsible for providing a completed, up-to-date metadata interview form to the GIS Specialist. The GIS Specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses.

An up-to-date metadata record is a required deliverable that should accompany each year's certified data. For long-term projects such as this one, metadata creation is most time consuming the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect changes in contact information and taxonomic conventions, to include recent publications, to update data disposition and quality descriptions, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for creating, parsing and posting the metadata record are provided in NCCN Metadata Development Guidelines (North Coast and Cascades Network—National Park Service, 2007). General procedures are as follows:

1. After the annual data quality review has been performed and the data are ready for certification, the Project Lead (or a designee) updates the metadata interview form.
    a. The metadata interview form greatly facilitates metadata creation by structuring the required information into a logical arrangement of 15 primary questions, many with additional sub-questions.
    b. The first year, a new copy of the NCCN Metadata Interview form (available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm) should be downloaded. Otherwise the form from the previous year can be used as a starting point, in which case the Track Changes tool in Microsoft Word should be activated in order to make edits obvious to the person who will be updating the XML record.

   c. Complete the metadata interview form and maintain it in the project workspace. Much of the interview form can be filled out by cutting and pasting material from other documents (e.g., reports, protocol narrative sections, and SOPs).
   d. The Data Manager can help answer questions about the metadata interview form.
2. Deliver the completed interview form to the GIS Specialist according to the product delivery instructions in **SOP 8: Product Delivery, Posting and Distribution**.
3. The GIS Specialist will then extract the information from the interview form and use it to create and update an FGDC- and NPS-compliant metadata record in XML format. Specific guidance for creating the XML record is contained in NCCN Metadata Development Guidelines (North Coast and Cascades Network—National Park Service, 2007).
4. The GIS Specialist will post the record and certified data to the NPS IRMA portal, and maintain a local copy of the XML file for subsequent updates. The Project Lead should update the metadata interview content as changes to the protocol are made, and each year as additional data are accumulated.

M. Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that: 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks (**Section K, Data Quality Review**); and 3) they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is the primary person responsible for completing an NCCN Project Data Certification Form, available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form should be submitted with the certified data according to the timeline in **Appendix C: Yearly Project Task List**. Refer to **SOP 7: Data Quality Review and Certification** and the delivery specifications in **SOP 8: Product Delivery, Posting and Distribution** for specific instructions.

N. Archiving and Records Management

All project files should be reviewed and organized by the Project Lead on a regular basis (e.g., annually in December). Unneeded draft documents and other intermediate files should be deleted to conserve space and maintain a clear and unambiguous record for future project staff. See **SOP 6: Project Workspace and Records Management** for more details. Decisions on what to retain and what to destroy should be made following guidelines stipulated in NPS Director's Order 19 (available at: http://data2.itc.nps.gov/npspolicy/DOrders.cfm), which provides a schedule indicating the amount of time that the various kinds of records should be retained.

Because this is a long-term monitoring project, good records management practices are critical for ensuring the continuity of project information. Files will be more useful to others if they are well organized, well named, and stored in a common format. Details for handling project files are described in **SOP 6: Project Workspace and Records Management**.

O. Annual Close-out

After the conclusion of the annual analysis cycle, the Project Lead, Data Manager and GIS Specialist should meet to discuss the analysis cycle, to document any needed changes to the SOPs or protocol sections, or to the database structure or front-end application.

4. Personnel and Operational Requirements

A. Personnel Requirements

Implementation of this protocol involves a wide range of skills including: remote-sensing interpretation, image processing, use and manipulation of spatial data, data analysis, and data reporting. The level of detail needed for image processing requires that personnel have significant understanding of remote sensing. In addition, a high level of ArcGIS™ skill is needed for analyzing and displaying spatial results. Roles and responsibilities to implement this protocol are shown in Table 11.

Table 11. Roles and responsibilities for Landscape Dynamics Monitoring in NCCN.

Role	Responsibilities
Project Lead	• Project administration, operations, and implementation • Track project objectives, budget, requirements, and progress toward meeting objectives • Coordinate and ratify changes to protocol • Ensure project compliance with park requirements • Maintain and archive project records • Certify each season's data for quality and completeness • Complete reports, metadata, and other products according to schedule
GIS Specialist	• Collect, record, enter and verify data, including field data • Perform data summaries and analysis, assist interpretation and report preparation • Develop and analyze spatial data and generate map output • Develop metadata for spatial data products • Primary steward of GIS data and products • Facilitate check-in, review and posting of data, metadata, reports, and other products to national databases and clearinghouses according to schedule
Intern	• Help prepare for field validation • Collect and enter field data
Data Manager	• Consult on data management activities • Maintain and update database application • Provide database training as needed
Network Program Manager	• Review annual reports for completeness and compliance with I&M standards and expectations
Park Curator	• Receive and archive copies of biennial reports, analysis reports, and other publications • Facilitate archiving of other project records (e.g., original field forms, etc.)
LARSE liaisons	• Consultant on technical issues related to project sampling design, statistical analysis, or other issues related to changes in protocol and SOPs

Implementation will be more efficient if one GIS specialist takes primary responsibility for technical processing of all imagery and for the interpretation and validation work. Because the interpretation of change signals requires an understanding of a variety of land-surface processes, network ecologists, geomorphologists and other specialists should be involved in the interpretation process at early stages.

B. Operational Requirements

Protocol implementation will be carried out by LARSE and NPS staff. LARSE will be responsible for processing Landsat images and running LandTrendr. LARSE has the computer hardware and associated processing software that NPS lacks to implement this protocol.

Annual Workload and Schedule

A scheduling timetable which outlines the workflow for the foreseeable duration of the program is shown in section **3.A: Recommended Reporting Schedule**, Table 7. The timing of the workflow is linked to extrinsic products. The first product is the NAIP aerial photography which is available for free and is essential for validation. Validation can only occur up to the year for which the NAIP aerial photography exists. The other inputs needed to begin each year's analysis are the processed Landsat TM/ETM+ imagery and LandTrendr results for each study area under analysis. Therefore, a typical annual schedule will include first getting the processed imagery and LandTrendr results from LARSE. Once imagery and results are in hand by the end of December, NPS processing and change type modeling occurs in late winter and early spring. Office and field validation occurs in spring and during the summer season, followed by analysis and report writing in the fall and early winter.

Facility and Equipment Needs

The primary hardware or facility requirement of this protocol is computational power and information storage. The GIS Specialist will need an up-to-date workstation with adequate storage and RAID capabilities for storing images and LandTrendr outputs and an active ArcGIS™ license. Periodic investment in server space may need to be made.

C. Costs and Budget Considerations

The main cost to implement this protocol is personnel expenses, primarily to support the GIS Specialist who will perform the majority of work. Table 12 itemizes costs for protocol implementation. Salary estimates are based on 2011 rates for wages and benefits and are likely to increase with time.

Table 12. Estimated Protocol Implementation Costs, as of 2011.

Project Stage / Budget Category	Personnel	Grade	Pay Periods	NCCN I&M Basic Protocol Costs	In-Kind Support from NCCN Parks	Other NCCN I&M Support Costs
Preparation and Coordination	NCCN Project Lead	GS-11	0.4	$1,231		
	GIS Specialist	GS-9	0.5	$1,509		
	Data Manager	GS-11	0.2			$709
	OSU Project Lead[1]		0.3	$1,750		
OSU Image Acquisition and Data Processing	OSU Research Assistant[1]		1	$7,500		
NCCN Data Processing	Filter raster data and generate polygons					
Filter and generate polygons	GIS Specialist	GS-9	1	$3,018		
Label Change Type	GIS Specialist	GS-9	1	$3,018		
Office Validation	NCCN Project Lead	GS-11	0.3	$923		
	GIS Specialist	GS-9	1	$3,018		
	Park Staff Biologist[2]	GS-12	1.5		$6,054	
Field Validation	GIS Specialist	GS-9	2	$6,036		
	Field Intern	Volunteer	4	$400		
Product Development	GIS Specialist	GS-9	1	$3,018		
Quality Review	GIS Specialist	GS-9	0.5	$1,509		
Metadata	NCCN Project Lead	GS-11	0.1	$308		
	GIS Specialist	GS-9	0.5	$1,509		
Data Certification & Delivery	NCCN Project Lead	GS-11	0.5	$1,540		
	GIS Specialist	GS-9	0.5	$1,509		
	Data Manager	GS-11	0.6			$2,126
Annual Data Analysis	NCCN Project Lead	GS-11	0.5	$1,540		
	GIS Specialist	GS-9	1	$3,018		
	Data Manager	GS-11	0.2			$709
Reporting & Product Development	NCCN Project Lead	GS-11	1.5	$4,618		
	GIS Specialist	GS-9	3	$9,054		
	Data Manager	GS-11	0.1			$354
	OSU Project Lead[1]		0.5	$2,900		
Product Delivery, Posting & Distribution	NCCN Project Lead	GS-11	0.3	$923		
	Data Manager	GS-11	0.1			$354
	NCCN Program Manager	GS-13	0.1			$533

Table 12. Estimated Protocol Implementation Costs, as of 2011 (continued).

Project Stage / Budget Category	Personnel	Grade	Pay Periods	NCCN I&M Basic Protocol Costs	In-Kind Support from NCCN Parks	Other NCCN I&M Support Costs
Archival & Records Mgmt.	NCCN Project Lead	GS-11	0.2	$616		
	GIS Specialist	GS-9	0.5	$1,509		
Annual Close-out	NCCN Project Lead	GS-11	0.2	$616		
	GIS Specialist	GS-9	0.5	$1,509		
	Data Manager	GS-11	0.3			$1,063
	OSU Project Lead[1]		0.2	$1,160		
Travel						
OSU Space and Computing[1]				$350		
NCCN Workstation Upgrades				$500		
Total cost of annual analysis and reporting				**$66,109**	**$6,054**	**$5,848**
Additional costs of ten-year analyses and reporting	NCCN Project Lead	GS-11	3	$9,237		
	GIS Specialist	GS-9	3	$9,056		
	Data Manager	GS-11	1			$3,543
Additional annual cost of ten-year report, three years for every 13 years of analysis (2 parks per year)				**$18,293**		**$3,543**

[1] Through annual cooperative agreement with Oregon State University. Indirect costs (17.5%) included.

[2] Five people at 0.3 pp each.

5. Future Directions

LandTrendr is a flexible tool with which to track changes to the land surface. This protocol addresses most, but not all of the original landscape dynamics monitoring goals generated by the NCCN. It does not currently address gradual changes or the growth of vegetation. This section discusses a few potential areas in which the protocol could expand, given enough time and funding.

A. Gradual Change

Chronic changes are captured as long, slow declines in the vegetation signal over many years. These are often associated with insects, but it is unclear whether other corollary processes, such as drought, might be helping drive the vegetation signal. Because many impacts of climate change are expected to express themselves slowly and steadily, this category of change may be of particular interest.

If proven useful to the network, the Greatest Disturbance layer could also be used to create a Gradual change layer. In contrast to the Rapid change layer, the Gradual change layer is limited to pixels with a change segment of **greater than** four years in duration. The same minimum mapping unit filtering would be applied, but the rule for the year of onset is relaxed, allowing adjacent pixels where the change initiated within four years of each other to be mapped into the same change patch. This is done to accommodate the progressive nature of some insect infestations and diseases that would be the primary change detection targets using the Gradual change layer.

As mentioned in **Appendix A: Description of the Landscape Change Categories**, determining the causal agent of change in areas that experience longer term changes is difficult. Validating the landscape change polygons is also challenging. The aerial detection survey component of the United States Forest Service's Forest Health Monitoring program (FHM) might provide useful spatial and temporal information to the validation and labeling process for a Gradual change layer (http://www.fs.fed.us/r6/nr/fid/data.shtml). More work is needed to determine both the NCCN priorities for monitoring gradual landscape changes and how to use available data for labeling and validating these areas.

B. Refining Categories

Some landscape change categories could potentially be further refined, if so desired by the network. For example, the "Mass Movement" class can be further divided into two distinct types, "Debris Topple" and "Debris Flow," thereby incorporating the role of streams in the landscape change process. The "Clearing" category labels could be expanded to include thinning and the appearance of logging roads. Within the Progressive Defoliation category, classes or types of insects or pathogens causing decline might be able to be detected. Relating LandTrendr and forest health is currently an active research topic and any applicable results or methods could be incorporated as they are developed.

C. Riparian

Changes in riparian areas are of significant interest to the NCCN. Currently the riparian category includes all types of changes that can occur in this zone that either remove vegetation or cause a significant transition in the floodplain, such as rock to water, or water to rock. Using LandTrendr

in combination with physiognomic class mapping, the detail of information about vegetation removal could be increased and the changes in terms of their reductions in deciduous or evergreen vegetation could be described. It would also be beneficial to investigate the conditions that lead to vegetation decline in concert with increasing wetness (see **Appendix A: Riparian**).

D. Recovery

Currently only metrics describing the greatest change segments are reported, but LandTrendr could provide a wealth of information about areas with an increasing vegetation signal in the NCCN. It might be possible to use recovery trajectories to track the forest encroachment in subalpine meadows, and the movement of the alpine treeline ecotone. Recovery trajectories could also be evaluated in riparian areas to monitor regrowth.

E. Landform Mapping

Over the past fifteen years, NCCN physical scientists have mapped landforms in all network parks (Dorsch et al. 2008, Riedel et al. In Review). At this point, the landform maps will remain a static product that will not be updated unless funding is provided for field work or aerial photo interpretation. A number of change types detected by the Landscape Dynamics Monitoring Protocol can be of interest to NCCN physical sciences staff for the purposes of updating the landform maps. For example, the landslides detected within the Mass Movement category can be used to flag new or reactivated debris avalanches that can be further investigated and mapped with higher resolution imagery. Riparian changes detected by the protocol can provide information on stream channel avulsions and the development of the Gradual change layer might allow mapping of long-term stream migration. Finally, the annual nature of the LandTrendr analysis might be useful for tracking frequency of debris flows and analysis of their spatial pattern.

F. New Methodologies

Other natural-resource agencies are recognizing the utility of moving to dense-time-series Landsat data for improved analysis. Momentum on this front may benefit NCCN.

Of particular note is a national-level monitoring initiative taking hold in the USDA Forest Service. LARSE researchers are members of the science team for the Landscape Change Monitoring System (LCMS) initiative, which is aimed at developing operational tools to use annual or more frequent Landsat data to track change across all vegetation types at the national scale. The temporal segmentation approach encapsulated in the LandTrendr algorithms is likely to become a component of this system, whether through LandTrendr proper or through new families of algorithms derived from LandTrendr and other cutting-edge change detection approaches such VCT (the Vegetation Change Tracker; Huang et al. 2010).

Should these tools reach an operational phase managed by national-level entities such as the USDA Forest Service's Remote Sensing Applications Center (RSAC) or the USGS, the responsibility for products currently provided by LARSE could conceivably migrate to these national entities. In addition to cutting costs, this could expand the pool of collaborating institutions.

It is also useful to note that the development of the NCCN Landscape Dynamics Protocol represents one of the first natural resource management agencies in the country using these dense

time-series data for monitoring. Thus, the NCCN Landscape Dynamics Monitoring Protocol could not only benefit from the LCMS initiative, but could in fact inform the decisions made for that initiative.

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Appendix A: Description of the Landscape Change Categories

This guide is designed to help identify and label landscape change types in the lab and in the field as part of the validation of change type labels generated by the RF model. This appendix provides written descriptions of the landscape changes, explains their typical position on the landscape and suggests tips to help reduce confusion when identifying various change types. Figures in this appendix show examples of landscape changes as seen on true color aerial photography and Landsat imagery that has undergone the Tasseled Cap transformation. The figures also provide examples of typical pixel spectral trajectories as seen in TimeSync software application. The colors used in the descriptions below refer to the hues of the Tasseled Cap imagery, which is used to visualize changes on Landsat scenes. For further guidance on interpreting the Tasseled Cap hues, the user should consult the first version of the protocol (Kennedy et al. 2007). See **SOP 4: Office Validation** for explanation of how spectral trajectories are generated in the TimeSync application.

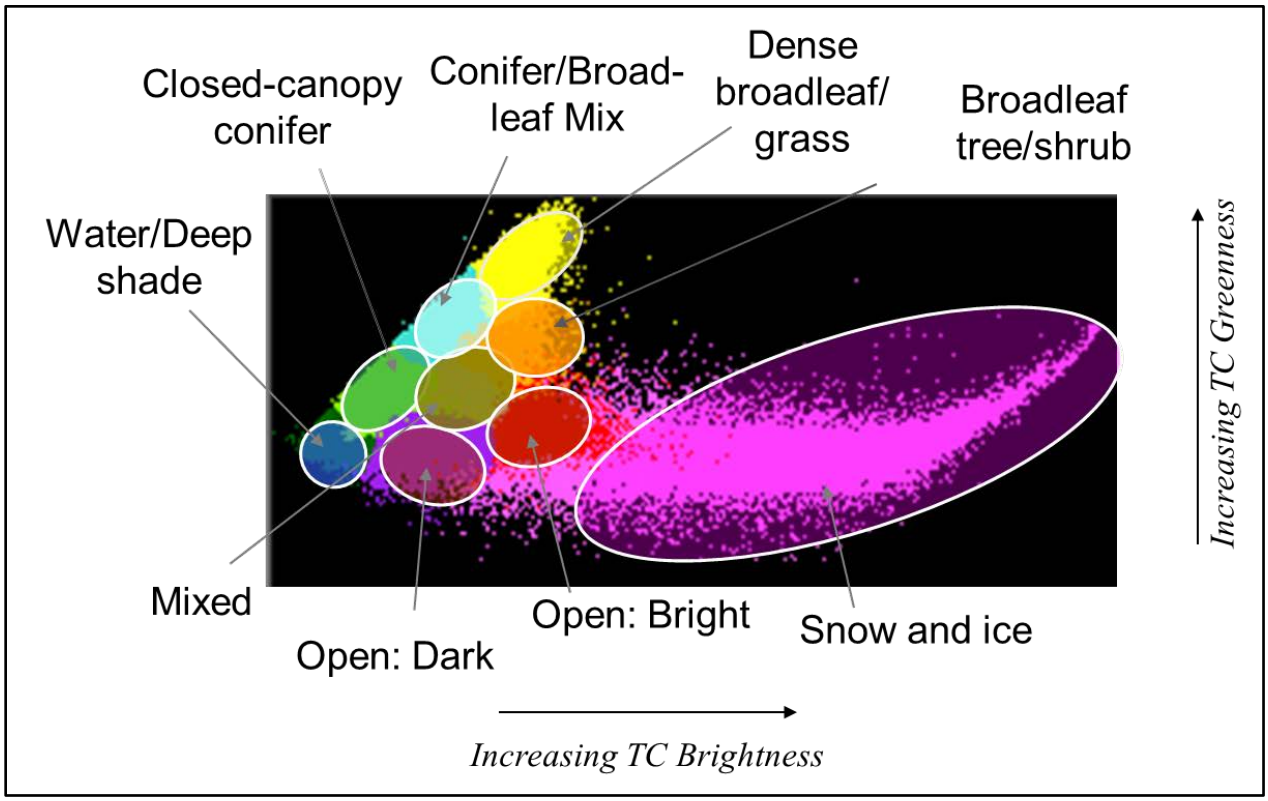


Figure A.1. Colors of typical land cover classes as seen on Landsat imagery that has undergone the tasseled cap (TC) transformation. Dark features such as shade, water or dark conifer canopy appear dark green or blue. Colors lighten as canopy structure decreases in complexity and canopy compositions shifts from evergreen to broadleaf. Open:Dark are often shadowed areas with little vegetation. Open:bright is typically exposed rock or parking lots.

1. Agriculture

This class is found predominately outside the park boundaries and is extensive in the NOCA study area, especially in the Chilliwack Valley of British Columbia. This change type is also found in the OLYM and MORA study areas, but to a lesser extent. Agricultural areas are dynamic landscapes, with fields undergoing cyclical planting, growth, harvesting and plowing. The specific changes in phases captured by LandTrendr within a given annual analysis will depend on the imagery dates. Fields are typically red or brown if recently plowed or left fallow and bright green or yellow if planted.

Figure A.2 shows an example of a landscape change polygon that would be placed in the "Agriculture" class. Aerial photography shows the patch located within a matrix of agricultural land use. The 2005 Landsat Tasseled Cap image shows the patch being planted with some kind of broadleaf crop (light green color). The 2006 Landsat image shows loss of greenness and transition to brown tones. This coloration usually corresponds to ground cover that has some vegetation and some bare earth components, suggesting that the field was recently planted. The TimeSync trajectory is typical for this type of change, showing cyclical nature of agricultural activities and switching between bare earth and planted cover types.

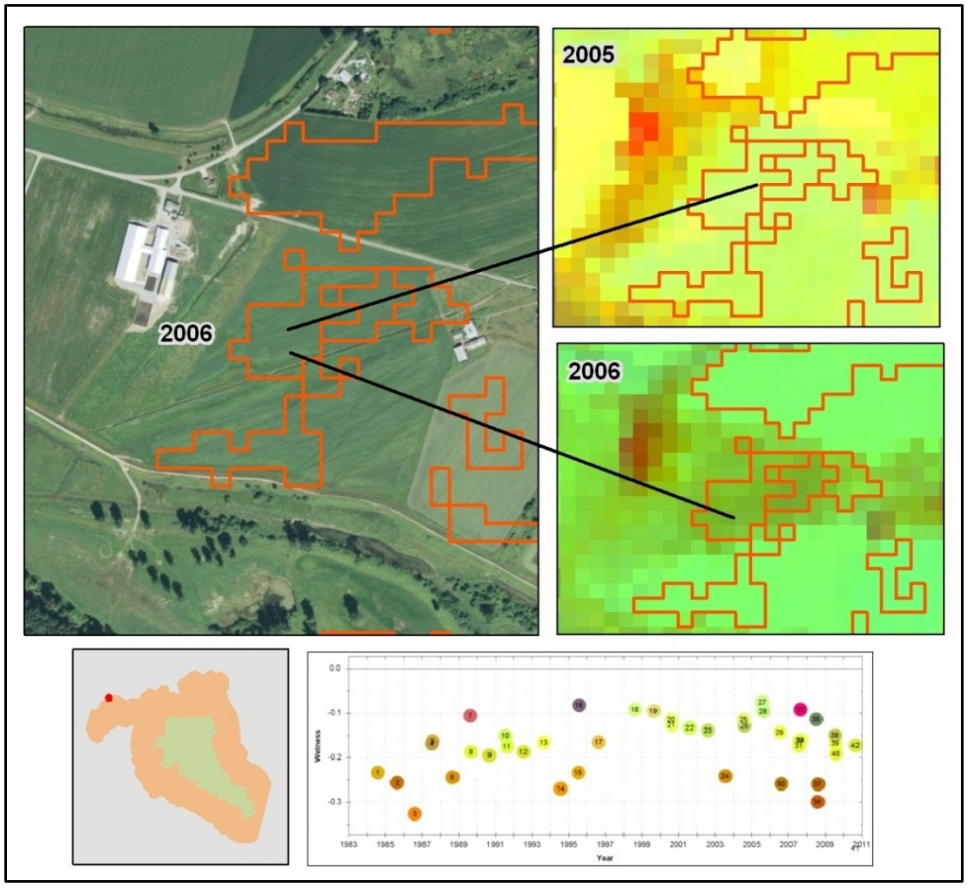


Figure A.2. Agriculture. The image on the left image shows LandTrendr change polygons with associated dates overlaid on an aerial photograph. The images on the right show the same areas on the Tasseled Cap Landsat chips prior to and after the change.

2. Annual Variability

This category was created in order to be able to model and remove polygons detected by LandTrendr that do not capture change of interest to the NCCN. Usually, these changes are associated with variability in snow cover, clouds, terrain shadows, or vegetation phenology that is not removed in the image processing steps and is of great enough magnitude to pass through filtering. Annual variability polygons are generally only found in high elevations areas with limited vegetation, such as above the tree line. The interpreter must exercise care in determining that a polygon of this class truly shows no change. The TimeSync trajectories of these changes usually show high degree of variability throughout the time period being examined and are dominated by red, brown and orange hues. Figure A.3 shows an example of a polygon that would be placed in the "Annual Variability" class. Landsat Tasseled Cap images from 2000 and 2006 are not significantly different, except for a slight variation in hues most likely related to differences in soil moisture during the image acquisition dates.

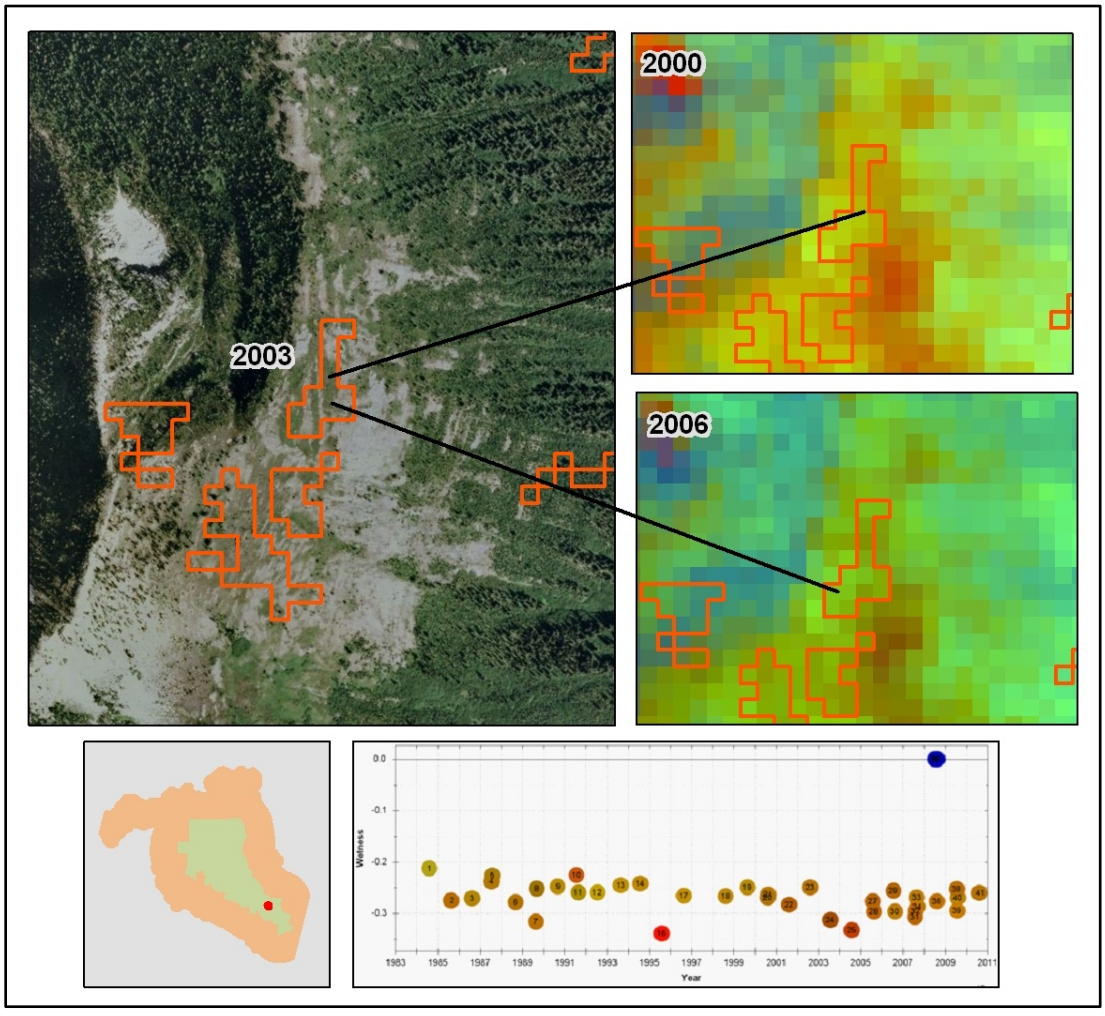


Figure A.3. Annual Variability. The picture of the steep and partially vegetated upper valley wall shows no visibly detectable change between 2000 and 2006 Landsat chips, even though change was detected for 2003. Note the impact of changes in soil moisture and phenology as the trajectory and imagery changes from orange to red to brown hues.

3. Avalanche

Avalanches originate in snow receiving zones on ridges or high on the valley wall. They are typically long, linear polygons, although some events can be broken up into multiple smaller polygons depicting areas of the greatest removal of vegetation. If the avalanche occurred in an existing avalanche chute, the TimeSync trajectory usually starts in bright greens and yellows, which are representative of low statured, mostly broadleaf vegetation – small conifers, deciduous shrubs and herbs (Figure A.4). If swaths of forest were removed, the TimeSync trajectory will start as greenish blue, representative of mature conifer forest. As avalanches typically remove some but not all of the vegetation, the trajectory after the event is typically shown in hues of red, brown and tan. Higher magnitude avalanches occasionally traverse the valley floor and leave a large pile of downed trees in their wake, which can usually be seen in the aerial photography.

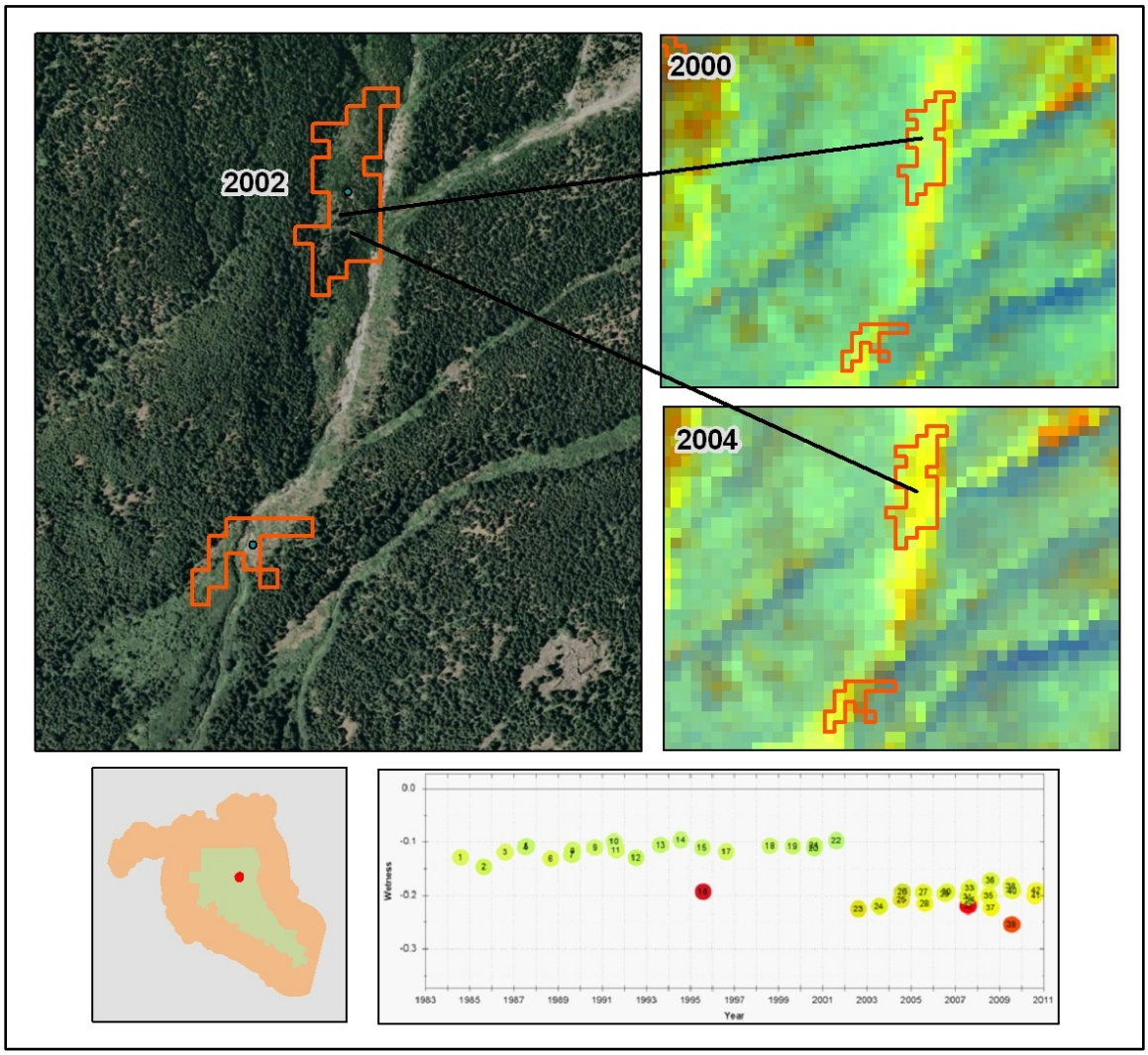


Figure A.4. Avalanche. The 2002 avalanche has removed patches of vegetation as it traveled down the existing avalanche chute.

4. Clearing

The Clearing category covers events that mostly occur in areas outside the park boundaries that are under active forest management or are adjacent to development in rural areas. Clearings include a range of forest management practices, from “clearcuts” in which nearly all the forest canopy is removed, to more patchy harvests such as select cuts, to thinning, to chemical treatment of broadleaf species. Typically, the clearing trajectory in TimeSync starts with greens and blues that indicate a mature conifer forest (Figure A.5). The trajectory then shifts to bright reds, oranges or browns that indicate open ground and quickly transition to greens that darken as regrowth becomes more mature and transitions from broadleaf to conifer types. In the aerial photography the cleared ground looks very brown and occasionally looks burned or black. Following the clearing, the trajectory usually shows the recovering broadleaf vegetation in a bright green, which slowly transitions to darker greens and blues of the conifer forest.

In the aerial photography the heights of the regrowing vegetation can be difficult to discern, but the regrowth is typically uniform and the polygon is typically an angular shape. Frequently, smaller linear polygons are detected a year or two prior to and adjacent to clearing polygons - these are logging roads that are built prior to clearing to access the logging site. These types of clearing will typically have a similar spectral trajectory, but might contain more blue and dark green hues if the road is surrounded by undisturbed conifer forest.

Figure A.6 shows a “Clearing” trajectory associated with a forest thinning or chemical treatment. In this type of clearing, broadleaf vegetation is cleared or treated to promote the growth of conifers. The trajectory shows a transition from lighter green hues associated with broadleaf vegetation to darker, bluer hues typical of conifers. Occasionally, this trajectory can also be seen within the park boundaries, especially along the highway 20 corridor in NOCA. These areas have been logged prior to their inclusion within the National Park and the trajectory shows vegetation succession. In this case, the polygon should be attributed to the “Annual Variability” category as NCCN does not monitor succession at this time. Care should be taken to differentiate these instances from legitimate clearings within the Seattle City Light power line corridors that also located along highway 20.

The Clearing category also includes land clearing that is associated with low-density rural development. The interpreter should assess how much of the change polygon is occupied by buildings after clearing has occurred and how much of the vegetation has regrown. If buildings occupy the minority of the pixels within the polygon and the majority of cleared vegetation within the polygon has recovered, the polygon should be labeled with “Clearing” category. If buildings are large enough and occupy the majority of the change polygon, or if the clearing is maintained, the area should be labeled “Development.”

In very rare cases, in the forest lands adjacent to OLYM, it can be difficult to distinguish windthrow from clearing and, depending on the resolution of the aerial photo, it might be difficult to determine if trees remain on the ground. The interpreter should look for clues such as logging roads, or distinctive fan pattern of skid areas due to high-line logging operations, before labeling the event as “Clearing.”

Clearing is found extensively around OLYM, on the west side of the MORA study area and west and north of NOCA. Some clearing polygons can also be detected within NOCA along the Seattle City Light power line corridors and in the Stehekin Valley.

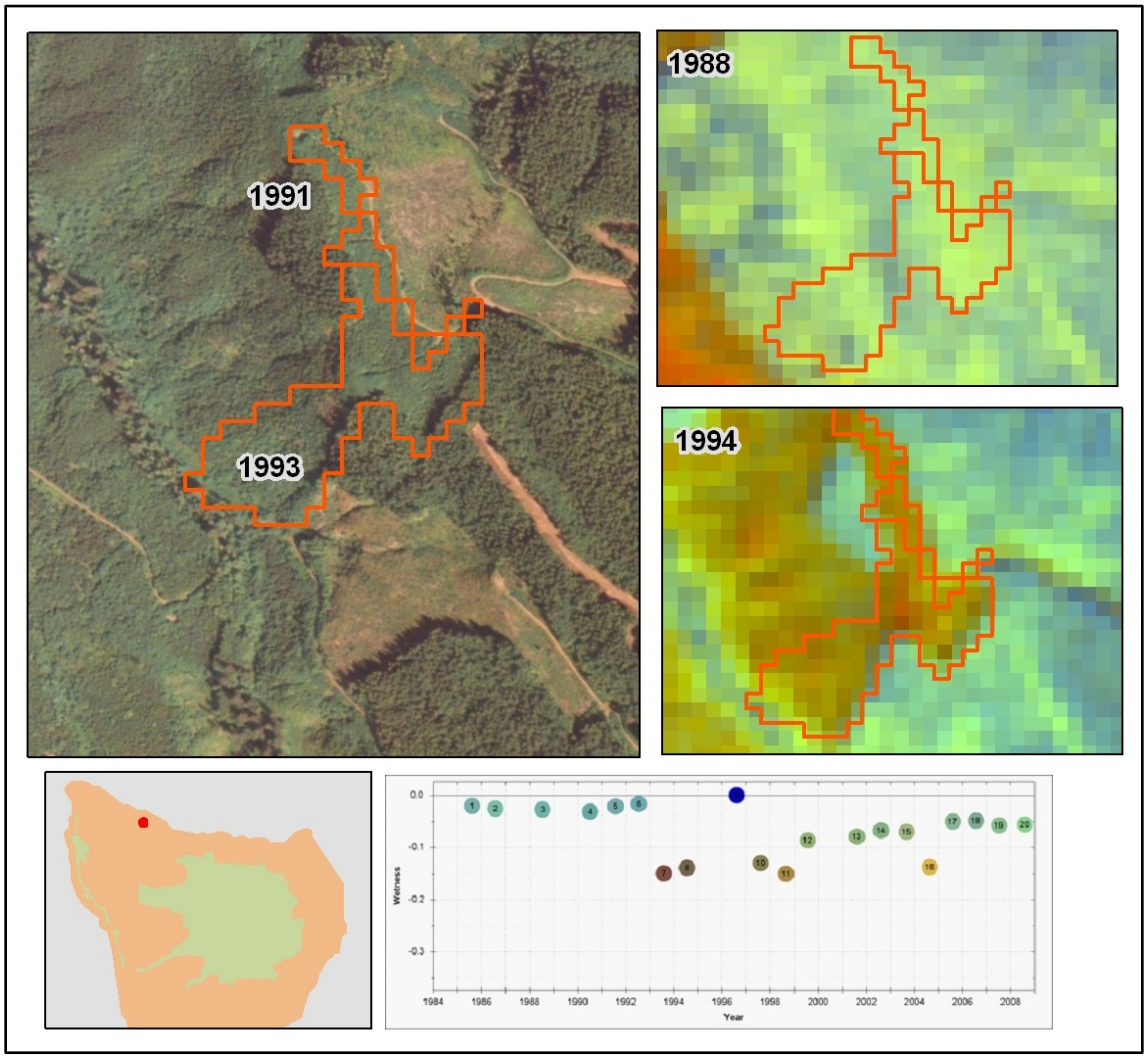


Figure A.5. Clearing. The aerial photo shows a 1993 clearcut that was preceded by a 1991 clearing for a road. Spectral values of the TimeSync trajectory and Landsat Tasseled Cap images from prior to and after the clearing clearly show transition between blue and green hues representative of conifer forest to browns and oranges of bare ground. The spectral trajectory shows quick transition to vegetation following the clearing. Changes associated with thinning or chemical treatment will usually show a small dip in the trajectory while the recovering vegetation is still mostly broadleaf. The recovery then continues and hues quickly change to darker green and blue representative of conifer forest. These trajectories will only be associated with clearings that happened prior to 1985 and do not show the original clearing (Figure A.6, below).

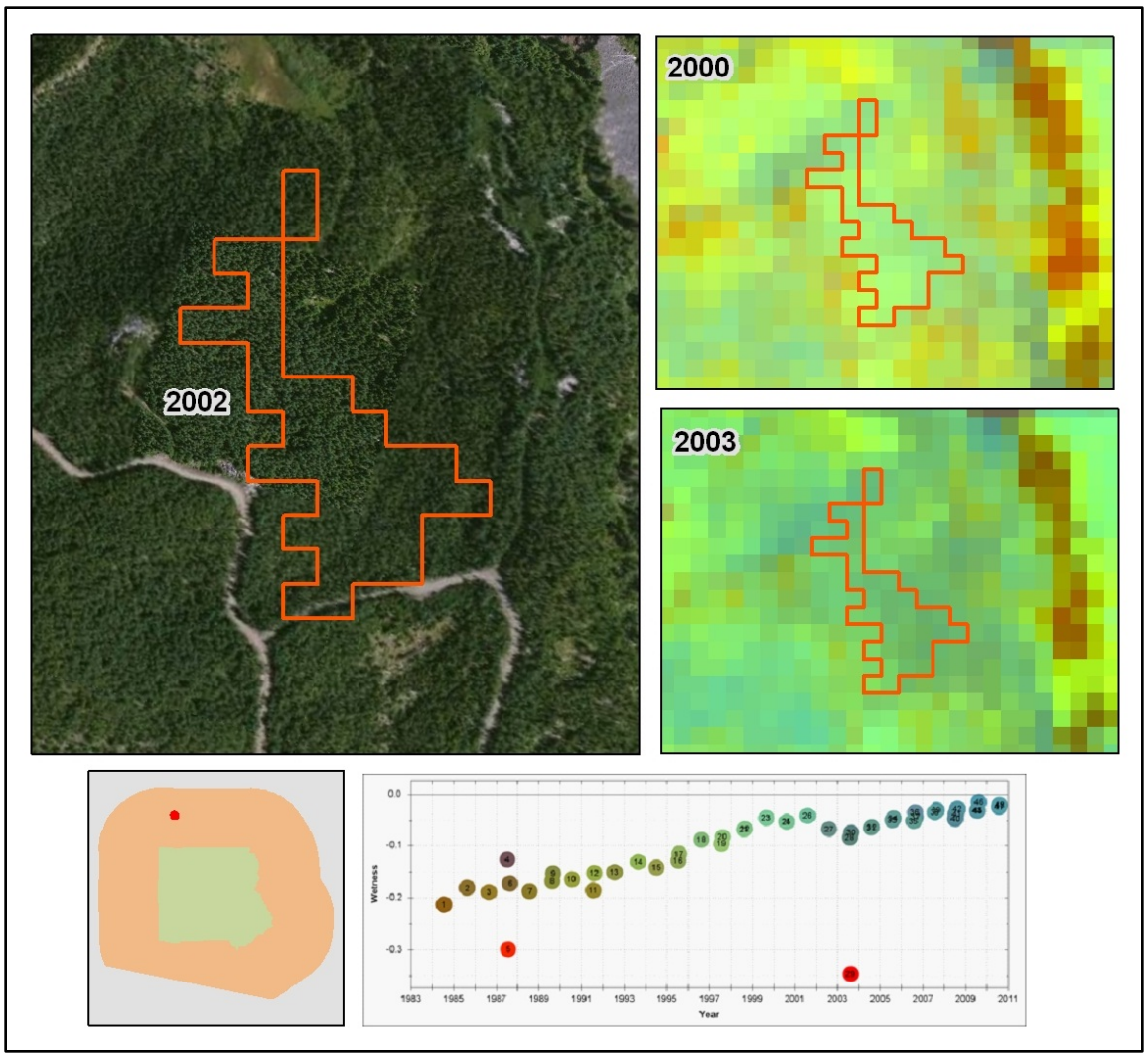


Figure A.6. Clearing - Thinning. A change polygon depicting either chemical or mechanical treatment of a pre-1985 clearcut. The first part of the TimeSync trajectory shows broadleaf vegetation growth. After the treatment, the trajectory dips temporarily and resumes upward climb with hues that are more representative of conifer vegetation.

5. Development

Development areas show a complete, persistent removal of the vegetation and transformation to a built landscape, with driveways, houses, cars, and other evidence of urbanization. Development can range from a few house structures to entire parking lots. Development can sometimes be captured though several years, with the first years appearing as clearing, followed by road and then house construction. For the purposes of this protocol, development label should only be assigned to areas that have a significant portion of the area occupied by buildings and paved surfaces. An addition to building construction, the interpreter should look for trajectories that indicate that the patch remains open following the event, rather than returning to the forested state characteristic of clearing and regrowth (Figure A.7).

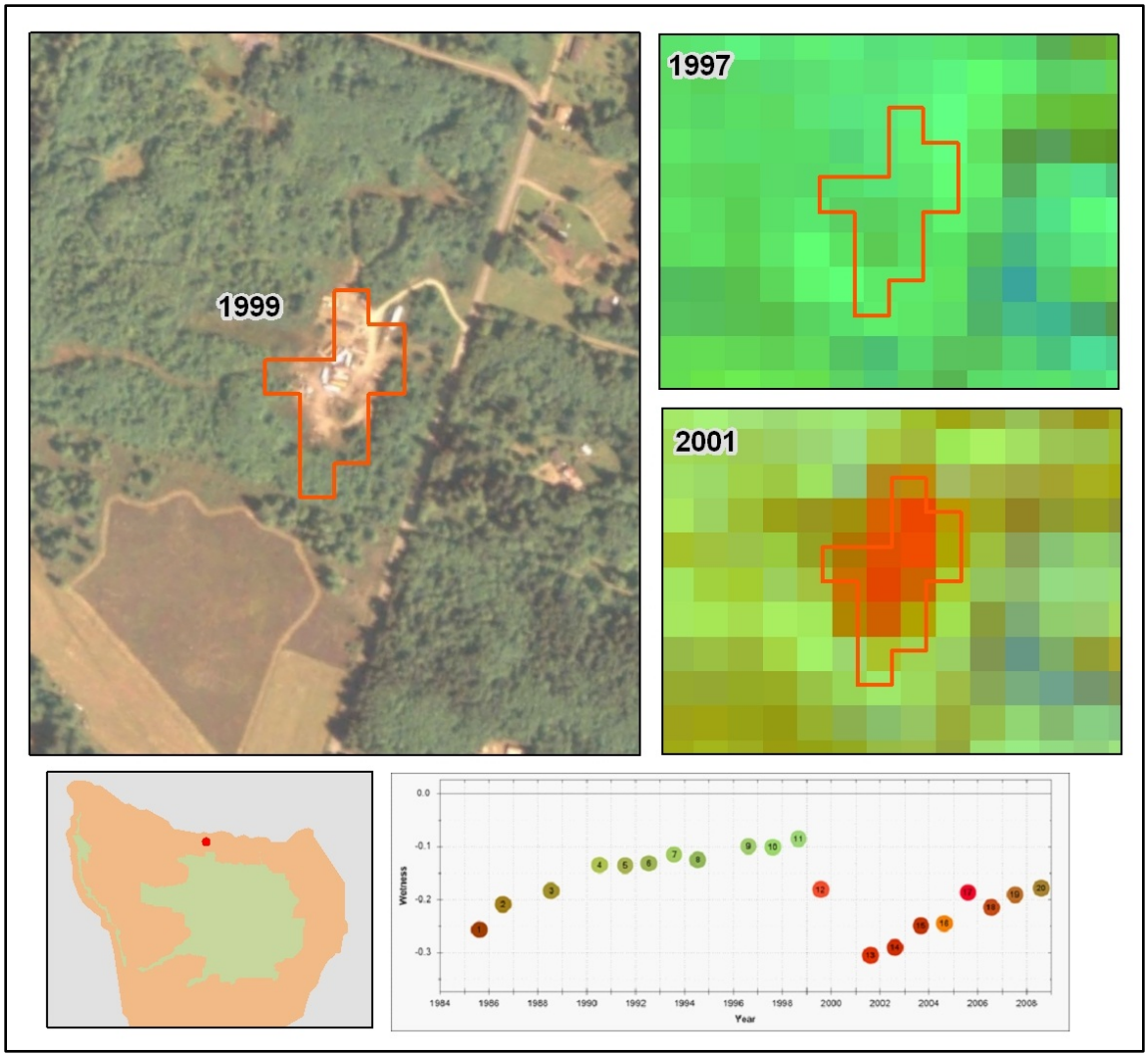


Figure A.7. Development. The Landsat Tasseled Cap images show dramatic transition from vegetated to bare ground cover types between 1997 and 2001, captured by LandTrendr as a 1999 change polygon. The TimeSync trajectory transitions from green to bright red colors, indicating that the area remained clear of vegetation following the original clearing. The 1995-1998 portion of the trajectory indicates a regrowth pattern from a previous disturbance suggesting that the area was cleared prior to 1985 and then cleared again for development.

6. Fire

Any fire of significant area will likely be corroborated from external sources. During validation, the interpreter should overlay change polygons with most recent fire perimeters from park databases. However, some fires outside park boundaries, and/or of either lower intensity or smaller size, may not be recorded. Fires tend to leave standing trees with no foliage, which can be seen in the aerial photography as thin shadows. Fire polygons are often large. Some lower intensity fires leave behind a mix of dead and singed trees. Sometimes active burning and smoke can been seen in the aerial photography, since the photos are usually taken in August. The trajectory in the TimeSync is similar to clearing- changing from blue and green of conifers to a mix of brighter colors where the vegetation has been completely burned, to orange for shrubby new growth (Figure A.8). Often, the interpreter will see vegetation located right outside the original fire perimeter dying two to three years following the fire. These changes should be labeled as "Fire," since it was the likely original cause of change.

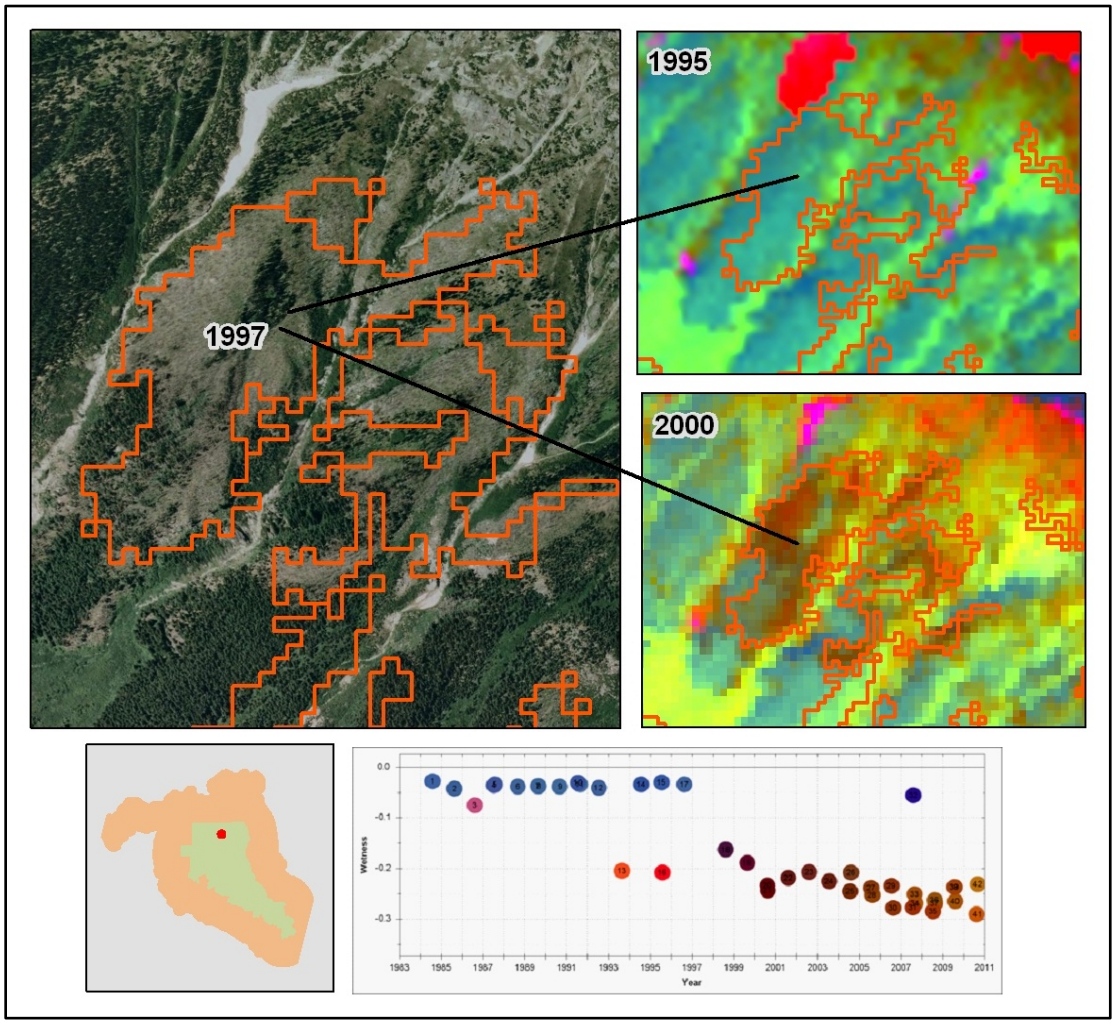


Figure A.8. Fire. Landsat Tasseled Cap images prior to and following a large 1997 fire show clear transition from mature conifer forest, represented by bluish green colors, to bare ground with minimal vegetation component, represented by browns and oranges.

7. Tree Toppling

The Tree Toppling category primarily includes forest areas where the trees have been both broken off and toppled to the ground in major wind events. This category is rare at NOCA and MORA. It is more common at OLYM, especially in the Quinault, Hoh, and Queets River valleys on the west side of the park and also in the northeast corner of the park. This category also includes areas where the Tree Toppling is due to root rot - the structural outcome is similar and the agent is typically hard to determine just from the imagery. Large Tree Toppling events can build on themselves, with subsequent events occurring in the vicinity of the original polygon. TimeSync trajectory of these events often shows some green vegetation remaining after the toppling, either because some of the trees are still standing or the foliage of the downed trees is not completely dead (Figure A.9). On the aerial photograph the interpreter should look for downed tree trunks. Windthrow events usually occur in areas on the landscape that are exposed to wind, either on top of ridges and knolls or along rivers.

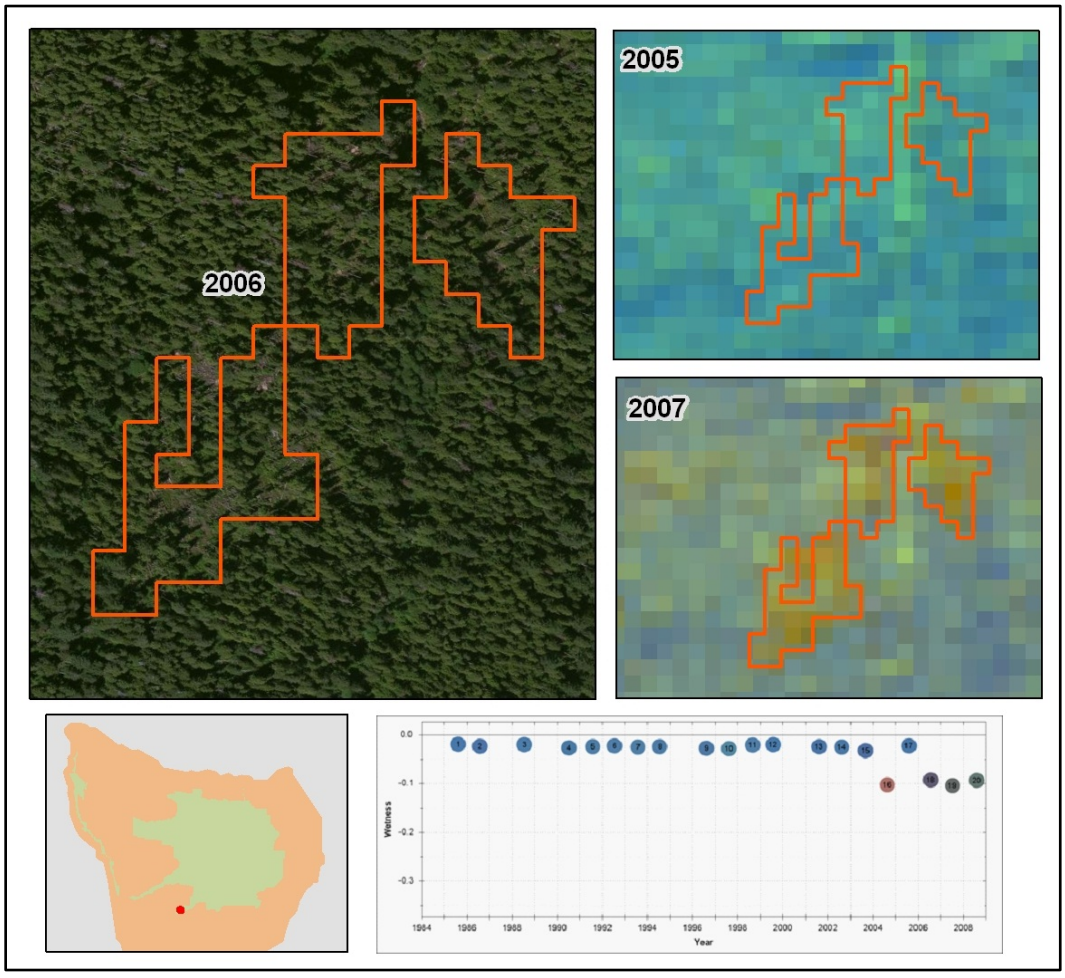


Figure A.9. Tree Toppling. A 2006 windthrow event at Olympic National Park. Tasseled Cap Landsat image from 2005 shows darker blue and green pixels of a mature conifer forest transitioning to brown and orange pixels of mixed bare earth and vegetation in 2007 following the 2006 event. TimeSync trajectory shows distinct reduction in wetness that is not as dramatic as would be expected from a total removal of vegetation.

8. Progressive Defoliation

This category is usually assigned to landscape change polygons where forest cover still remains, but has undergone slow changes in spectral values that represent a loss of greenness and wetness. Interpreting the color change in TimeSync is therefore more challenging. The interpreter will see a very slight dip in the trajectory with decrease in blueness and greenness. However, the decrease is not big enough to suggest change from conifer to broadleaf vegetation or bare earth (Figure A.10).

The decreasing greenness of the forest can be difficult to discern in the aerial photography. In some stands the decline is due to LandTrendr detecting individual trees which have completely died. These dead trees appear in the aerial photos as bright red or yellow. In some stands the decline is due to the tip and top limbs of a significant proportion of the trees succumbing to some pathogen. This type of decline shows up as a subtle greying of the canopy in the aerial photos and can be hard to discern if the color balance of the photos is poor. In addition, change polygons in this category can have both types of declining trees. In general, the interpreter should place in this category any change polygon where forest canopy has not been removed or thinned in any way. Progressive Defoliation can in some cases be corroborated with polygons from the Forest Service's Forest Health Monitoring program (FHM). One should be cautioned, however, that the FHM polygons are not spatially accurate and should not be used as a definitive outline or location of the change.

This category also contains vegetated polygons along streams that have been affected by water, with vegetation showing loss of vigor, but there is no evidence of inundation The trajectory will show a slight decline in wetness (rather than increase characterized by inundation).

Although Progressive Defoliation can be found at any elevation, it is most prevalent at higher elevations especially on the east sides of study areas of MORA, NOCA and OLYM, which are drier.

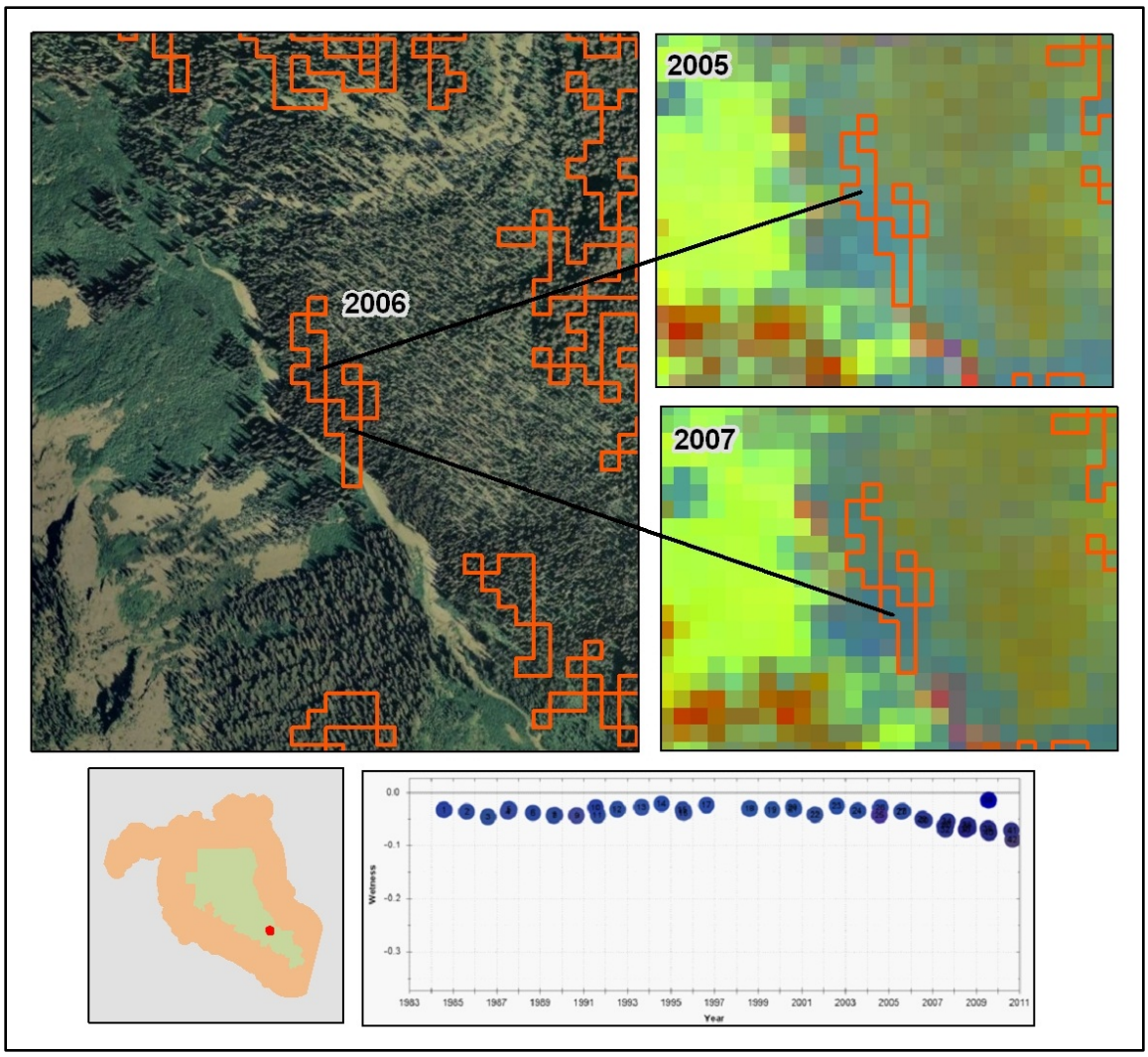


Figure A.10. Progressive Defoliation. Landsat Tasseled Cap images from prior to and after the 2006 change show no significant change in pixel coloration suggesting no transition in cover type. The spectral trajectory, however, shows a slight dip in wetness, indicative of reduction in vegetation vigor.

9. Mass Movement

This category includes a variety of vegetation-removing changes that expose rock or bare ground. Larger events are typically called landslides, and are found on valley walls away from streams or creeks. Most landslides totally remove vegetation and are often persistent. Some rare events, however, are better described as “soil creeps” or “slumps” and are characterized by only partial removal of vegetation. Debris flows are mass movements associated with water discharge, such as streams. Mass movements are distinguished from the riparian category in that they occur on valley walls, perpendicular to the valley floor, and on slopes greater than 10%. The Riparian category is associated with changes found on the valley floor, along low gradient rivers. If the change occurred on the valley floor, but the average slope value for the entire polygon is greater than 15%, the interpreter should label the change as “Mass Movement.” Mass movements are distinguished from avalanches by the magnitude of change: mass movement leaves little to no vegetation; and by shape and context. The interpreter should look for persistent red and orange colors in the TimeSync trajectory following the event (Figure A.11).

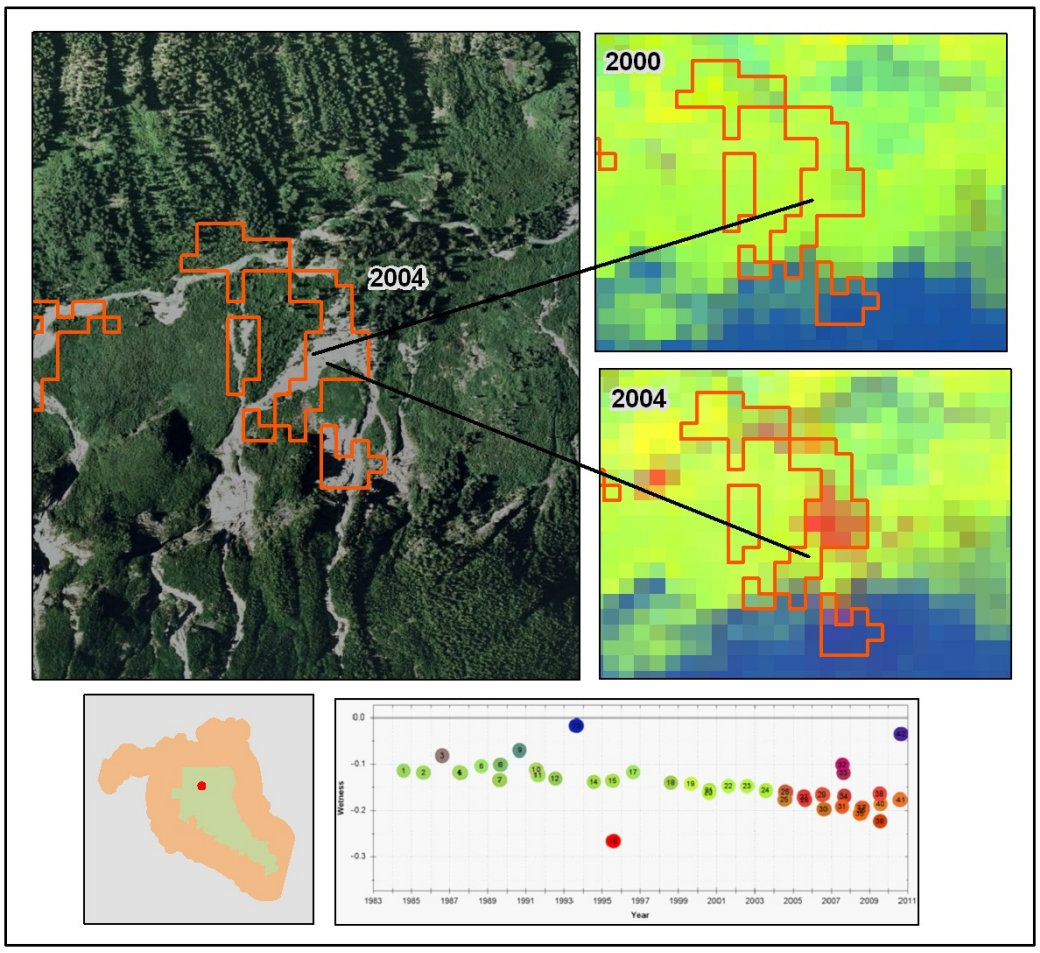


Figure A.11. Mass Movement. In 2004 debris flow at North Cascades National Park, bright green colors characteristic of broadleaf vegetation are replaced by bright reds and browns following total vegetation removal. Note that the wetness component of the trajectory has not dropped significantly, suggesting presence of moisture in the soil.

10. Riparian

Riparian polygons are restricted to the valley floor where the gradient is much lower (average slope for change polygon is below 15%) and the valley floor is wider. Typical riparian polygons show areas where either conifer or broadleaf vegetation previously existed and have been converted to either active river channel, with water, or river bank, with gravel and sediment. The spectral trajectories of these changes show either sudden increase in wetness or brightness, depending on the resulting cover type. These changes are usually easily identified on aerial photos (Figure A.12).

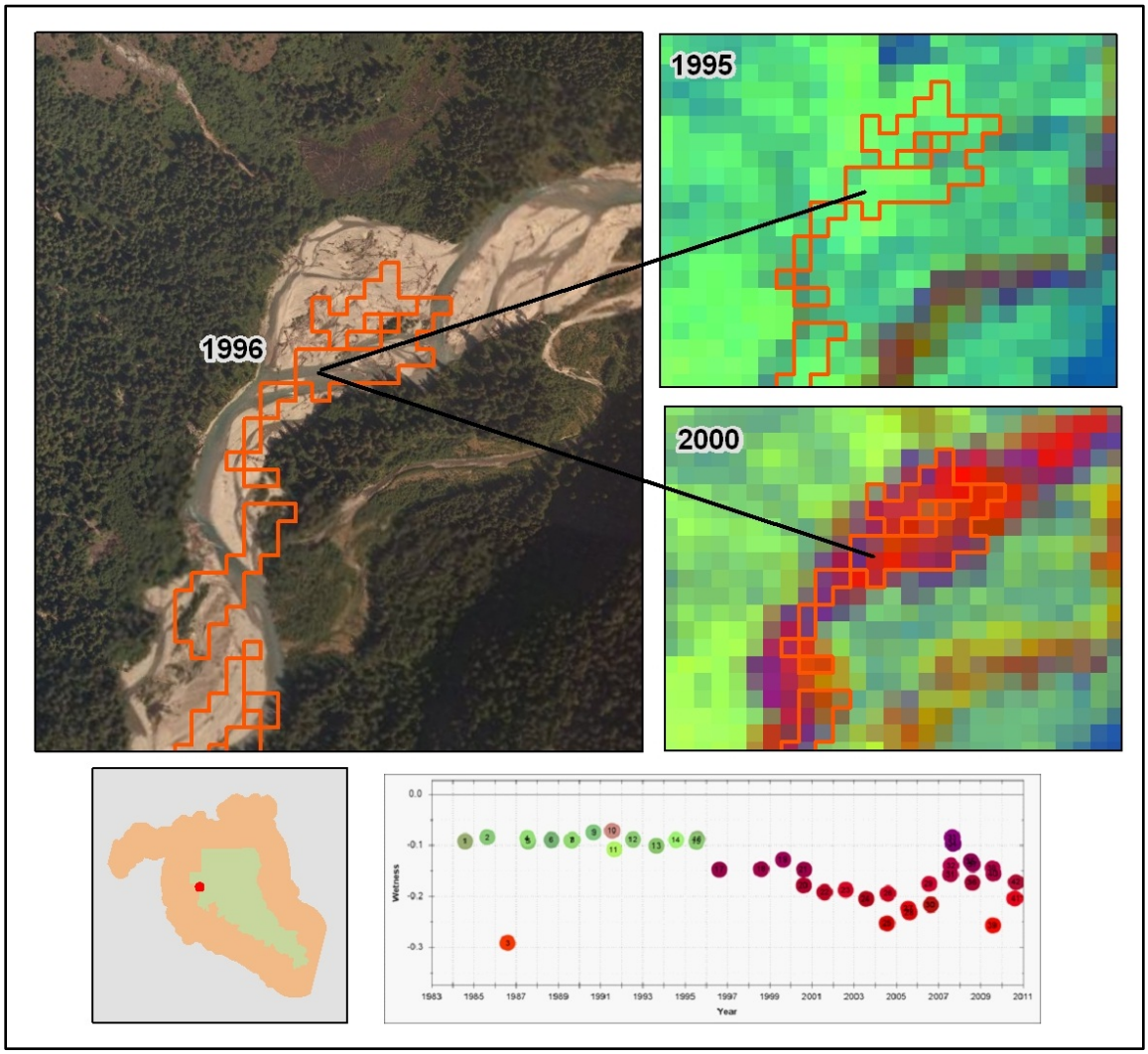


Figure A.12. Riparian. This 1996 change can easily be categorized as "Riparian" by its location in the large river channel. Dramatic and persistent decrease in greenness is evident in both the tasseled cap Landsat imagery and the TimeSync trajectory. Note the presence of blue tones following the event that are indicative of some water pixels present within the change polygon.

The riparian category also includes forested and mixed-forested polygons in the riparian floodplain that have been inundated either temporarily or permanently. It is difficult to verify the change in these areas as often the forest canopy looks the same in the aerial photography. It is possible that these areas are undergoing some hydrologic change which has either increased soil

moisture past the current species' tolerance, or which has brought alluvial material that has buried roots past species' tolerance. It is also possible that the decline is due to root rot, or some other pathogen and LandTrendr has detected the canopy death that precedes eventual collapse. The interpreter should place these changes in the riparian category even if there is no evidence of tree collapse, but there is a clear increase of wetness signal in the trajectory (Figure A.13).

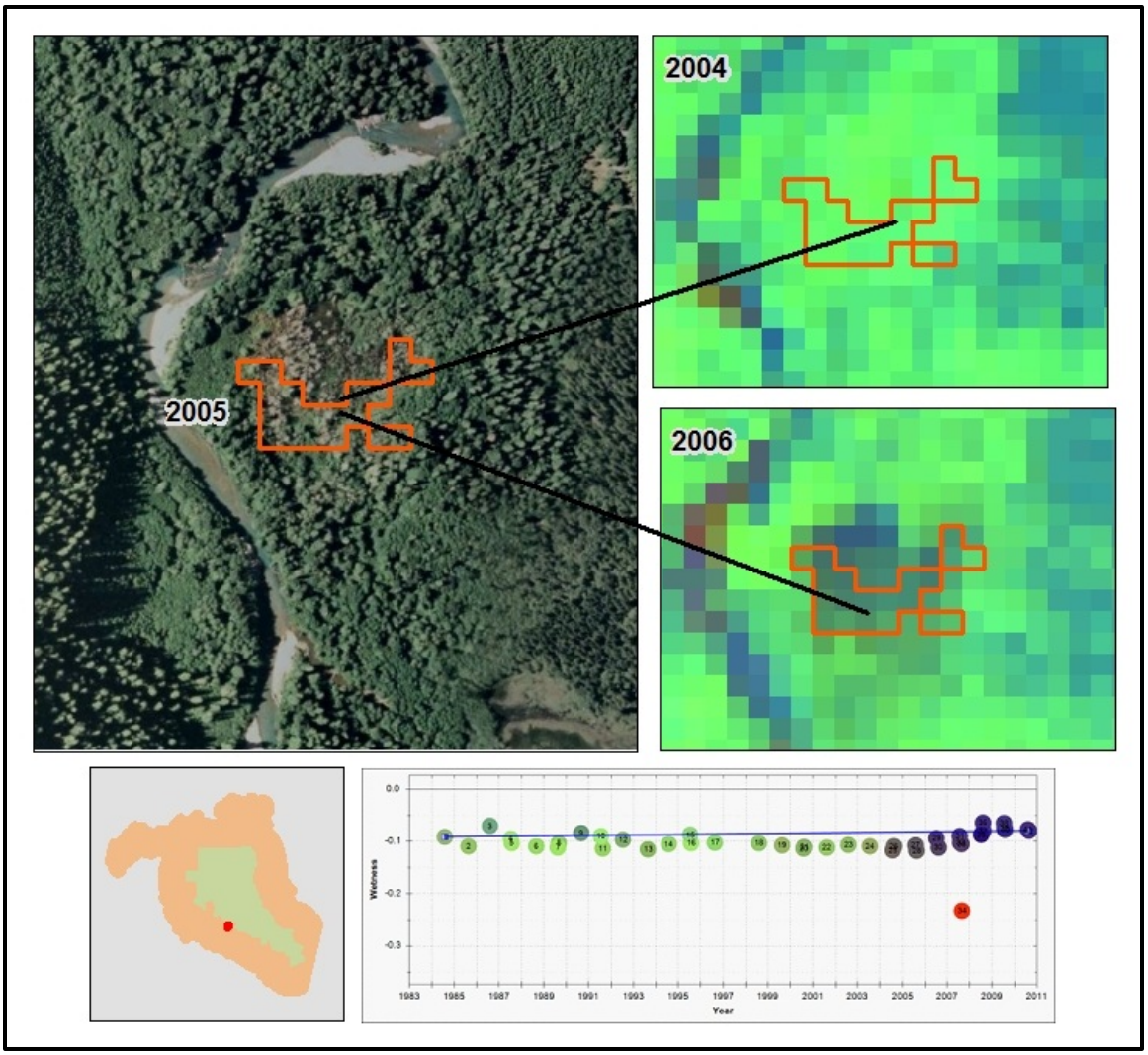


Figure A.13. Riparian - Inundation. This change polygon located close to a river shows spectral and visual signs of inundation. Both the Landsat imagery and TimeSync trajectory indicate an increase in wetness.

11. Literature Cited

Kennedy, R.E, W.B. Cohen, A.A. Kirschbaum and E. Haunreiter. 2007. Protocol for Landsat-based monitoring of landscape dynamics and North Coast and Cascades Network Parks: U.S. Geological Survey Techniques and methods 2-G1.

Appendix B: Template for Landscape Dynamics Monitoring Annual Report

1. Overview

This Standard Operating Procedure describes methods for analyzing data associated with the NCCN Landscape Dynamics Monitoring protocol and provides guidelines and templates for the annual and 10-year reports.

The project database includes features that allow the analyst to query the database to produce most of the data summary tables that should be included in the annual report, and allow for an easy transition between the database and the properly formatted summary tables described below. Spatial and temporal trend assessments require exporting data to other software applications for manipulation and analysis.

2. Report Template

Introduction/Background

Boilerplate for each report covering the following:

- Park(s) covered, map of study area, and period of analysis
- Unique characteristics of imagery or LandTrendr updates
- Overview of accomplishments of current year

Methods and Results

- Quick review of methods, highlight any deviations or challenges with implementation
- Detection of change and trend, based on initiation of monitoring in 2011. Values reported for each study area and type of landscape change. Agricultural and Annual Variability categories are not reported on because they are not of interest to NCCN.

Table B.1. Area (ha) of the North Cascades Study Area (NOCA) affected by landscape change by type in 2007-2009. Total is the total study area. Inside refers to inside the park boundary, and outside refers to the study area outside of and not including the park.

	2007			2008			2009		
Type	**Study Area**	**Inside NOCA**	**Outside**	**Study Area**	**Inside NOCA**	**Outside**	**Study Area**	**Inside NOCA**	**Outside**
Avalanche	81.1	9.4	71.7	162.3	69.4	92.9	352.2	115.7	236.4
Clearing	931.4	5.4	926.0	340.1	5.6	334.6	273.6	0.0	273.6
Development	161.0		161.0	140.5		140.5	46.5		46.5
Fire	890.5	301.7	588.8	379.4	57.2	322.2	163.8	41.9	121.9
Mass Movement	42.1	36.1	6.0	65.7	53.9	11.8	40.9	12.8	28.2
Progressive Defoliation	2262.4	252.6	2009.8	145.1	16.3	128.8	173.9	49.2	124.7
Riparian	46.5	9.5	37.0	23.9	0.9	23.0	48.0	7.8	40.1
Tree Toppling	18.4	2.6	15.8	20.4	1.7	18.7	63.6	0.0	63.6
Grand Total	**4648.6**	**630.7**	**4017.9**	**1649.1**	**222.1**	**1427.0**	**1437.4**	**262.6**	**1174.8**

Table B.2. Number of landscape changes by type 2007-2009. Total refers to the entire NOCA study area. Inside refers to inside the park boundary, and outside refers to the study area outside of and not including the park. Fire and Progressive Defoliation categories are not reported on because individual events can consist of multiple polygons, which can considerably overstate the actual number of events.

	2007			2008			2009		
Type	**Study Area**	**Inside NOCA**	**Outside**	**Study Area**	**Inside NOCA**	**Outside**	**Study Area**	**Inside NOCA**	**Outside**
Avalanche	47	8	39	78	29	49	157	34	123
Clearing	178	4	174	80	3	77	39		39
Development	58		58	68		68	24		24
Mass Movement	27	22	5	25	20	5	22	10	12
Riparian	32	9	23	12	1	11	24	4	20
Tree Toppling	9	2	7	9	1	8	17		17
Grand Total	**1537**	**216**	**1321**	**545**	**85**	**460**	**561**	**123**	**438**

Table B.3. Top 10 landscape change events by size within the study area. The InPark variable indicates whether the event was located within the park boundary.

Year	InPark?	Size (ha)	Type
2007	N	125.73	Fire
	N	88.02	Clearing
	N	85.68	Fire
	N	57.69	Clearing
	N	45.99	Fire
	Y	45.99	Fire
	N	44.37	Clearing
	N	43.65	Progressive Defoliation
	N	42.84	Clearing
	N	41.76	Fire
2008	N	223.29	Fire
	Y	44.37	Fire
	N	39.60	Agricultural
	N	34.20	Clearing
	N	27.72	Clearing
	N	23.49	Clearing
	N	21.33	Agricultural
	N	21.33	Clearing
	Y	19.17	Mass Movement
	N	18.27	Clearing
2009	N	87.75	Fire
	N	38.43	Clearing
	N	36.09	Clearing
	N	32.40	Tree Toppling
	N	25.83	Clearing
	N	24.39	Clearing
	N	21.69	Clearing
	Y	20.97	Avalanche
	N	18.90	Progressive Defoliation
	N	18.72	Agricultural

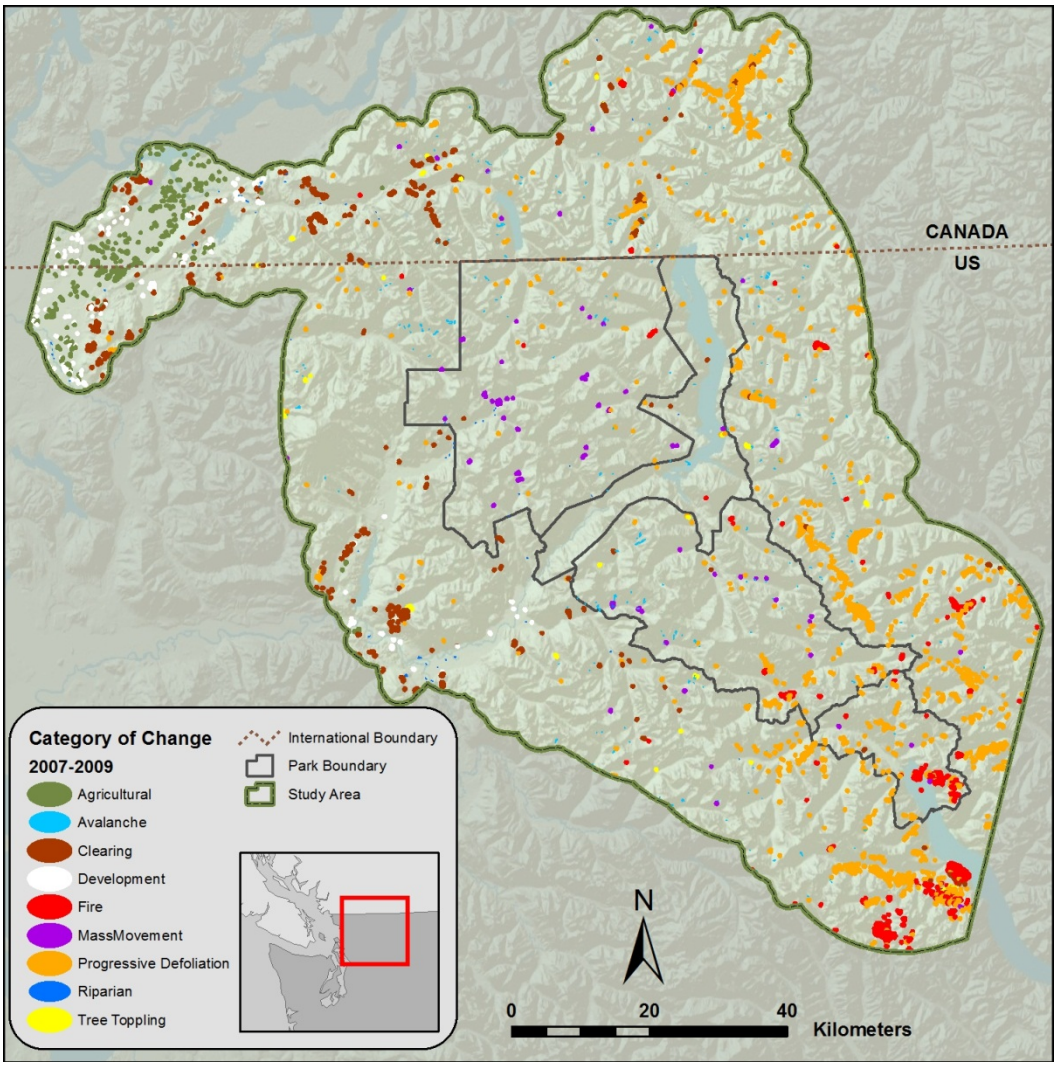


Figure B.1. Map of NOCA study area showing landscape change polygons by type.

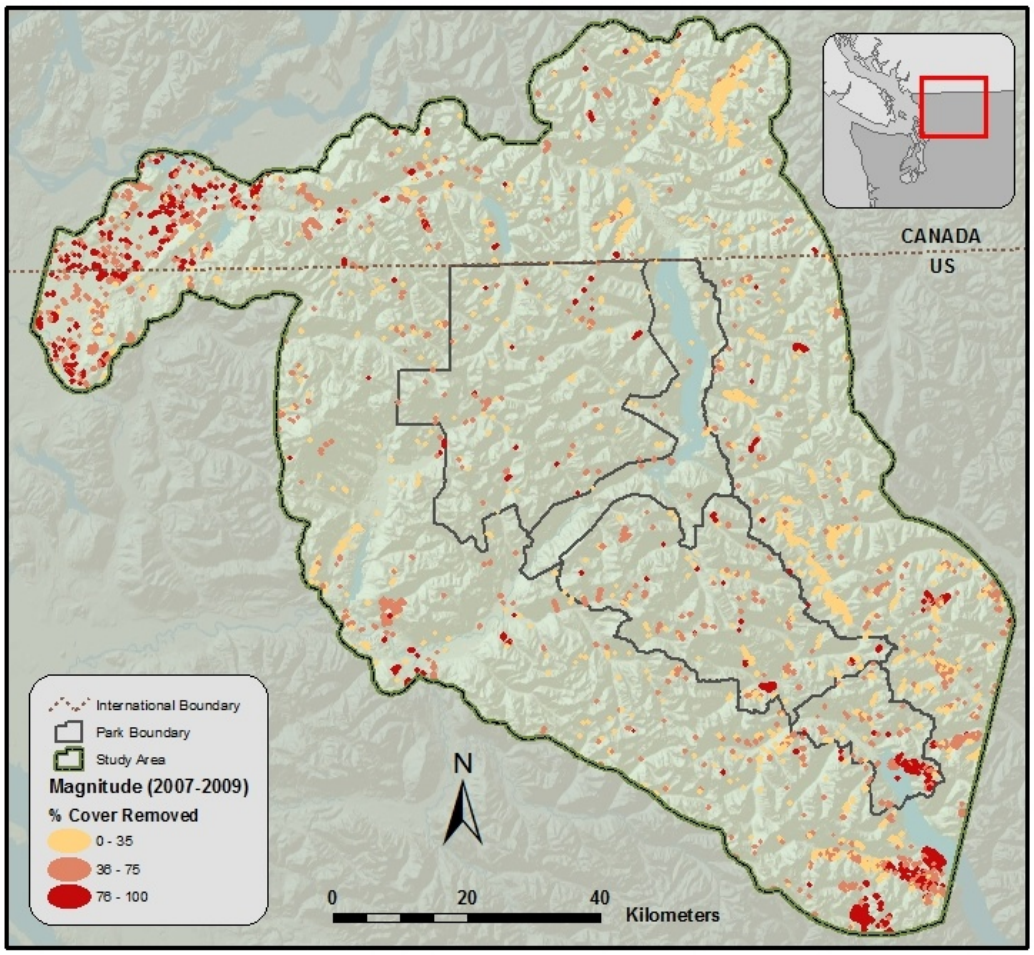


Figure B.2. Map of NOCA study area showing landscape change polygons by magnitude.

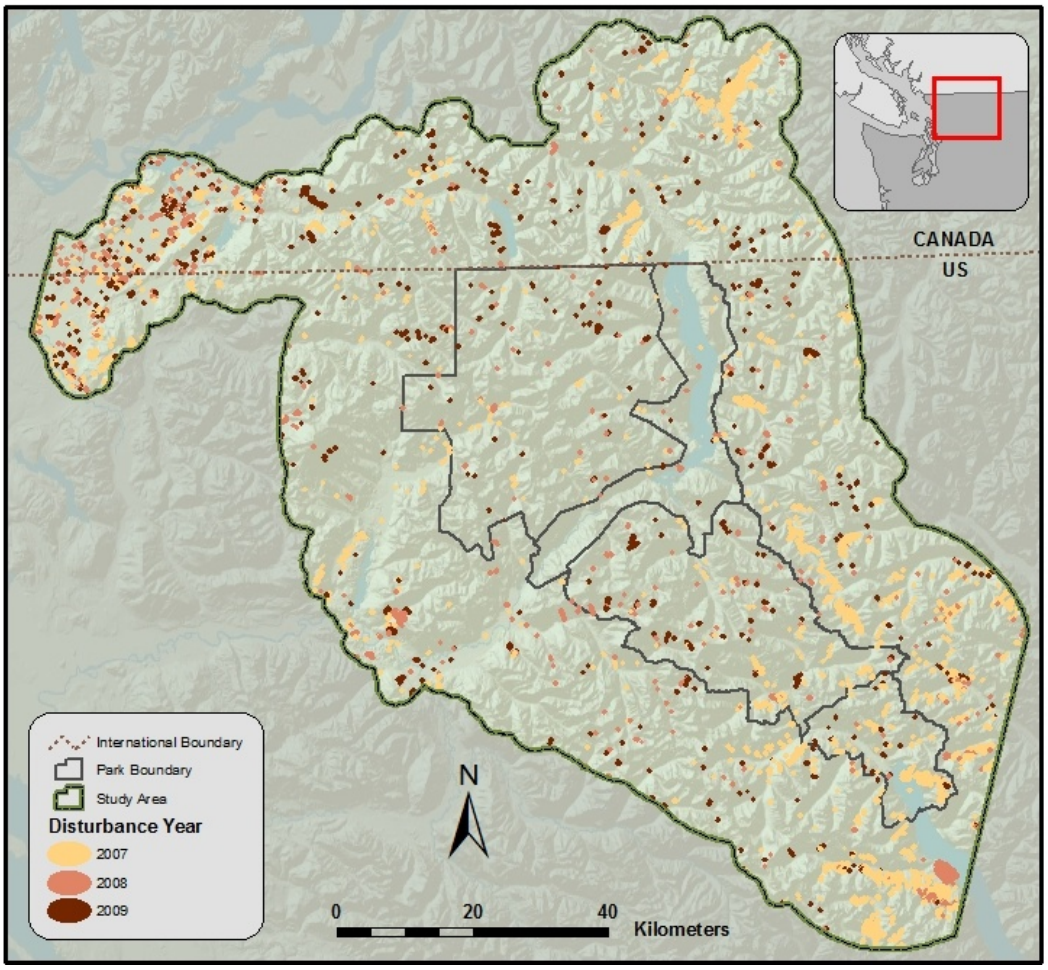


Figure B.3. Map of NOCA study area showing landscape change polygons by year of onset.

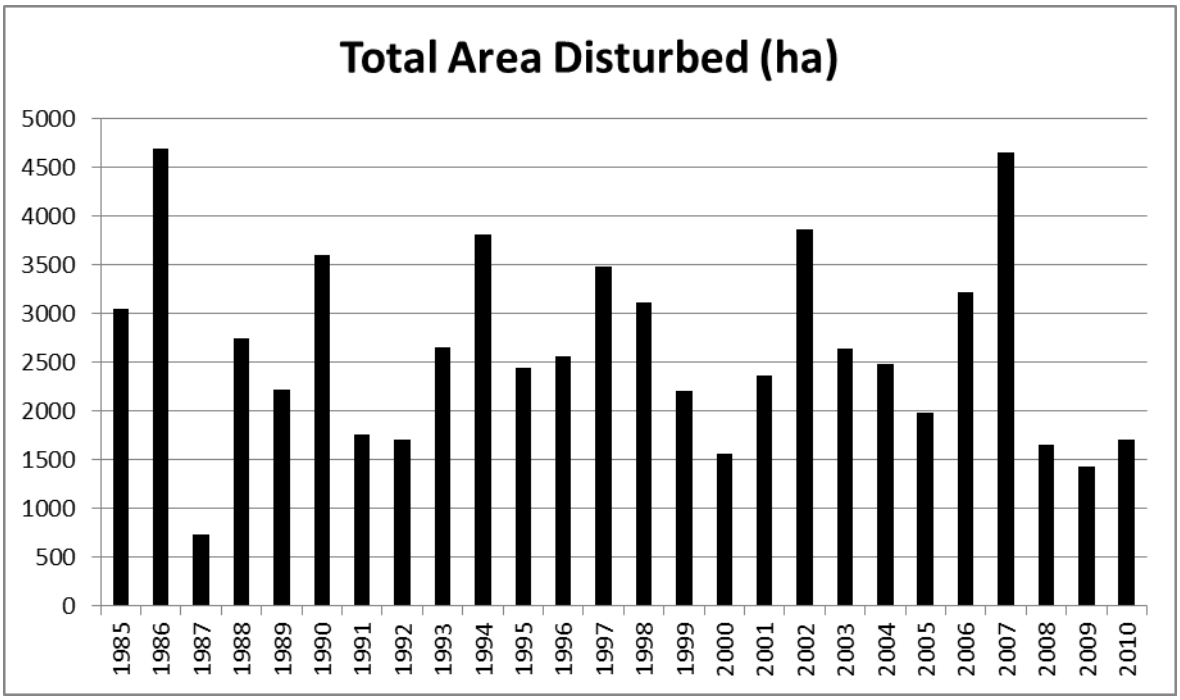


Figure B.4. Time series of total area disturbed for NOCA study area

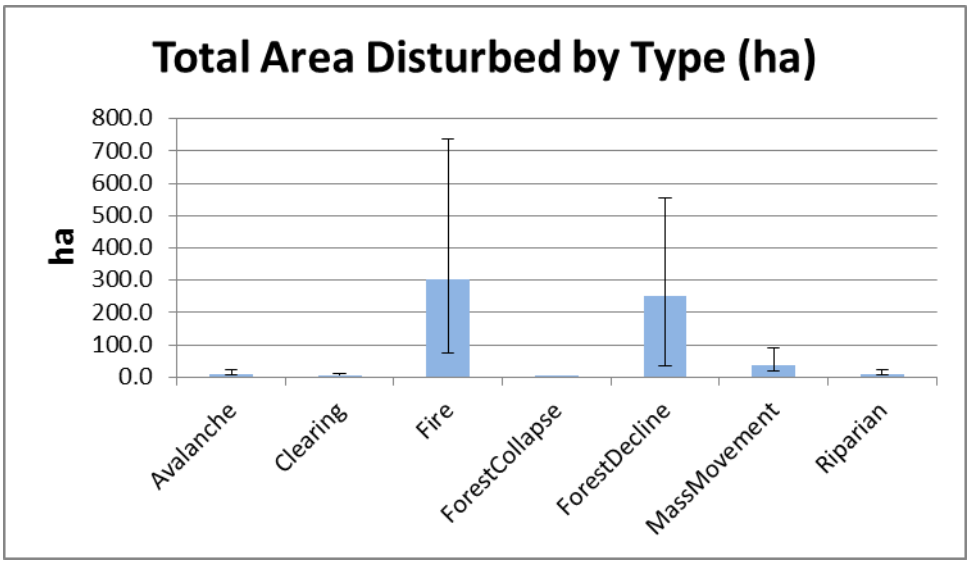


Figure B.5. Example data reporting for 2007 landscape changes inside NOCA, 2007. Total estimate of area includes upper and lower bounds calculated from the accuracy matrix.

Table B.4. Example error matrix for inside NOCA.

RF Model	Validation: Annual Variability	Avalanche	Clearing	Development	Fire	Tree Toppling	Progressive Defoliation	Mass Movement	Riparian	Unknown	**Grand Total**	User's Accuracy
Annual Variability	30						10	1		3	**44**	68.2
Avalanche	2	10			1		16	3	1	4	**37**	27.0
Clearing	1	5	29	1			2	1		1	**40**	72.5
Development				0							**0**	N/A
Fire		3			15		2				**20**	75.0
Tree Toppling						0	1				**1**	0.0
Progressive Defoliation	3	2			9		144			8	**166**	86.7
Mass Movement	3	1					1	5			**10**	50.0
Riparian	2	1			2				3	1	**9**	33.3
Unknown										0	**0**	N/A
Grand Total	**41**	**22**	**29**	**1**	**27**	**0**	**176**	**10**	**4**	**17**	**327**	
Producer's Accuracy	73.2	45.5	100.0	0.0	55.6	N/A	81.8	50.0	75.0	0.0		
Overall Accuracy	72.17											
Kappa Statistic	59.38											

A second accuracy matrix comparing office validation and field validation results will be shown in a similar manner.

Summary/Conclusions

- Description of differences among years.
- Further narrative about larger magnitude changes- origin, affect etc, including context in terms of important climate drivers
- Discussion of longer term trend

Appendix C: Yearly Project Task List

Table C.1. This table identifies each task by project stage, indicates who is responsible, and establishes the timing for its execution. Protocol sections and SOPs are referenced as appropriate.

Project Stage	Task Description	Responsibility	Timing
Preparation (*Section 3D, 3E; SOP 1, 6)*	Draft and submit task agreement modification to incorporate current FY year funding	Project Lead, Data Manager, and GIS Specialist	By May 1
	Distribute field observation forms to divisions, presentations at seasonal training etc. Update GPS data dictionaries.	Project Lead and GIS Specialist	By May 1
	Prepare project workspace for use	Project Lead	By Dec 31
	Update and deploy database application for data entry	Data Manager and GIS Specialist	by Sep 1
Data Acquisition (SOP 1)	Analysis period imagery, LandTrendr results and ancillary data sent by LARSE	LARSE	By Dec 31
	Relevant NAIP imagery processed and organized to facilitate analysis	GIS Specialist	By Dec 31
	QA/QC LandTrendr results for content	GIS Specialist	By Jan 15
Data Processing (*Section 2C and 2D; SOP 2,3 and4*)	Run filtering, attribute extraction and change labeling models for study area	GIS Specialist	By Jan 30
	Select validation polygons for inside and outside park boundary	GIS Specialist	By Feb 15
	Validate polygons, create accuracy matrix for outside park boundary	GIS Specialist	By April 1
Field Validation *(Section 2D; SOP 5)*	Select change polygons inside park for field validation	GIS Specialist	By April 15
	Recruit an intern and provide training	GIS Specialist	By July 1
	Conduct field validation	GIS Specialist /intern	By August 31
	Enter field data into database and verify all records. Process GPS data as needed.	GIS Specialist	By Sept 30
	Enter any incidental field data from the previous year into database. Associate incidental field observations with known change polygons.	GIS Specialist	By Sept 30
	Create accuracy matrix for inside park	GIS Specialist	By Sept 30
	Generate final change labels	GIS Specialist	By Sept 30
Quality Review (*Section 3J; SOP 7*)	Quality review and data validation using database tools (SOP 7)	GIS Specialist	By Oct 30
Metadata (*Section 4K; SOP 7*)	Update project metadata interview form	GIS Specialist	Nov
Data Certification & Delivery (*Section 4M; SOP 7 and 8*)	Certify the year's data and complete the certification report (SOP 8)	GIS Specialist	By Nov 30
	Deliver certification report, certified data, and updated metadata to Data Manager and GIS Specialist (SOP 7)	Project Lead	By Dec 1
	Store certified data files in project workspace (SOP 8)	Data Manager	Dec 15
	Review and update project geodatabase and associated metadata records (SOP 8)	GIS Specialist	Dec 15
	Finalize and parse metadata records, store in the project workspace (SOP 8)	Data Manager and GIS Specialist	By Dec 31

Table C.1. This table identifies each task by project stage, indicates who is responsible, and establishes the timing for its execution. Protocol sections and SOPs are referenced as appropriate (continued).

Project Stage	Task Description	Responsibility	Timing
Data Analysis[2] (*Section 3B*)	Analyze three years of data and test for trends. Prepare tables and maps of results for presentation in three-year report. Record results into project database	Project Lead, Data Manager, and GIS Specialist	Dec-Jan (following year)
Reporting & Product Development (*Section 3C; SOP 6*)	Export automated summary queries and reports from database	Project Lead, GIS Specialist	Dec-Jan (following year)
	Refer to the proper report template from the NPS website (http://www.nature.nps.gov/publications/NRPM/index.cfm); create annual report based on template (template will also be available in project workspace folder).	Project Lead, GIS Specialist	Dec-Jan (following year)
Product Delivery (*Section 3C; SOP 6*)	Submit draft I&M report to Network Program Manager for review	Project Lead	By Feb 30 (following year)
	Review report for formatting and completeness, notify Project Lead of approval or need for changes	Network Program Manager	March
	Upload completed report to NCCN Digital Library [1], notify Data Manager (SOP 7)	Project Lead	Upon approval
	Deliver other products according to the delivery schedule and instructions (SOP 7)	Project Lead	Upon completion
	Product check-in	Data Manager	Upon receipt
Posting & Distribution (*Section 3C SOP 6*)	Submit metadata to the NPS Data Store [2]	Data Manager	By Feb 30 (following year)
	Create an online reference record and post reports to the NPS Data Store [2]	Data Manager	Upon receipt
	Submit certified data and GIS data sets to the NPS Data Store [2]	Data Manager	Feb (after 2-year hold)
	Store finished products slated for permanent retention in NCCN Digital Library [1]	GIS Specialist	Upon completion
Archiving & Records Management (*Section 3L; SOP 6*)	Review, clean up and store and/or dispose of project files according to NPS Director's Order 19[3]	Project Lead	March (following year)
Annual Close-out (*Section 3M*)	Conference call to discuss annual analysis (close out); discuss who needs to do what to get data ready for analysis	Project Lead, Data Manager, and GIS Specialist, LARSE	April (following year)
	Discuss and document needed changes to analysis and reporting procedures	Project Lead and Data Manager	By May 31

[1] The NCCN Digital Library is a document management system implemented in Microsoft SharePoint for maintaining important digital files – such as reports, protocol documents, and select project images – within a content management system, and to make them available to NCCN and NPS users.

[2] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).

[3] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://data2.itc.nps.gov/npspolicy/DOrders.cfm.

Appendix D: NCCN Landscape Dynamics Monitoring Protocol Database Documentation

There are three database components for this project: the project relational database for storing and processing tabular and summary information; the geodatabase for spatial data storage and manipulation, and the TimeSync application for accomplishing data validation Note: Draft database documentation will be updated after the protocol has passed peer review.

This appendix documents the structure and contents of the three databases.

1. Project Database Documentation

The database for this project consists of three types of tables: core tables describing the "who, where and when" of data collection, project-specific tables, and lookup tables that contain domain constraints for other tables. Although core tables are based on NCCN standards, they may contain fields, domains or descriptions that have been added or altered to meet project objectives.

The database includes the following data tables:

tbl_Polygons	Change polygons across parks and years
tbl_GIS_Attributes	GIS attribute data for polygons
tbl_Model_Probabilities	Model probability matrix of change type by polygon
tbl_Transactions	Log of user and application transactions made on attribute data records
tbl_Events	Field observation event
tbl_Images	Images associated with field observation events
tbl_Observers	Observers associated with field observation events
tbl_QA_Results	Quality assurance query results for the working data set
tbl_Edit_Log	Edit log for changes made to data after certification

The following are a few of the more prominent lookup tables:

tlu_Attributes	List of GIS attributes used as model parameters and descriptive correlates
tlu_Change_Type	List of change types
tlu_Confidence_Code	List of user confidence codes for change type assignments
tlu_Project_Crew	List of personnel associated with a project

Figure D.1 shows the entity relationship diagram for the project database.

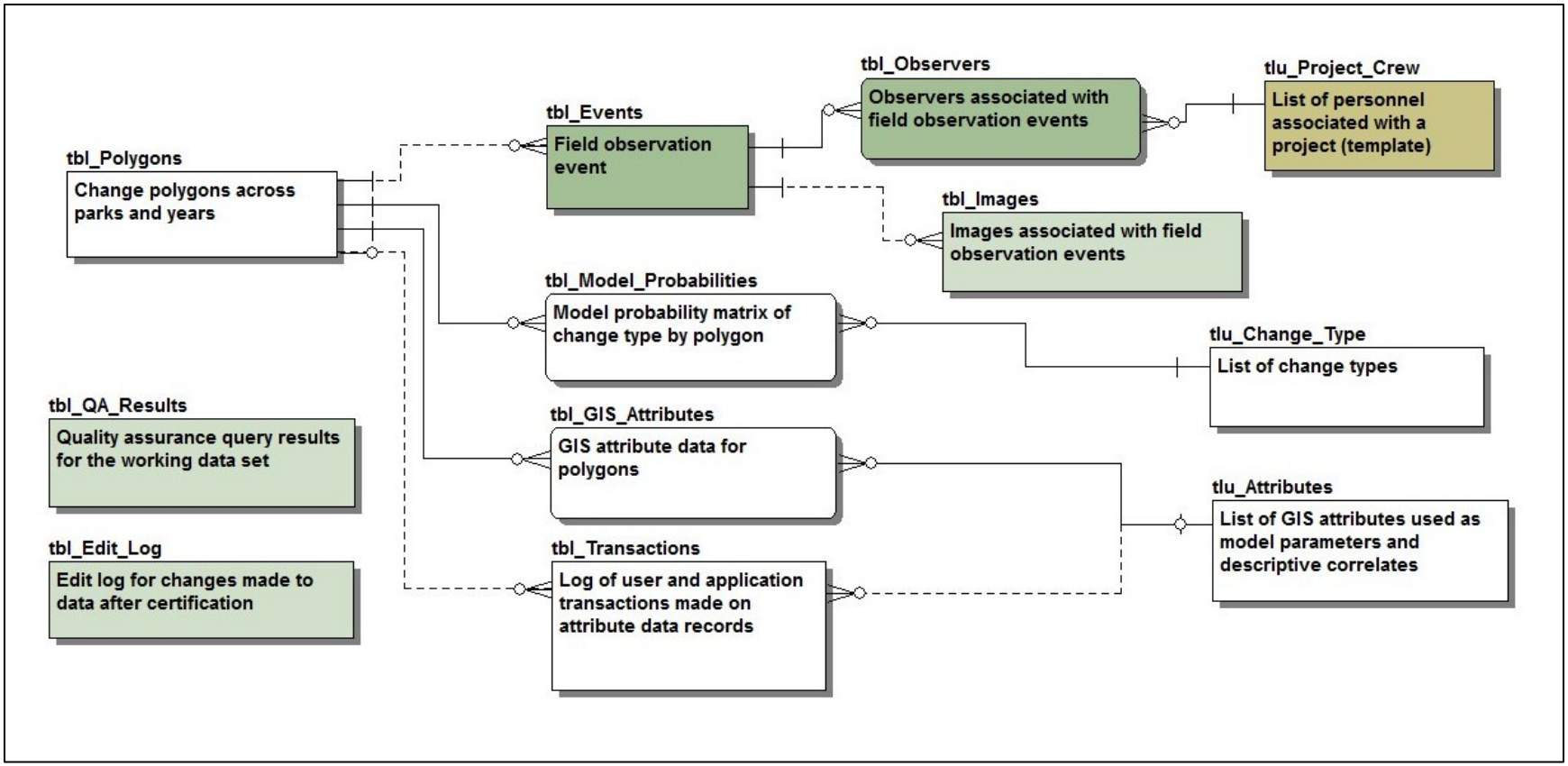


Figure D.1. Entity relationship diagram for the project database. Relationships between tables are represented by lines. Dark green tables represent core standard tables; light green represents extended standard tables; light brown are standard lookup tables. Project-specific tables are unshaded.

A. Data Dictionary

File name: Landscape Change Monitoring Database (LPa01)
Report date: 10/2/2012 10:21:02 AM

Required fields are denoted with an asterisk (*).

tbl_Edit_Log - Edit log for changes made to data after certification

Index	*Index columns*
Edit_date	Edit_date
Edit_type	Edit_type
pk_tbl_Edit_Log (primary)	Data_edit_ID
Project_code	Project_code
Table_affected	Table_affected
User_name	User_name

Field name	*Index/key*	*Data type*	*Description*
Data_edit_ID	primary *	text (50)	Unique identifier for each data edit record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "CLa01"		
Edit_date	indexed *	datetime	Date on which the edits took place
	Default: Now()		
Edit_type	indexed *	text (12)	Type of edits made: deletion, update, append, reformat, tbl design
Edit_reason	*	text (100)	Brief description of the reason for edits
User_name	indexed *	text (50)	Name of the person making data edits
Table_affected	indexed	text (50)	Table affected by edits
Fields_affected		text (200)	Description of the fields affected
Records_affected		text (200)	Description of the records affected
Data_edit_notes		memo	Comments about the data edits

tbl_Events - Field observation event

Index	*Index columns*
Alt_type	Obs_type
Analysis_yr	Disturbance_yr
Certified_date	Certified_date
Datum	Obs_datum
Entered_date	Entered_date
Park_code	Park_code
pk_tbl_Events (primary)	Event_ID
Polygon_ID	Polygon_ID
Project_code	Project_code
Updated_date	Updated_date
Verified_date	Verified_date
Visit_date	Visit_date

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary *	text (50)	Unique identifier for each event
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Park_code	indexed *	text (4)	Park with which the polygon is associated
Visit_date	indexed *	datetime	Date on which the field observation was made
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "LPa01"		
Disturbance_yr	indexed *	smallint	Year that the observer identified as the disturbance year
	Constraint: >=1900 And <=2100		
Polygon_ID	indexed (FK)*	int	Polygon associated with the field observation (determined in the office)
Obs_type	indexed	tinyint	Change type identified during the field observation event
Confidence		tinyint	User confidence in the primary change type identification
Other_types		text (255)	Other change types considered and why
Change_desc		memo	Observer description of the cause, duration, magnitude and timing of the disturbance, colors, textures, etc.
Photos_taken		tinyint	Indicates whether photographic images were recorded as part of the field observation
	Constraint: Is Null Or 0 Or 1		
Obs_UTME		int	UTM easting (zone 10N, meters) as recorded in the field
Obs_UTMN		int	UTM northing (zone 10N, meters) as recorded in the field
Obs_W_deg		single	Longitude in degrees West, as recorded in the field
Obs_W_min		single	Longitude decimal minutes, as recorded in the field
Obs_N_deg		single	Latitude in degrees North, as recorded in the field
Obs_N_min		single	Latitude decimal minutes, as recorded in the field
Obs_datum	indexed	text (5)	Datum of observed coordinates
	Default: "NAD83"		
Coord_source		text (12)	Source of coordinate data
Coord_notes		text (255)	Field comments about the observation coordinates
GPS_file_name		text (50)	GPS rover file used for data downloads
GPS_model		text (25)	Make and model of GPS unit used to collect field coordinates
X_final		int	UTM easting (zone 10N, NAD83, meters), including any offsets or manual adjustments
Y_final		int	UTM northing (zone 10N, NAD83, meters), including any offsets or manual adjustments
Event_notes		memo	Comments about the event record
Entered_by		text (50)	Person who entered the data for this event
Entered_date	indexed	datetime	Date on which data entry occurred
	Default: Now()		
Updated_by		text (50)	Person who made the most recent updates
Updated_date	indexed	datetime	Date of the most recent edits
Verified_by		text (50)	Person who verified accurate data transcription
Verified_date	indexed	datetime	Date on which data were verified
Certified_by		text (50)	Person who certified the record for accuracy and completeness
Certified_date	indexed	datetime	Date on which the record was certified
Is_excluded		bit	Flag to exclude the sampling event from data summary output
	Default: False		
QA_notes		memo	Quality assurance comments for the selected sampling event

tbl_GIS_Attributes - GIS attribute data for polygons

Index	*Index columns*
Polygon_ID	Polygon_ID
QA_flag	QA_flag
Attribute_ID	Attribute_ID
pk_tbl_GIS_Attributes (primary)	Polygon_ID, Attribute_ID

Field name	*Index/key*	*Data type*	*Description*
Polygon_ID	primary (FK)*	int	Change polygon
Attribute_ID	primary (FK)*	smallint	GIS attribute
Att_value		single	Attribute value
QA_flag	indexed	text (1)	Data quality flag value assigned to the record during the quality review
	Default: 0		
Certified	*	tinyint	Indicates whether this record has been through a documented quality review process
	Default: 0		
	Constraint: 0 Or 1		

tbl_Images - Images associated with field observation events

Index	*Index columns*
Event_ID	Event_ID
Image_label	Image_label
Image_quality	Image_quality
Image_type	Image_type
pk_tbl_Images (primary)	Image_ID
Sort_order	Sort_order

Field name	*Index/key*	*Data type*	*Description*
Image_ID	primary *	text (50)	Unique identifier for each image record
	Default: =Format(Now(),"yyyymmddhhnnss") & '-' & 1000000000*Rnd(Now())		
Event_ID	indexed (FK)*	text (50)	Sampling event
Image_type	indexed	text (20)	Type of image
	Default: "Ground photo"		
Image_label	indexed	text (25)	Image caption or label
Image_desc		text (255)	Brief description of the image bearing, perspective, etc.
Frame_number		text (10)	Frame number for photographic images
Image_date		datetime	Date on which the image was created, if different from the sampling event date
Image_source		text (50)	Name of the person or organization that created the image
Image_quality	indexed	tinyint	Quality of the image
Is_edited_version		bit	Indicates whether this version of the image is the edited (originals = False)
Object_format		text (20)	Format of the image
Orig_format		text (20)	Format of the original image
Image_edit_notes		text (200)	Comments about the editing or processing performed on the image
Image_is_active		bit	Indicates whether the image is still being used for navigation or interpretation
	Default: True		
Image_path		text (255)	Path for the image file
Image_filename		text (100)	Name of the image including extention (.jpg) but without the image path
Image_notes		memo	Comments about the image
Sort_order	indexed *	int	Sort order for displaying records in the order they were entered

tbl_Model_Probabilities - Model probability matrix of change type by polygon

Index	*Index columns*
Obs_type	Model_type
pk_tbl_Model_Probabilities (primary)	Polygon_ID, Model_type
Polygon_ID	Polygon_ID

Field name	*Index/key*	*Data type*	*Description*
Polygon_ID	primary (FK)*	int	Change polygon
Model_type	primary (FK)*	tinyint	Change type
P_value		single	Model probability value
Comments		text (255)	Remarks about the model change type probability record

tbl_Observers - Observers associated with field observation events

Index	*Index columns*
Contact_ID	Contact_ID
Event_ID	Event_ID
Observer_role	Observer_role
pk_tbl_Observers (primary)	Event_ID, Contact_ID, Observer_role

Field name	*Index/key*	*Data type*	*Description*
Event_ID	primary (FK)*	text (50)	Sampling event identifier
Contact_ID	primary (FK)*	text (50)	Observer identifier
Observer_role	primary *	text (25)	Role of the observer during data collection (optional)
Observer_notes		text (200)	Comments about the observer specific to this sampling event

tbl_Polygons - Change polygons across parks and years

Index	*Index columns*
Analysis_yr	Analysis_yr
Area_ha	Area_ha
Duration_yrs	Duration_yrs
Magnitude	Magnitude
Park_code	Park_code
pk_tbl_Locations (primary)	Polygon_ID
Polygon_num	Polygon_num
udx_tbl_Polygons (unique)	Analysis_yr, Park_code, Polygon_num
Valid_type	Valid_type
Valid_type1	Alt_type
Valid_type2	Model_type

Field name	*Index/key*	*Data type*	*Description*
Polygon_ID	primary *	int	Unique identifier for each polygon record across parks and years
Analysis_yr	unique *	smallint	Analysis year for the change polygon
	Constraint: >=1900 And <=2100		
Park_code	unique *	text (4)	Park with which the polygon is associated
Polygon_num	unique *	int	Numeric code assigned to each park polygon (repeated among parks and years)
X		single	Easting coordinate for the polygon centroid, in Albers coordinate system
Y		int	Northing coordinate for the polygon centroid, in Albers coordinate system
In_park		tinyint	Indicates whether the polygon is inside the park boundary
	Constraint: Is Null Or 0 Or 1		
Selected	*	tinyint	Indicates whether the polygon was selected for validation
	Default: 0		
	Constraint: 0 Or 1		

Is_final	*	tinyint	Indicates whether the validation for this polygon is complete
	Default: 0		
	Constraint: 0 Or 1		
Valid_type	indexed	tinyint	Primary change type identified during GIS validation
Confidence		tinyint	User confidence in the primary change type identification
Alt_type	indexed	tinyint	Alternative change type identified during GIS validation (e.g., in case of ambiguity)
Magnitude	indexed	single	Magnitude of change detected, in terms of percent reduction in cover from original cover type
	Constraint: Is Null Or (>=0 And <=100)		
Duration_yrs	indexed	single	Duration of the change, in years
	Constraint: Is Null Or (>=0 And <=100)		
Area_ha	indexed	single	Area of the change polygon, in hectares
Validation_date		datetime	Date on which the GIS validation was performed
Validation_by		text (50)	Person who performed the GIS validation
Validation_notes		text (250)	Comments about this record related to GIS validation
Model_type	indexed	tinyint	Most probable change type identified by the model
Model_date		datetime	Date on which change type modeling was performed
Veg_type		text (50)	Vegetation type prior to change
Elevation_m		single	Elevation at the centroid, in meters
Slope_deg		single	Slope steepness at the centroid, in degrees
Aspect_deg		single	Slope aspect at the centroid, in degrees
Polygon_notes		text (250)	General notes related to this polygon record
Created_date		datetime	Time stamp for record creation
	Default: Now()		
Updated_date		datetime	Date on which the most recent edits were made
Updated_by		text (50)	Person who made the most recent updates
Certified	*	tinyint	Indicates whether this record has been through a documented quality review process
	Default: 0		
	Constraint: 0 Or 1		
Certified_date		datetime	Date on which the record was certified
Certified_by		text (50)	Person who certified the record for accuracy and completeness
QA_notes		memo	Quality assurance comments for the selected event

tbl_QA_Results - Quality assurance query results for the working data set

Index	*Index columns*
Data_scope	Data_scope
pk_tbl_QA_Results (primary)	Query_name, Time_frame, Data_scope
Query_name	Query_name
Query_result	Query_result
Query_type	Query_type
Time_frame	Time_frame

Field name	*Index/key*	*Data type*	*Description*
Query_name	primary *	text (100)	Name of the quality assurance query
Data_scope	primary *	tinyint	Scope of the data included in queries: 0=Uncertified events only, 1=Both certified and uncertified, 2=Certified events only
Time_frame	primary *	text (30)	Field season year or range of dates for the data being passed through quality assurance checks
Query_type	indexed	text (20)	Severity of data errors being trapped: 1=Critical, 2=Warning, 3=Information
Query_result	indexed	text (50)	Query result as the number of records returned the last time the query was run
Query_run_time		datetime	Run time of the query results
Query_description		memo	Description of the query
Query_expression		memo	Evaluation expression built into the query
Remedy_desc		memo	Details about actions taken and/or not taken to resolve errors
Remedy_date		datetime	When the remedy description was last edited
QA_user		text (50)	Name of the person doing quality assurance
Is_done	*	bit	Temporary flag to indicate that the user is done reviewing this query even if some records remain

tbl_Transactions - Log of user and application transactions made on attribute data records

Index	*Index columns*
Action_code	Action_code
Attribute_ID	Attribute_ID
pk_tbl_Transactions (primary)	Trans_ID
Polygon_ID	Polygon_ID
QA_flag	QA_flag
Time_stamp	Time_stamp

Field name	*Index/key*	*Data type*	*Description*
Trans_ID	primary *	int	Unique identifier for each transaction
Time_stamp	indexed *	datetime	Transaction time stamp
	Default: Now()		
Action_code	indexed *	text (10)	Action taken during the transaction
User_name		text (50)	User name associated with the transaction
Polygon_ID	indexed (FK)	int	Polygon for data involved in the transaction (null for global updates/deletes, or for views on multiple sites)
Attribute_ID	indexed (FK)	smallint	Attribute affected by the transaction, if specific to a particular attribute (null for imports, delete operations, table views, etc.)
QA_flag	indexed	text (1)	Data quality flag value assigned individually or in bulk by the user
Trans_notes		text (255)	User annotations made at the time of the transaction
Completed	*	tinyint	Indicates whether the transaction was successfully completed
	Default: 0		
	Constraint: 0 Or 1		
Review_notes		memo	Other annotations made after the transaction record was made
Review_by		text (50)	User associated with the last review/edit to this record
Review_date		datetime	Timestamp of the last review/edit to this record

tlu_Action_Code - List of action codes used to log application transactions

Field name	*Index/key*	*Data type*	*Description*
Action_code	primary *	text (10)	
Action_desc		text (100)	
Sort_order		tinyint	

tlu_Attributes - List of GIS attributes used as model parameters and descriptive correlates

Index	*Index columns*
Att_group	Att_group
Attribute_name	Attribute_name
pk_tlu_Attributes (primary)	Attribute_ID
udx_tlu_Attributes (unique)	Attribute_code
Units	Units
Updated_date	Updated_date

Field name	*Index/key*	*Data type*	*Description*
Attribute_ID	primary *	smallint	Unique parameter identifier
Attribute_code	unique *	text (25)	Abbreviated code used as the column header for the attribute
Attribute_name	indexed	text (100)	Attribute name
Is_active	*	tinyint	Indicates that the attribute record is currently in use
	Default: 1		
	Constraint: 0 Or 1		
Att_group	indexed	text (20)	Grouping field for attributes (user-defined)
Units	indexed	text (25)	Attribute units (or blank if unitless)
Source_desc		text (255)	Description of the source of attribute data
File_name		text (100)	Name of the attribute GIS file
File_path		text (255)	Path to the attribute GIS file
Min_value		single	Threshold minimum value below which records are flagged as suspect during load operations
Max_value		single	Threshold maximum value above which records are flagged as suspect during load operations
Attribute_desc		memo	Definition of the attribute
Updated_by		text (50)	Person who made the most recent updates
Updated_date	indexed	datetime	Date of the most recent edits
	Default: Now()		

tlu_Change_Type - List of change types

Index	*Index columns*
Change_label (unique)	Change_label
pk_tlu_Change_Type (primary)	Change_code

Field name	*Index/key*	*Data type*	*Description*
Change_code	primary *	tinyint	Unique numeric code for each change type
Change_label	unique *	text (25)	Change type label
Type_desc		text (100)	Brief description of the change type
Definition		memo	More complete change type definition, including diagnostic characteristics
Is_active		tinyint	Flag to indicate whether the change type record is in active use (for picklists, etc.)
	Default: 1		
	Constraint: 0 Or 1		

tlu_Confidence_Code - List of user confidence codes for change type assignments

Index	*Index columns*
Confidence_label (unique)	Confidence_label
pk_tlu_Confidence_Code (primary)	Confidence_code

Field name	*Index/key*	*Data type*	*Description*
Confidence_code	primary *	tinyint	Unique numeric code
Confidence_label	unique *	text (25)	Confidence label
Confidence_desc		text (100)	Confidence level description

tlu_Coord_Source - List of coordinate data sources (standard)

Field name	*Index/key*	*Data type*	*Description*
Coord_source	primary *	text (12)	
Coord_source_desc		text (100)	
Sort_order		tinyint	

tlu_Datum - List of coordinate datum codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Datumprimary *		text (5)	
Datum_desc		text (50)	
Sort_order		tinyint	

tlu_Edit_Type - List of the types of post-certification edits made to data (standard)

Field name	*Index/key*	*Data type*	*Description*
Edit_type	primary *	text (12)	
Edit_type_desc		text (100)	
Sort_order		tinyint	

tlu_GPS_Model - List of GPS devices used to collect coordinate data (template)

Field name	*Index/key*	*Data type*	*Description*
GPS_model	primary *	text (25)	
Sort_order		tinyint	

tlu_Image_Format - List of image, map, and photographic formats (template)

Field name	*Index/key*	*Data type*	*Description*
Image_format	primary *	text (12)	
Image_format_desc		text (100)	
Sort_order		tinyint	

tlu_Image_Quality - List of quality ranks for images (template)

Index	*Index columns*
Image_quality (unique)	Image_quality
pk_tlu_Image_Quality (primary)	Quality_code

Field name	*Index/key*	*Data type*	*Description*
Quality_code	primary *	tinyint	
Image_quality	unique *	text (20)	
Image_quality_desc		text (100)	

tlu_Image_Type - List of image types (template)

Field name	*Index/key*	*Data type*	*Description*
Image_type	primary *	text (12)	
Image_type_desc		text (100)	
Sort_order		tinyint	

tlu_Observer_Role - List of observer role assignments (template)

Field name	*Index/key*	*Data type*	*Description*
Observer_role	primary *	text (25)	
Role_desc		text (100)	
Sort_order		tinyint	

tlu_Parks - List of NCCN parks and park codes (standard)

Field name	*Index/key*	*Data type*	*Description*
Park_code	primary *	text (4)	
Park_name		text (50)	

tlu_Project_Crew - List of personnel associated with a project (template)

Index	*Index columns*
pk_tlu_Project_Crew (primary)	Contact_ID
Project_code	Project_code
Contact_location	Contact_location
Contact_updated	Contact_updated
First_name	First_name
Last_name	Last_name
Organization	Organization

Field name	*Index/key*	*Data type*	*Description*
Contact_ID	primary *	text (50)	Unique identifier for the individual (Lastname_Firstname_MI)
Project_code	indexed *	text (10)	Project code, for linking information with other data sets and applications
	Default: "LPa01"		
Last_name	indexed *	text (24)	Last name
First_name	indexed	text (20)	First name
Middle_init		text (4)	Middle initials
Organization	indexed	text (50)	Employer (e.g., NPS-MORA)
Position_title		text (50)	Position title held by the individual
Email		text (50)	Email address
Work_voice		text (25)	Work phone number
Work_ext		text (5)	Work extension number
Mobile_voice		text (25)	Mobile phone number
Home_voice		text (25)	Home phone number
Fax		text (25)	Fax number
Contact_location	indexed	text (255)	Where the individual is located
Contact_notes		memo	Notes about the contact
Contact_created		datetime	Time stamp for record creation
	Default: Now()		
Contact_updated	indexed	datetime	Date of the last update to this record
Contact_updated_by		text (50)	Person who made the most recent edits
Contact_is_active		bit	Indicates that the contact record is currently available for data entry pick lists
	Default: True		

tlu_QA_Flag - List of data quality flags

Index	*Index columns*
Flag_code (unique)	Flag_code
pk_tlu_QA_Flag (primary)	Flag_ID

Field name	*Index/key*	*Data type*	*Description*
Flag_ID	primary *	text (1)	
Flag_code	unique *	text (50)	
Flag_desc		text (200)	

2. GeoDatabase Documentation

The GIS Specialist is responsible for development and maintenance of the project geodatabase. The ArcGIS™ file geodatabase contains change polygons with limited attributes retained for mapping and report purposes. The project geodatabase resides in \Data\Geodatabase\ directory and is named LPa01_Landscape_Change.gdb. The project geodatabase contains landscape change polygons for all parks participating in the project from 1985 to the present (Figure D.2).

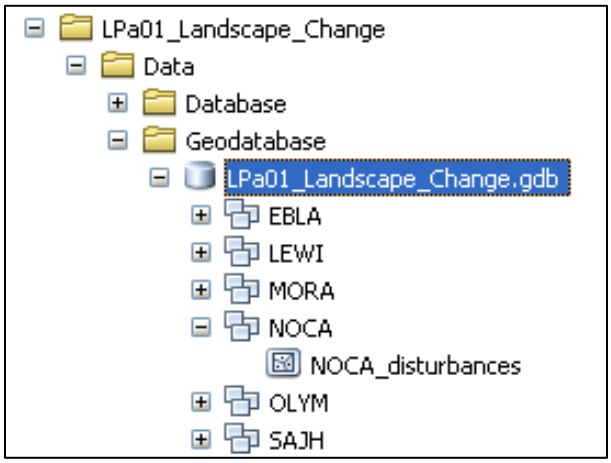


Figure D.2. Screenshot of the project geodatabase organization.

There is a feature dataset for each park containing landscape change polygons and limited attributes needed to for map generation or simple statistical analysis (Figure D.3).

Field Name	Data Type
OBJECTID	Object ID
Shape	Geometry
Location_code	Double
Final_agent	Text
In_park	Text
Magnitude	Float
Analysis_year	Short Integer
Shape_Length	Double
Shape_Area	Double

Figure D.3. Disturbance feature class fields.

3. TimeSync Application Documentation

Every year the GIS Specialist will create a new Access database for use in TimeSync. Templates of the database for each Landsat scene are provided with the protocol. The database contains coordinates and IDs for polygon centroids identified for validation. These centroids are used by TimeSync to display polygon's spectral trajectory and to locate the polygon on Landsat image chips. A separate database template is provided for each Landsat Scene. The template database is located in \Spatial_info\PARK\SCENE\timesync\ directory and is called

SCENE_timesync_template.mdb. The database contains tables with information necessary to run TimeSync (Figure D.4)

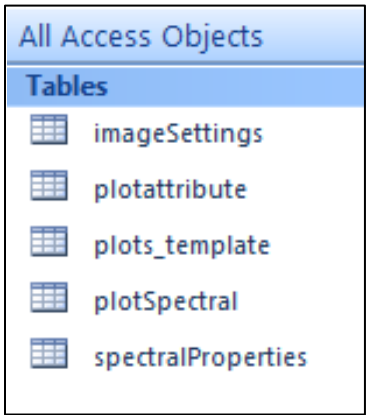


Figure D.4. Screenshot of the tables contained in the TimeSync validation database.

Tables "imageSettings," "plots_template" and "spectralProperties" are the only ones necessary for the type of validation NCCN is conducting. However, the other two tables are necessary for the TimeSync to open correctly and should remain in the database, even if not used. In Table D.1 below the field structure for each of the tables found in the database SCENE_timesync_template.mdb is documented.

Table D.1. Field name, type and size of fields included in SCENE_timesync_template.mdb database.

Table	Field Name	Type	Size
imageSettings	bgw_image_list	Text	255
	refl_image_list	Text	255
	scaler	Double	8
plotattribute	plotid	Long Integer	4
	imagedate	Text	255
	tree	Integer	2
	nontreeveg	Integer	2
	open	Integer	2
	shadow	Integer	2
	source	Text	255
plots_template	PLOTID	Long Integer	4
	X	Double	8
	Y	Double	8
plotSpectral	plotid	Long Integer	4
	imagedate	Text	50
	b	Double	8
	g	Double	8
	w	Double	8
	b5	Double	8

Table D.1. Field name, type and size of fields included in SCENE_timesync_template.mdb database (continued).

Table	Field Name	Type	Size
	pixelcount	Long Integer	4
	isvertex	Yes/No	1
	description	Text	255
	image	OLE Object	-
	interpreter	Text	255
	cover	Text	255
	coverconfidence	Text	255
	segmentconfidence	Text	255
	comments	Memo	-
spectralProperties	spectralid	Long Integer	4
	bmin	Double	8
	bmax	Double	8
	bmean	Double	8
	bstd	Double	8
	gmin	Double	8
	gmax	Double	8
	gmean	Double	8
	gstd	Double	8
	wmin	Double	8
	wmax	Double	8
	wmean	Double	8
	wstd	Double	8
	description	Text	255
	b5min	Double	8
	b5max	Double	8

Appendix E. Job Hazard Analysis

The Job Hazard Analysis for the Landscape Dynamics Monitoring Protocol is presented in the following Figure E.1.

JOB HAZARD ANALYSIS (JHA)	Date:	**page 1 of 4**
Park Unit: **EBLA, LEWI, MORA, NOCA, OLYM, SAJH**	JOB TITLE: **Landscape Change Validation**	Analysis by:
	Job Performed by:	Reviewed by:
Division: **Resource Management**	Supervisor: **Catharine Thompson**	Approved by:
Tools and Equipment:	GPS units, notebooks, handheld radios, spare batteries for radios and GPS units, first aid kits, field maps.	
Personal Protective Equipment:	Standard field apparel: long pants, long-sleeved shirts, boots with ankle support. Sun protection: sun screen, sun glasses,	
Training and/or certifications	Good physical condition	
A. SEQUENCE OF JOB STEPS	**B. POTENTIAL JOB HAZARDS**	**C. SAFE ACTIONS AND PROCEDURES**
Office Work- computer use for email, data entry and analysis	Muscle and eye strain, repetitive stress injury	* Proper posture and use of ergonomic furniture * Take breaks every hour; stretch
Travel to Site in Vehicle	Vehicle condition	* Be familiar with the vehicle and its operation
	Weather	* Check gauges, tires, fluids and exterior
	Road Conditions	* Check for spare tires, jumper cable and jack
	Other Drivers	* Use defensive driving techniques- anticipate traffic situations
	Animals	which develop far ahead of your vehicle
	Backing Vehicle	* Obey traffic laws and wear seatbelt at all times
		* Reduce speed when driving on wet serufaces or rough roads
		* Do not talk on radio or cell phone while driving
		* Do not put hot drinks on your lap
		* Do not drive when distracted, tired or ill
		* Be vigilant for park visitors and wildlife in or near the road
Hiking to work areas on trails, routes or off trail navigation	Losing a crew member	* Have a travel plan for each day and make sure it is understood by all crewmembers
		* Stop at trail junctions and regroup
		* Arrange meeting places and times - all crewmembers must wear a watch
		* Travel in a group when possible; travel at least in radio pair; always travel together when off-trail
		* Stay in communication via radio or stay in sight
		* Carry radio and spare batteries
		* Carry a whistle to use if lost; signal in threes to indicate SOS
		* Do not panic - have a mental plan for what to do if lost
		* If lost, follow prearranged procedures (most likely to stay put); have emergency equipment (food, shelter, heat, clothing) ; if lost for a long period, consider moving to an area where you can be seen by helicopter (gravel bar or ridge top); do not leave your gear if you travel

Figure E.1. Job Hazard Analysis form.

JHA - CONTINUATION SHEET	JOB TITLE: **Landscape Change Validation**	page 2 of 4
A. SEQUENCE OF JOB STEPS	**B. POTENTIAL JOB HAZARDS**	**C. SAFE ACTIONS AND PROCEDURES**
Hiking to work areas on trails, routes or off trail navigation - cont'd	Traveling on rough uneven terrain, steep slopes and forested slopes	* Wear sturdy boots with good soles; dig in heels while descending; use trees and solid rocks for handholds when they are available; use trekking poles; move slowly and deliberately across steep areas
		* Have map and compass and other navigational aids and know how to use them
		* Be aware of slippery situations: 1) bare rock covered with small rocks, moss, or leaves; 2) stumps and branches; 3) wet rocks and logs
		* When traveling in areas with loose rock or scree stagger your positions so that you are not immediately below someone; yell "rock" if you dislodge one
		* Be aware of branches at face level even when you are focusing on the ground
		* Be aware of unstable and loose rocks
		* When crossing snow fields, use trekking poles or ice axes for stability; kick steps in the snow surface; plant feet deliberately, and move slowly; use plunge steps when descending snowy slopes; practice fall-arrest techniques (roll onto stomach, dig elbow, feet and knees in); avoid traveling on snow in early morning or on a cold day when the surface may be frozen
	Lightening storms	* Turn your radio off
		* If near vehicle, get entirely inside
		* If in the out of doors: separate the group; get off ridge tops and away from trees; get as low as possible and lie on non-conductive material such as a thermarest
		* As a last resort, assume a crouch position on the ground with the weight on the balls of your feet, your feet together, head lowered, and ears covered
	Wind storms	* If it is windy enough to blow small twigs and branches out of the trees, try to get out of the woods or find an area away from hazard trees
	Hypothermia	* Layer your clothing such that it will be easy to regulate your body temperature by adding or subtracting layers; DO NOT wear cotton as a layer; wear clothing that stays warm when wet, such as wool or clothing made from synthetic material
		* Remove wet clothing immediately after hiking; carry spare layers in accessible part of pack
		* Recognize the signs of hypothermia in yourself and others
		* Have shelter such as tent, sleeping bag or emergency shelter
		* Have the means to create heat such as matches or a stove
		* Carry and eat high-calorie foods; stay well-hydrated
	Exposure to heat and sun	* Have hat, sunscreen and sunglasses, long sleeves and pants
	Dehydration/Exhaustion	* Take frequent rest stops (15 min per every 2 hours) and stay hydrated- keep water accessible
		* Recognize the signs of dehydration (headache, fuzzy, dizzy)
	Injuries	* Have first aid kit, stabilize injured person, treat for shock and know how to initiate rescue via radio
		* Reduce pack weights when possible
		* Pay attention to how you put your pack on - avoid twisting motions; get help to put your pack on or place pack on surface or against tree
		* Make sure your pack is properly fit and well packed (heavy items centrally located and balanced)
		* Follow safe crossing techniques: unhook your pack; grab each other by the back, forming an chain; use a brace such as a stick or trekking poles; travel diagonally upstream against flow; watch for debris and other hazards
		* What is downstream of you creates your biggest threat - scout out a crossing that would put you in the least danger if you were to be taken by the current
		* Waterproof items in pack, epecially the bottom
		* Have sandals
		* Be careful on slippery logs

Figure E.1. Job Hazard Analysis form (continued).

JHA - CONTINUATION SHEET	JOB TITLE: **Landscape Change Validation**	page 3 of 4
A. SEQUENCE OF JOB STEPS	**B. POTENTIAL JOB HAZARDS**	**C. SAFE ACTIONS AND PROCEDURES**
Camping and working in the outdoors	Exposure to allergy causing plants and insects	* Alert crew members to possible problems with allergens; be alert for toxic plants and alert to common bee and wasp nesting habitat and activity-especially the person in front
		* Carry Benadryl®, epi-pen or other anti-histimine, headnet, bug repellent, bug net or bug tent; anyone can have an allergic reaction to bug bites; over-scratching bites can cause infection; keep areas clean
		* Do not eat any fungi or plant unless you are 100% sure it is edible; do not eat any mushroom unless it has been cooked
	Exposure to Giardia, E. coli and other pathogens	* Do not drink any water unless it has been filtered, boiled or treated in some fashion
		* Urinate away from streams and water; dig a cathole for solid waste and bury toilet paper
		* Clean all cooking gear during and between tours with hot water and soap; bring your toothbrush
		* Wash hands when possible and carry hand cleaner.
	Burns and lacerations	* Cut away from yourself and on a hard surface
		* Wear your boots. Pour hot water away from self, use appropriate implement to handle hot pots and stove
		* Do not put face directly near stove when lighting, do not overprime stove
		* Use stove on flat, cleared area, do not overprime stove
	Malnutrition	* Make sure the stove is working when you start your tour and has all appropriate parts, know how to use and repair stove, have spare parts and instructions for stove, spare lighters and have sufficient gas for tour
		* Bring a variety of healthy, nutritious food that will give you good energy during travel and work; do not rely on sugar snacks
		* Pay attention when packing food for tour; use list and check it several times; don't pack at the last minute
		* Prevent animals from getting into your food by hanging it in bucket or using a bear canister; bring a bag, rope and clip to hang food.
	Wildlife encounters	* Give bears a wide berth; if approached by bear or cougar, make yourself large and noisy, wave arms, yell, bang pots, grab a stick, and back away; do not run; if attacked, fight back; report incident to the park's wildlife biologist
	Strange or aggressive human interactions	* Terminate contact with visitor and leave the area; contact dispatch

Figure E.1. Job Hazard Analysis form (continued).

INSTRUCTIONS FOR COMPLETING THE JOB HAZARD ANALYSIS FORM

Job Hazard Analysis (JHA) is an important accident prevention tool that works by finding hazards and eliminating or minimizing them *before* the job is performed, and *before* they have a chance to become accidents. Use your JSA for job clarification and hazard awareness, as a guide in new employee training, for periodic contacts and for retraining of senior employees, as a refresher on jobs which run infrequently, as an accident investigation tool, and for informing employees of specific job hazards and protective measures. Set priorities for doing JHA's: jobs that have a history of many incidents, jobs that have produced disabling injuries, jobs with high potential for disabling injury or death, and new jobs with no accident history. Here's how to do each of the three main parts of a Job Hazard Analysis:

SEQUENCE OF JOB STEPS

Break the job down into steps. Each of the steps of a job should accomplish some major task. The task will consist of a *set* of movements. Look at the first *set* of movements used to perform a task, and then determine the next logical *set* of movements. For example, the job might be to move a box from a conveyor in the receiving area to a shelf in the storage area. How does that break down into job steps? Picking up the box from the conveyor and putting it on a hand truck is one logical set of movements, so it is one job step. Everything is related to that one logical set of movements is part of that job step.

The next logical *set* of movements might be pushing the loaded hand truck to the storeroom. Removing the boxes from the truck and placing them on the shelf is another logical set of movements. And finally, returning the hand truck to the receiving area might be the final step in this type of job.

Be sure to list *all* the steps in a job. Some steps might not be done each time checking the casters on a hand truck, for example. However, that task is a part of the job as a whole, and should be listed and analyzed.

POTENTIAL HAZARDS

Identify the hazards associated with each step. Examine each step to find and identify hazards – actions, conditions, and possibilities that could lead to and accident.

It's not enough to look at the obvious hazards. It's also important to look at the entire environment and discover every conceivable hazard that might exist.

Be sure to list health hazards as well, even though the harmful effect may not be immediate. A good example is the harmful effect of inhaling a solvent or chemical dust over a long period of time.

It's important to list *all* hazards. Hazards contribute to accidents, injuries, and occupational illnesses.

In order to do part three of a JHA effectively, you must identify potential and existing *hazards*. That's why it's important to distinguish between a hazard, and accident and an injury. Each of these terms has a specific meaning:
HAZARDS – Potential danger. Oil on the floor is a hazard.
ACCIDENT – An unintended happening that may result in injury, loss or damage. Slipping on the oil is an accident.
INJURY – The result of an accident. A sprained wrist from the fall would be an injury.

Some people find it easier to identify possible accidents and illnesses and work back from them to the hazards. If you do that, you can list the accident and illness types in parentheses following the hazard. But be sure you focus on the *hazard* for developing recommended actions and safe work procedures.

SAFE ACTION OR PROCEDURE

Using the first two columns as a guide to decide what actions are necessary to eliminate or minimize the hazards that could lead to an accident, injury, or occupational illness.

Among the actions that can be taken are, 1) engineering the hazard out; 2) providing personal protective equipment; 3) job instruction training; 4) good housekeeping; and 5) good ergonomics (positioning the person in relation to the machine or other elements in the environment in such a way as to eliminate stresses and strains).

List recommended safe operating procedures on the form, and also list required or recommended personal protective equipment for each step of the job.

Be specific. Say *exactly* what needs to be done to correct the hazard, such as, "lift using your leg muscles." Avoid general statements like, "be careful."

Give a recommended action or procedure for *every* hazard.

If the hazard is a serious one, it should be corrected immediately. The JSA should then be changed to reflect the new conditions.

Figure E.1. Job Hazard Analysis form (continued).

Appendix F: Administrative History

Protocol Version 1 (2000-2007)

As part of the National Park Service's larger goal of developing long-term monitoring programs in response to the Natural Resource Challenge of 2000, the North Coast and Cascades Network (NCCN) parks determined that monitoring landscape dynamics was necessary to track the health of park ecosystems (Weber et al. 2005). Dr. Andrea Woodward, United States Geologic Survey (USGS), provided primary guidance during this phase of protocol development. In 2002, a workshop was held, which began the process of defining strategies for remote-sensing based monitoring (Woodward et al. 2002). One of the central conclusions of this workshop was that Landsat Thematic Mapper/Enhanced Thematic Mapper (TM/ETM+) data should serve as the core tool for NCCN landscape change monitoring.

USGS was the primary lead for developing the first version of the protocol. Based on the interest in using Landsat, USGS partnered with the U.S. Department of Agriculture Forest Service (USFS) via cooperative agreement 03WRPG0008. Work was split into three tasks: 1) develop a study plan, 2) test and evaluate a protocol, 3) protocol writing, and 4) protocol revision. The first meeting with NPS personnel was held on January 14th, 2004. The goal of this meeting was to identify and prioritize monitoring goals. Priorities were revisited and adjusted at a second meeting on May 13th, 2004, so that only monitoring goals that were identified as achievable using TM/ETM+ data were retained. An important decision in this early stage was to use a change-focused monitoring in order to only track landscape change through time, in contrast with starting with a baseline map and monitoring landscape change as compared to that baseline.

The USFS then produced a protocol for using two-date change detection to find landscape changes. Version 1 of the protocol was available by July 5, 2005 and Version 2 by March 31, 2006. The final version was published by the USGS in 2007 (Kennedy et al. 2007). The protocol contained detailed SOPs for all phases of implementation. At this time, Natalya Antonova, GIS specialist at NOCA, and Katherine Beirne, GIS specialist at OLYM, implemented the protocol for MORA, NOCA and OLYM.

Protocol Implementation (2007-2009)

Several key modifications were made to the protocol's initial startup phase SOP, compared to as originally designed. First, baseline images from 2004 and 2005 were used in order to utilize contemporary NPS field data, rather than data from the previous decade. Second, the OLYM baseline image development method had to be substantially altered to accommodate the fact that OLYM is covered by multiple Landsat scenes. In the change detection phase, the 2005 baseline image (2004 for OLYM) was compared to a 2006 image. The results from the two-date change detection demonstrated that the current protocol could successfully detect the types of change of interest to the NCCN. However, the results were overwhelmingly dominated by a large amount of "uninteresting" change due to differences in phenology, cloud cover, shadows and snow, and image-to-image registration. Techniques for reducing this type of change were explored, including: developing cloud, shadow and snow masks; and increasing the minimum mapping unit. False change due to differences in phenology remained particularly intractable.

Difficulties were also encountered during the change validation and accuracy assessment phases of protocol implementation. Individual interpreters varied in their approach to the validation

process, both in delineating polygons and handling fuzzy boundaries. The accuracy assessment became more of a measure of how well the interpreted mimicked the computer algorithm process, rather than an assessment of how well the algorithm mapped real change. The protocol implementation, results, and challenges as outlined above are summarized in a Natural Resource Technical Report (Antonova et al. 2010).

In summary, the first version of the protocol incorporated the best remote sensing methods for two-date change detection available at the time, but meaningful result were overwhelmed by uninteresting change that the method detected.

Assessing and Adopting New Methods (2009-2012)

In 2008, the USGS, who had been tasked with protocol development, culminated their participation at North Coast and Cascades Inventory and Monitoring Network 3-year Start-up Review, which occurred from November 26-30, 2007 (Fancy 2008). This transition left the landscape dynamics vital sign without an assigned NPS lead.

During the review meeting, the NCCN assigned priorities to the vital signs in order to help prioritize the limited funding available to distribute across all 14 vital signs for which protocols were under development. In a process of peer voting, landscape dynamics remained as a top, or "Tier-1" vital sign (Fancy 2008), reflecting the substantial and continued support by the NCCN Board of Directors and technical committee. In the fall of 2008, Dr. Catharine Copass Thompson was invited to take on the role of the Protocol Lead as it complemented other duties related to vegetation inventory and mapping.

In the time between the development and implementation of the version 1 of the landscape change protocol, the USFS two-date change detection method evolved considerably in response to the release of the entire Landsat archive. The existence of improved methods made it difficult to envision continuing with the first version of the protocol. In May, 2010, NCCN commenced a new cooperative agreement with Oregon State University (J8W07100011) to explore the utility of using the new LandTrendr approach, and, if it was usable, to also explore methods for labeling change polygons with their agent of change. The collaborative work was extended to include the development of version 2 of the protocol. In addition to the update to the change detection methods used for monitoring, one other major difference between the first and second versions of the protocols is that the Version 1 also budgeted for aerial photography to be flown for each park approximately every 7 years. Version 2 of the protocol will rely on the freely-available National Agricultural Imagery Program (NAIP) photos, which should be available every 2-3 years.

Two elements of the development work for Version 2 of the protocol received support from non-I&M funding sources. In 2011, Natalya Antonova received a grant from the PWR GIS Call in order to develop the ArcGIS models used to filter LandTrendr results. Support was also received from the NCCN Science Learning Network to fund the summer internship program through Western Washington University, (via cooperative agreement J8W07110003), which tested the office and field validation methods.

The draft of protocol Version 2 was submitted for NPS peer review in December, 2012.

Literature Cited

Antonova, N. V., K. Beirne, and C. C. Thompson. 2010. Implementation of landscape dynamics monitoring at the North Coast and Cascades Network: initial assessment of change detection methods. Natural Resource Report NPS/NCCN/NRTR—2010/328. National Park Service, Fort Collins, Colorado.

Fancy, S. 2008. 3-year start-up review of the North Coast and Cascades Inventory & Monitoring Network report and recommendations by the Interagency Review Panel.

Weber, S., A. Woodward, and J. Freilich. 2009. North Coast and Cascades Network vital signs monitoring report (2005). Natural Resource Report NPS/NCCN/NRR—2009/098. National Park Service, Fort Collins, Colorado.

Woodward, A., S. A. Acker, and R. Hoffman, 2002. Use of remote sensing for long term ecological monitoring in the North Coast and Cascades Network: Summary of a Workshop. USGS. http://fresc.usgs.gov/olympic/research/rewkspsummary.pdf.

SOP 1: Acquiring LandTrendr Data and Scenes

Revision Date	Author	Changes Made	Reason for Change

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1. Overview

The work described in this protocol represents a highly collaborative endeavor between the NCCN and LARSE. Information flows during the annual project cycle such that processed imagery and LandTrendr results come from LARSE and are further processed by the NPS. Close contact is maintained during the processing and analysis phase. Analyzed data, maps and description of trends and conclusions of general interest are reported back to LARSE. This SOP outlines the needed administrative tasks to facilitate the cooperation with LARSE. It explains the annual timeline and process for administering cooperative agreements through the PNW Cooperative Ecosystems Study Unit (CESU- http://www.cfr.washington.edu/research.cesu/- accessed 11/11), lists necessary documentation and provides examples of needed text for these documents. It also gives a detailed list of data to be processed by LARSE and when deliverables are needed in order to meet protocol delivery commitment, which should facilitate the drafting of annual modification or any future cooperative agreements. This SOP should be updated with actual agreement documents once the first agreement is drafted, in the meantime, selections from other current agreements will serve as placeholders and provide example text as those documents are drafted.

2. Timeline and Process for Administering Cooperative Agreements

The Project Lead, GIS Technician, or someone else closely affiliated with the protocol will need current certification as Agreements Technical Representative (ATR) in order to be the key official on the task agreements. All agreements are considered task agreements off the umbrella agreement that describes the relationship between the member institutions (including Oregon State University, with which LARSE). Once signed, agreements generally last no more than 5 years. Once created, agreements can be modified to accommodate changes in funding, workplan, deliverables, key officials or other details.

This SOP assumes that a 5 year task agreement has already been put into place. Each year, this agreement will need to be modified to add annual funding or modify the workplan. Every year the following steps will need to be followed. This information is taken from http://www.cfr.washington.edu/research.cesu/Announcements/PWR_CESU_Brief_Steps_doc_2012.pdf (accessed 5/12).

1. December - contact CESU NPS Research Coordinator (currently Chris Lauver) and let him or her know you intend to submit a modification to the agreement.

2. By March 15 - prepare and submit IAGP (Individual Agreement Plan) by uploading it to the PWR contracting home page. http://inpniscsfern1:8000/sites/PWR/pwrcontracting/SitePages/Home.aspx. The IAGP requires the following information:

Table 1.1. Fields needed for IAGP.

IAGP Field Name
IAGP Number
PR Number
Park/Office
ATR Name
Date Prepared
Cooperator Name
Project Description
Key Officials
Proposed Start Date
Date Agreement Submitted to Contracting
Estimated Amount
Funding Source
Who will Certify for Funds Account number

3. Prepare a draft agreement modification using the current CESU template. For this protocol, the modifications with typically add the current year's funds and therefore will need a new itemized budget.

4. Obtain CESU approval. Email Research Coordinator and CESU the draft agreement or modification for corrections and approval.

5. Once approved, the Research Coordinator sends the agreement to the PWR CESU program assistant (currently Linda Whitson), who emails you to notify you that a Purchase Request (PR) entry needs to be submitted. PRs are created using the program Interior Department Electronic Acquisition System (IDEAS), and for which you will need to find an administrative assistant to create the entry.

6. The PR entry requires a short list of information (Table 1.2). The PR entry is routed to the PWR CESU program assistant, with supervisory and budget approvals, and the modification or agreement needs to be attached but it must be in .doc rather than .docx format.

Table 1.2. Info needed for the IDEAS entry.

IDEAS Entry Data Needed
IAGP Number
PR Number
Route To:
Amount
Justification

7. Oakland Contracting approves the TA/MOD and sends it to OSU for signature. Lilette Baltodano or someone else in PWR contracting office will email the ATR the final version once she has received it. Note that this can take 45-60 days.

3. Documents Needed to Process Agreements

This section has some selections of text and example agreements or modifications that will be needed when drafting and maintaining the task agreement and subsequent modifications.

A. IAGP and Substantial Involvement Documents

The main purpose of the substantial involvement documentation is to outline clearly why the proposed collaboration meets the requirements of a Cooperative Agreement rather than some other form of acquisition. The high level of collaboration inherent to this protocol must be explained clearly in this and other documents. Figure 1.1 gives example language from the substantial involvement documentation for a recent agreement for similar collaboration.

DOCUMENTATION FOR USE OF A COOPERATIVE AGREEMENT
In accordance with 505 Departmental Manual Chapter 2

Project Title: Application of LandTrendr Results to NCCN Landscape Dynamics Monitoring

Cooperative Agreements Number or PR Number __ _ J8W07100011_____

Type of funds to be used for this project (i.e. ONPS, NRC, Fee Demo, Fire, Donation, please be specific): **_____NRPC Inventory and Monitoring_____**

1. What type of competition is appropriate? (*In accordance with 505 DM 2.12*)
   This will be a Task Agreement written against the CESU Master Cooperative Agreement.

2. Why was this cooperator selected?
   This cooperator has developed a unique method for tracking landscape change using satellite based remote sensing. The North Coast and Cascades Network (NCCN) would like to work together with the cooperator to evaluate whether their method could be used to successfully accomplish landscape dynamics monitoring goals in the NCCN parks.

3. Who are the parties to the agreement?
   Oregon State University, the National Park Service, and the PNW CESU.

4. What is the purpose of the agreement?
   The purpose of the agreement is to work collaboratively with OSU to assess the feasibility of using a new method for detecting landscape change over time in the NCCN parks.

5. What are the deliverables expected?
   Expected deliverables are 1) labeled maps of landscape change created using the LandTrendr algorithm and 2) a report describing the efficacy of the labeling exercise in the context of NCCN landscape dynamics monitoring goals.

6. Explain the nature of the anticipated substantial involvement. What will NPS specifically do to carry out the project? *(In accordance with 505 DM 2.8.E(3) & 2.9.B(2))*
   The NPS ATR and NPS GIS technician will work closely with the OSU PI to evaluate their landscape change detection methods. The NPS GIS technician will be responsible for several results processing steps, the products of which will next be evaluated by both the NPS staff and the OSU PI during joint work sessions. In addition to GIS technician time, the NPS will provide project oversight.

7. Why is the substantial involvement considered to be necessary?
   Substantial involvement of NPS staff time is essential to this collaborative effort- the purpose of this agreement is to facilitate an ongoing interaction between the ATR and PI addressing the use of their methods and products to monitor landscape change in the NCCN. This agreement will coordinate the flow of information between the two parties, with the goal of determining whether a longer-term relationship will be established.

Figure 1.1. Example text from a substantial involvement form.

8. Explain why the project or activity entails a relationship of assistance rather than a contract. How will the NPS benefit from this collaboration?
This activity is mutually beneficial to both parties. OSU provides assistance to the NPS in the matter of Inventory and Monitoring (I&M) Landscape Change Protocol Development. NPS provides assistance to the OSU facilitating work to add new labels and to evaluate different approaches to summarizing their results. Furthermore, additional I&M networks are potentially interested in using OSU monitoring approach therefore, the results of this collaboration will be of wider interest and assist other networks in landscape dynamics protocol development.

9. What is the public purpose of support or stimulation? *(In accordance with 505 DM 2.6.C)*
The public purpose of this work is to support Inventory and Monitoring (I&M) Landscape Change Protocol Development in the NCCN parks. As part of the National Park Service's larger goal of developing long-term monitoring programs in response to the Natural Resource Challenge of 2000, the parks of the North Coast and Cascades Network (NCCN) have determined that monitoring landscape dynamics is necessary to track ecosystem health over time.

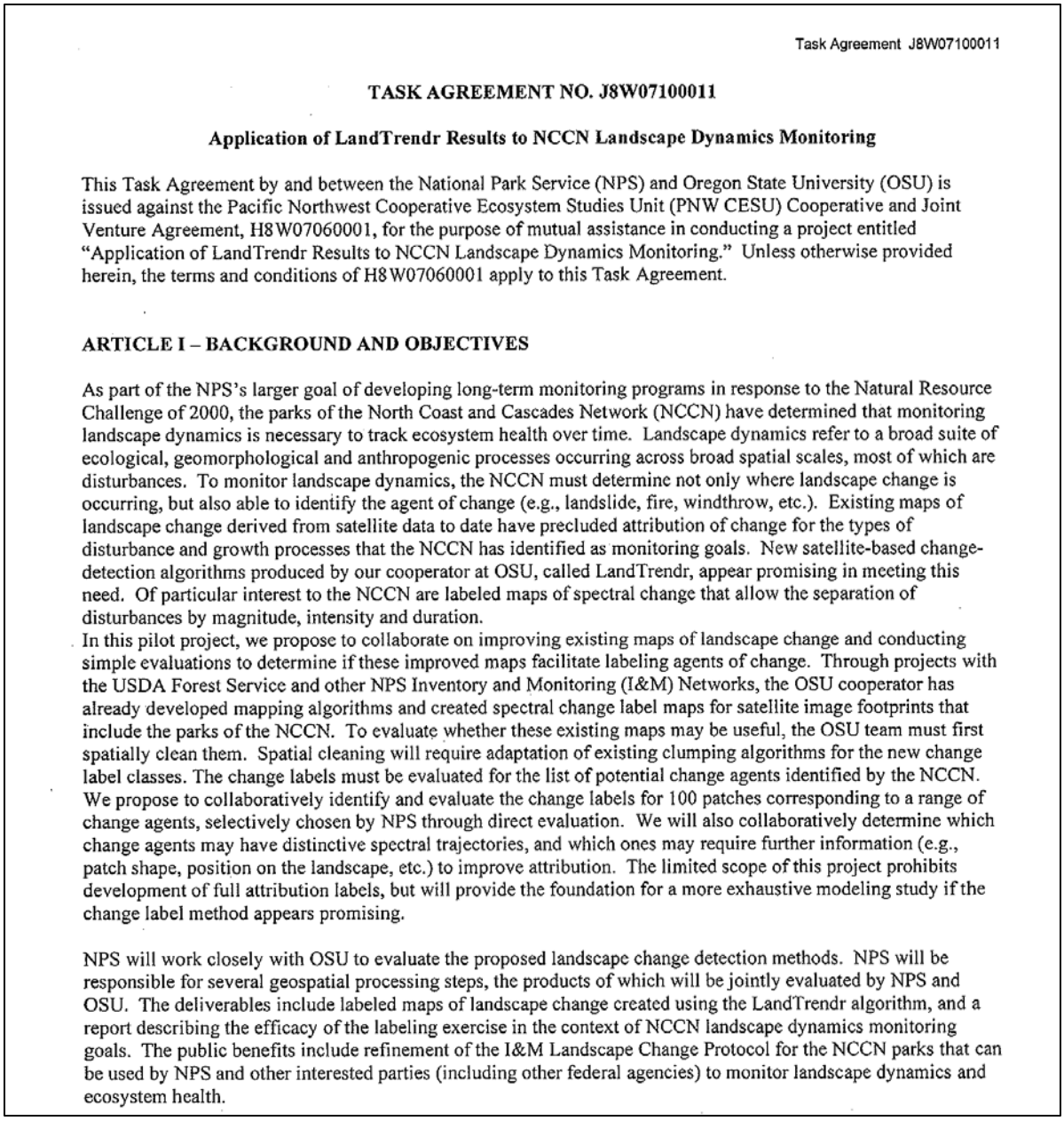
10. Which law or laws authorize granting of assistance for performance of this project or activity?
The PNW CESU Cooperative Agreement references the authorities for conducting CESU projects.

11. How was the determination made that the costs proposed are accurate and proper? (Explain how the costs for the project determined and provide rationale for determining that they are acceptable).
The cooperator determined costs based on similar work, using OSU salary figures and estimates of time needed to address the proposed tasks.

Figure 1.1. Example text from a substantial involvement form (continued).

B. Task Agreement

The purpose of the task agreement is to outline the roles and responsibilities of both parties, to indicate the account number, budget and other administrative details, and to describe the workplan and timeline for deliverables. The background and objectives section is the longest section of the task agreement. The text in Figure 1.2 may prove useful in drafting a future task agreement.



Task Agreement J8W07100011

TASK AGREEMENT NO. J8W07100011

Application of LandTrendr Results to NCCN Landscape Dynamics Monitoring

This Task Agreement by and between the National Park Service (NPS) and Oregon State University (OSU) is issued against the Pacific Northwest Cooperative Ecosystem Studies Unit (PNW CESU) Cooperative and Joint Venture Agreement, H8W07060001, for the purpose of mutual assistance in conducting a project entitled "Application of LandTrendr Results to NCCN Landscape Dynamics Monitoring." Unless otherwise provided herein, the terms and conditions of H8W07060001 apply to this Task Agreement.

ARTICLE I – BACKGROUND AND OBJECTIVES

As part of the NPS's larger goal of developing long-term monitoring programs in response to the Natural Resource Challenge of 2000, the parks of the North Coast and Cascades Network (NCCN) have determined that monitoring landscape dynamics is necessary to track ecosystem health over time. Landscape dynamics refer to a broad suite of ecological, geomorphological and anthropogenic processes occurring across broad spatial scales, most of which are disturbances. To monitor landscape dynamics, the NCCN must determine not only where landscape change is occurring, but also able to identify the agent of change (e.g., landslide, fire, windthrow, etc.). Existing maps of landscape change derived from satellite data to date have precluded attribution of change for the types of disturbance and growth processes that the NCCN has identified as monitoring goals. New satellite-based change-detection algorithms produced by our cooperator at OSU, called LandTrendr, appear promising in meeting this need. Of particular interest to the NCCN are labeled maps of spectral change that allow the separation of disturbances by magnitude, intensity and duration.

In this pilot project, we propose to collaborate on improving existing maps of landscape change and conducting simple evaluations to determine if these improved maps facilitate labeling agents of change. Through projects with the USDA Forest Service and other NPS Inventory and Monitoring (I&M) Networks, the OSU cooperator has already developed mapping algorithms and created spectral change label maps for satellite image footprints that include the parks of the NCCN. To evaluate whether these existing maps may be useful, the OSU team must first spatially clean them. Spatial cleaning will require adaptation of existing clumping algorithms for the new change label classes. The change labels must be evaluated for the list of potential change agents identified by the NCCN. We propose to collaboratively identify and evaluate the change labels for 100 patches corresponding to a range of change agents, selectively chosen by NPS through direct evaluation. We will also collaboratively determine which change agents may have distinctive spectral trajectories, and which ones may require further information (e.g., patch shape, position on the landscape, etc.) to improve attribution. The limited scope of this project prohibits development of full attribution labels, but will provide the foundation for a more exhaustive modeling study if the change label method appears promising.

NPS will work closely with OSU to evaluate the proposed landscape change detection methods. NPS will be responsible for several geospatial processing steps, the products of which will be jointly evaluated by NPS and OSU. The deliverables include labeled maps of landscape change created using the LandTrendr algorithm, and a report describing the efficacy of the labeling exercise in the context of NCCN landscape dynamics monitoring goals. The public benefits include refinement of the I&M Landscape Change Protocol for the NCCN parks that can be used by NPS and other interested parties (including other federal agencies) to monitor landscape dynamics and ecosystem health.

Figure 1.2. Example background text from a task agreement.

C. Task Agreement Modification

The task agreement must be modified if a section needs changing. It is likely the agreement will need modification annually in order to add the current year's funding and update the account number. The following example modification (Figure 1.3) shows the format for a modification. The revised sections are referred to by number and the updated text is included. Note that a new budget must be submitted if the modification includes adding new funds.



Task Agreement J8W07100011
Modification 01

Pacific Northwest Cooperative Ecosystem Studies Unit
Task Agreement Modification
National Park Service

TASK AGREEMENT NO.:	MODIFICATION NO.	COOPERATIVE AGREEMENT NO.:	EFFECTIVE DATES:
J8W07100011	01	H8W07060001	05/15/2010 – 05/16/2011

COOPERATOR: Oregon State University

PROJECT TITLE: Application of LandTrendr Results to NCCN Landscape Dynamics Monitoring

PURPOSE OF MODIFICATION: This no-cost modification extends the project to accommodate changes in the processing steps of the change agent label model development.

MODIFICATION:

1. **ARTICLE III – TERM OF AGREEMENT**, is modified to read as:

   This Task Agreement is effective on May 15, 2010 and will extend through May 16, 2011.

2. **ARTICLE VI.A.4-5. – PROJECT PRODUCTS**, is modified to read as:

   4. Collaborative work to evaluate which change agents appear separable by spectral change label alone. *By December 1, 2010*

   5. Project report summarizing labeling exercise. *By February 1, 2010*

3. **All other terms and conditions remain unchanged.**

STATE OF OREGON ACTING BY AND THROUGH THE STATE BOARD OF HIGHER EDUCATION ON BEHALF OF OREGON STATE UNIVERSITY

Aedra Reynolds
Grant and Contract Officer

12-21-10
Date

NATIONAL PARK SERVICE PACIFIC WEST REGIONAL OFFICE

Lilette J. Baltodano
Contracting Officer

Date

Figure 1.3. Example task agreement modification.

4. Schedule for Deliverables from LARSE

The current stack of images LARSE has processed goes from 1985 through 2009 for most scenes in the NCCN. During each annual work cycle, LARSE will append 3 years of processed Landsat imagery to the stack of images for each scene undergoing analysis in that timestep. The Greatest Disturbance layers will be generated from LandTrendr for the entire time step (1985-analysis date). Figure SOP1.3 depicts the project schedule from 2011 through 2025, and may be helpful for drafting task agreements and modifications.

Year of Delivery:		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Processed scenes and LandTrendr from 1985 through year:	2010	4626, 4627														
	2010		4727, 4826, 4827													
	2012			4728, 4726												
	2013				4626, 4627											
	2014					4727, 4826, 4827										
	2015						4728, 4726									
	2016							4626, 4627								
	2017								4727, 4826, 4827							
	2018									4728, 4726						
	2019										4626, 4627					
	2020											4727, 4826, 4827				
	2021												4728, 4726			
	2022													4626, 4627		
	2023														4727, 4826, 4827	
	2024															4728, 4726

Figure 1.4. Timeline for deliverables from LARSE. The modification written for the year of delivery would need to indicate which Landsat scenes need processing as indicated in boxes along diagonal.

SOP 2: Filtering LandTrendr Results and Extracting Attributes

Revision Date	Author	Changes Made	Reason for Change

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E. Export Attribute Table to .csv Format SOP2-11

1. Overview

The Greatest Disturbance raster products provided by LARSE include groups of pixels that are caused by noise, rather than actual landscape changes, and that need to be removed. These noise pixels are removed to produce distinct change patches that can be attributed with a landscape change type. A Rapid change patch is defined by a collection of adjacent pixels, using an eight-neighbor rule, that have the same year of onset, have a duration value of less or equal to four years, and that are found in groups of greater than nine pixels, the minimum mapping unit (MMU) (Figure 2.1). The eight-neighbor rule allows all eight pixels surrounding a target pixel to be evaluated for inclusion in a patch, rather than just the four pixels in the cardinal directions.

A. Software Requirements

These procedures were developed using ESRI ArcGIS™, version 10.0 Service Pack 2. Unless noted, the data sources and model used are assumed to be in ESRI ArcGIS™ format, version 10.0 Service Pack 2.

B. Coordinate System

Unless noted, all ArcGIS layers use Albers Conic Equal Area coordinate system, North American Datum 1983, defined by the following parameters:

```
PROJCS["Albers_Conic_Equal_Area",GEOGCS["GCS_North_American_1983",DATU
M["D_North_American_1983",SPHEROID["GRS_1980",6378137.0,298.257222101]
],PRIMEM["Greenwich",0.0],UNIT["Degree",0.0174532925199433]],PROJECTIO
N["Albers"],PARAMETER["false_easting",0.0],PARAMETER["false_northing",
0.0],PARAMETER["central_meridian",-
96.0],PARAMETER["standard_parallel_1",29.5],PARAMETER["standard_parall
el_2",45.5],PARAMETER["latitude_of_origin",23.0],UNIT["Meter",1.0]]
```

The referenced Projection file can be found in \LPa01_landscape_change\Spatial_info\Albers_Conic_Equal_Area.prj.

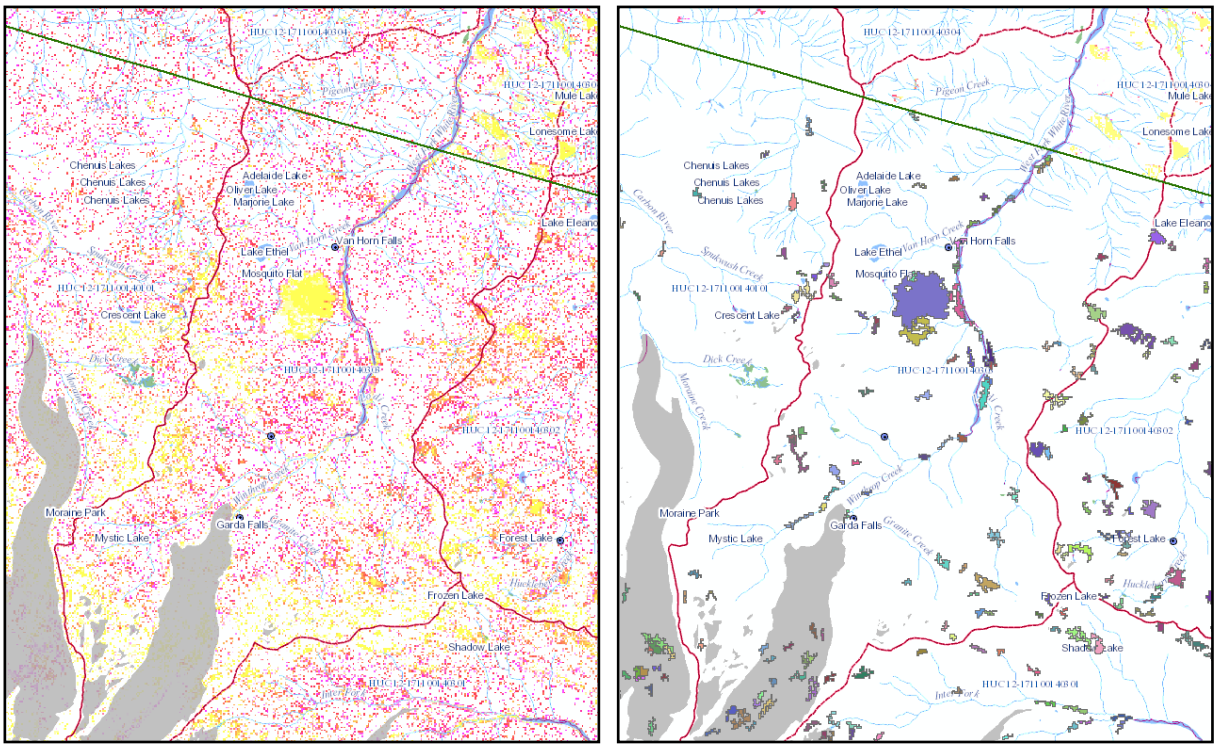


Figure 2.1. LandTrendr unfiltered change output image (left) and landscape change patches following filtering (right). North-central area of Mount Rainier NP with NHD Hydro reference layers.

2. Filtering Landscape Change Patches

A. Create Target Workspace

The ArcGIS Spatial Analyst extension is required. Make sure it is enabled by selecting Tools → Extensions from ArcCatalog or ArcMap. The model generates several raster and vector products which are stored in an ArcGIS file geodatabase (i.e. the target workspace). This geodatabase must be created prior to running the model. In ArcCatalog create a new file geodatabase in the \Spatial_info\PARK\ directory. Name the file geodatabase PARK_SCENE_rapid_StartYear_EndYear.gdb.

B. Define Model Parameters

Open ArcCatalog.

Open ArcToolbox and right-click the ArcToolbox top node.

Select 'Add Toolbox' and navigate to the \Spatial_info\Models\ LandTrendr Patch Tools.tbx file.

Open the LandTrendr Patch Tools toolbox and open the Create Patch Polygons model by double-clicking on the model name.

The model was designed to be used for any of the study areas in the network. This is accomplished by defining a number of model parameters before the model is run. Choose the LandTrendr Unfiltered Output Raster Layer by navigating to \Spatial_info\PARK\SCENE\ and selecting LT045_nbr_SCENE_greatest_ disturbance.bsq.

Update the source file by clicking inside the select box and appending '\Band_1' (without quotes) to the end of the file path. This will prompt the model to use only the disturbance year band from the source raster.

Choose the target output file geodatabase created in "Create Target Workspace" section as the Output Workspace.

Make sure the minimum mapping unit for defining patches is nine pixels.

Select the study area feature class by navigating to \Spatial_info\PARK\PARKbase.gdb.

C. Run the Model

The model dialog should look similar to this:

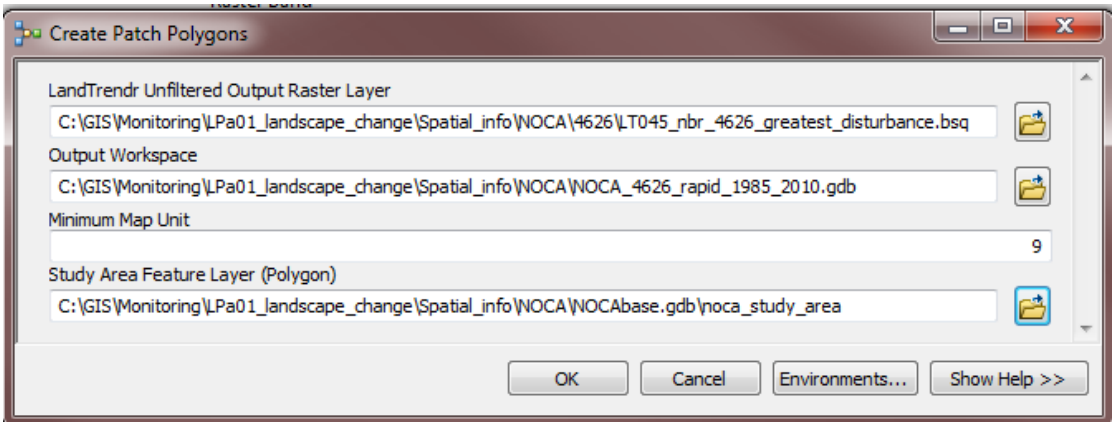


Figure 2.2. Screenshot of the model dialog box showing the Create Patch Polygons model with filled-in parameters.

Choose 'OK' to run the model. Depending on the study area extent, it may take several minutes to run.

Once the model has completed all the processing steps, open \Spatial_info\PARK\PARK_SCENE_rapid_StartYear_EndYear.gdb and verify that all raster and vector layers shown in Figure 2.3 have been added.

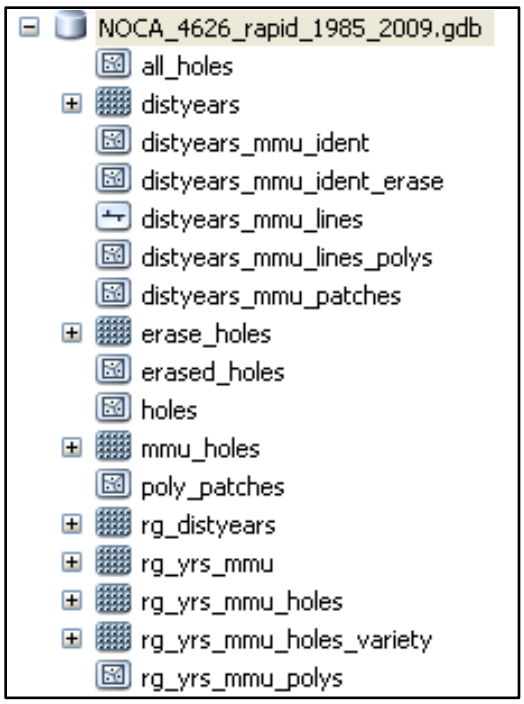


Figure 2.3. A screenshot of the file structure of the output layer from the Create Patch Polygons model.

D. Review the Output Patches

Open ArcMap and add the following output rasters and feature classes to ArcMap:

poly_patches: the polygon feature class of landscape change patches, includes Patch_ID and Change_Year attributes

raster_patches: the raster version of landscape change patches, Value = Year_1

unfiltered Greatest Disturbance layer from OSU/Band1

Apply symbology to the poly_patches feature class: right-click poly_patches in the table of contents → Properties → Symbology. Choose Categories → Unique Values and select Change_Year from the Value Field drop down.

Toggle between raster_patches and the unfiltered raster to verify that the patches were formed correctly:

All pixels within a patch are from the same year
All patches contain at least 9 pixels

Toggle between poly_patches feature class and raster_patches to verify that the polygons were created correctly:

Polygon boundaries match the boundaries of the raster patches
holes that were filled inside patches are smaller than 9 pixels

3. Extracting Attributes

A. Overview

For each landscape change patch, there are 5 general types of descriptors that can be used to describe the change:

Pre-landscape change spectral attributes
Post-landscape change spectral attributes
Landscape change spectral attributes
Landscape change shape attributes
Environmental variables

Two ArcGIS Models were designed to extract patch attributes in each of these categories using available ArcGIS tools and field calculations and attach them as fields to the poly_patches feature class generated by the filtering model in the previous section of the SOP. The extracted attributes are then used to assign a change type to patches via the RF type labeling model described in **SOP 3: Labeling Landscape Change Types**.

B. Extract Landscape and Shape Attributes

Input Layers

Each park has a geodatabase with base layers that act as inputs for the filtering and attribute extraction models. The geodatabase name and location is \Spatial_info\PARK\PARKbase.gdb. Table 2.1 contains a list of base layers on the PARKbase.gdb.

Define Model Parameters

Open ArcCatalog.

Open ArcToolbox and right-click the ArcToolbox top node.
Select ‘Add Toolbox’ and navigate to the \Spatial_info\Models\ LandTrendr Patch Tools.tbx file.

Open the LandTrendr Patch Tools toolbox and open the Extract Landscape and Shape Attributes model.

The model was designed to be used for any of the study areas in the network. This is accomplished by defining a number of model parameters before the model is run.
Define “Patches” layer by navigating to \Spatial_info\PARK\ and selecting Poly_patches feature class within PARK_SCENE_rapid_StartYear_EndYear.gdb.

Define “Input Workspace” as \Spatial_info\PARK\PARKbase.gdb .

Define “Output Workspace as \Spatial_info\PARK\
PARK_SCENE_rapid_StartYear_EndYear.gdb.

Run the Model

Once the parameters have been defined, the model dialog should look similar to Figure 2.4.

Table 2.1. Layers in geodatabases containing park base GIS layers.

Layer	Description
AspectClass	Aspect classified into 9 categories (Flat, N, NE, etc.)
DEM	10 m Digital Elevation Model for the study area
DirStrmClass	Direction to closest stream classified into 8 categories (N, NE, etc)
DistStrm	Distance to closest stream in meters
Eastness	The sine transformed value of the aspect. Eastness will be close to 1 if the aspect is eastward and will be close to -1 if the aspect is westward and will be close to 0 if the aspect is either North or South.
Landforms	Landform classification with the following landform types: 1=canyons, deeply incised streams 2=midslope drainages, shallow valleys 3= upland drainages, headwaters 4=u-shaped valleys 5=plains 6=open slopes 7=upper slopes, mesas 8=local ridges, hills in valleys 9=midslope ridges, small hills in plains, 10=mountain tops,high ridges.
Northness	The cosine transformed value of the aspect a lakes' basin opens towards. Northness behaves similarly to Eastness, except that values close to 1 represent North facing slopes
SlopePos2000	Slope Position Classification using 2000-meter window. Six categories: 1=valley, 2=toe slope, 3=flat, 4=midslope, 5=upper slopes, and 6=ridges.
SlopePos500	Slope Position Classification using 500-meter window.
TCI	Topographic Conversion Index. Measure of wetness.
TPI2000	Standardized topographic position index calculated using 2000-meter window. An index that expresses whether a given cell is higher or lower than its neighbors.
TPI500	Standardized topographic position index calculated using 500-meter window.

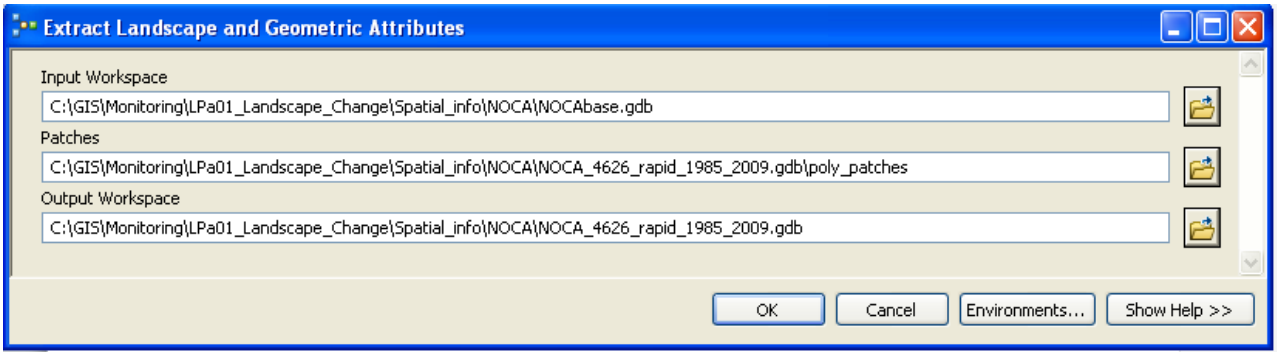
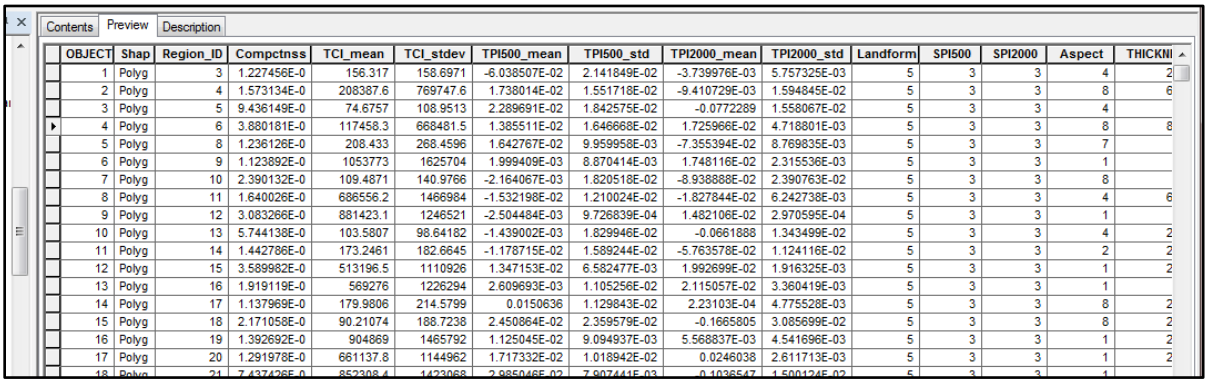


Figure 2.4. Screenshot of the model dialog box showing the Extract Landscape and Geometric Attributes model with filled-in parameters.

Choose 'OK' to run the model. Depending on the study area extent, it may take several minutes to run. The model uses the "Zonal Statistics as a Table" tool to calculate zonal statistics for each raster dataset in the Input Workspace and appends the selected attributes to the poly_patches feature class. The model also calculates various shape indices and appends those to poly_patches feature class table. Landscape and Geometric variables in Table 4 in the main body of the protocol are extracted or calculated by this model.

Review Added Landscape and Patch Attributes

In ArcCatalog, navigate to \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb, select poly_patches feature class and verify that all the attributes have been added to the table, that there are no missing values, and that the values are of appropriate format and range for a particular attribute (Figure 2.5). Refer to Table 4 in the main portion of the protocol to determine what the format should be. For example, Aspect value should be an integer from 1 to 9 representing one of the Aspect classes (Flat, N, NE, etc.).



OBJECT	Shap	Region_ID	Compctnss	TCI_mean	TCI_stdev	TPI500_mean	TPI500_std	TPI2000_mean	TPI2000_std	Landform	SPI500	SPI2000	Aspect	THICKNI
1	Polyg	3	1.227456E-0	156.317	158.6971	-6.038507E-02	2.141849E-02	-3.739976E-03	5.757325E-03	5	3	3	4	2
2	Polyg	4	1.573134E-0	208387.6	769747.6	1.738014E-02	1.551718E-02	-9.410729E-03	1.594845E-02	5	3	3	8	6
3	Polyg	5	9.436149E-0	74.6757	108.9513	2.289691E-02	1.842575E-02	-0.0772289	1.558067E-02	5	3	3	4	
4	Polyg	6	3.880181E-0	117458.3	668481.5	1.385511E-02	1.646668E-02	1.725966E-02	4.718801E-03	5	3	3	8	8
5	Polyg	8	1.236126E-0	208.433	268.4596	1.642767E-02	9.959958E-03	-7.355394E-02	8.769835E-03	5	3	3	7	
6	Polyg	9	1.123892E-0	1053773	1625704	1.999409E-03	8.870414E-03	1.748116E-02	2.315536E-03	5	3	3	1	
7	Polyg	10	2.390132E-0	109.4871	140.9766	-2.164067E-03	1.820518E-02	-8.938888E-02	2.390763E-02	5	3	3	8	
8	Polyg	11	1.640026E-0	686556.2	1466984	-1.532198E-02	1.210024E-02	-1.827844E-02	6.242738E-03	5	3	3	4	6
9	Polyg	12	3.083266E-0	881423.1	1246521	-2.504484E-03	9.726839E-04	1.482106E-02	2.970595E-04	5	3	3	1	
10	Polyg	13	5.744138E-0	103.5807	98.64182	-1.439002E-03	1.829946E-02	-0.0661888	1.343499E-02	5	3	3	4	2
11	Polyg	14	1.442786E-0	173.2461	182.6645	-1.178715E-02	1.589244E-02	-5.763578E-02	1.124116E-02	5	3	3	2	2
12	Polyg	15	3.589982E-0	513196.5	1110926	1.347153E-02	6.582477E-03	1.992699E-02	1.916325E-03	5	3	3	1	2
13	Polyg	16	1.919119E-0	569276	1226294	2.609693E-03	1.105256E-02	2.115057E-02	3.360419E-03	5	3	3	1	
14	Polyg	17	1.137969E-0	179.9806	214.5799	0.0150636	1.129843E-02	2.23103E-04	4.775528E-03	5	3	3	8	2
15	Polyg	18	2.171058E-0	90.21074	188.7238	2.450864E-02	2.359579E-02	-0.1665805	3.085699E-02	5	3	3	8	2
16	Polyg	19	1.392692E-0	904869	1465792	1.125045E-02	9.094937E-03	5.568837E-03	4.541696E-03	5	3	3	1	2
17	Polyg	20	1.291978E-0	661137.8	1144962	1.717332E-02	1.018942E-02	0.0246038	2.611713E-03	5	3	3	1	2
18	Polyg	21	7.437426E-0	852308.4	1423068	2.985046E-02	7.907441E-03	-0.1036547	1.500124E-02	5	3	3	1	

Figure 2.5. Screenshot of the poly_patches feature class attribute table after extraction and calculation of landscape and geometric variables.

C. Extract Spectral Attributes

Input Layers

Spectral variables for each patch are extracted from multiple bands of the two raster layers provided by LARSE group as part of the Cooperative Agreement. The layers are located in \LPa01_landscape_change\Spatial_info\PARK\SCENE\Outputs\StartYear_EndYear\ directory and contain the following spectral variables:

Table 2.2. List of spectral variables found in the Landsat image directory (from OSU).

File Name	Band	Attribute
LT045_nbr_SCENE_greatest_disturbance.bsq	1	Year of disturbance
	2	Disturbance magnitude
	3	Disturbance duration
	4	Pre-disturbance NBR value
LT045_nbr_4626_greatest_disturbance_ftv_predist.bsq	1	Pre-disturbance Brightness
	2	Pre-disturbance Greenness
	3	Pre-disturbance Wetness
	4	Disturbance Brightness Magnitude
	5	Disturbance Greenness Magnitude
	6	Disturbance Wetness Magnitude
	7	Post-disturbance Brightness
	8	Post-disturbance Greenness
	9	Post-disturbance Wetness
	10	Recovery Brightness Magnitude
	11	Recovery Greenness Magnitude
	12	Recovery Wetness Magnitude

Define Model Parameters

Open ArcCatalog.

Open ArcToolbox and right-click the ArcToolbox top node.
Select 'Add Toolbox' and navigate to the \LPa01_Landscape_Change\Spatial_info\Models\ LandTrendr Patch Tools.tbx file.

Open the LandTrendr Patch Tools toolbox and open the Extract Spectral Attributes model.

The model was designed to be used for any of the study areas in the network. This is accomplished by defining a number of model parameters before the model is run.
Define the "Patches" layer by navigating to the \LPa01_Landscape_Change\Spatial_info\PARK\ and selecting poly_patches feature class within the PARK_SCENE_rapid_StartYear_EndYear.gdb.

Define "Input Workspace" as \LPa01_landscape_change\Spatial_info\PARK \SCENE\Outputs\StartYear_EndYear\.

Define "Output Workspace as \LPa01_Landscape_Change\Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb.

Run the Model

Once the parameters have been defined, the model dialog should look similar to Figure 2.6.

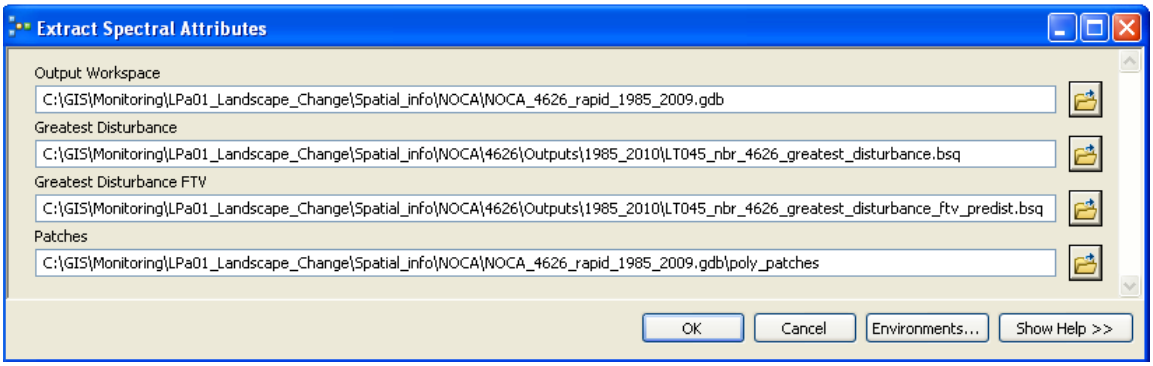


Figure 2.6. Screenshot of model dialog box showing the Extract Spectral Attributes model with filled in parameters.

Choose 'OK' to run the model. Depending on the study area extent, it may take several minutes to run. The model uses "Zonal Statistics as a Table" tool to calculate zonal statistics for the listed bands in each of the two raster datasets in the Input Workspace and appends the selected attributes to the poly_patches feature class.

Review Added Spectral Attributes

In ArcCatalog, navigate to \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb, select the poly_patches feature class and verify that all the attributes have been added to the table, that there are no missing values, and that the values are of appropriate format and range for a particular attribute (Figure 2.7). Refer to Table 4 in the main portion of the protocol to determine what the format should be.

Contents | Preview | Description

PreNBR	stdPreNBR	Mag	stdMag	Dur	stdDur	PostWet	stdPostWet	PostGreen	stdPostGreen	PostBright	stdPostBrig	PreBright	stdPreBright	PreGreen
604.6667	29.20046	19	6.429101	3	0.942809	-612.7778	59.34602	789.5555	84.25241	1693	73.0099	2016.778	127.7504	1325
581.5493	50.28645	49.80282	8.456383	1.028169	0.1654555	-919.2676	184.7646	464.2535	155.0725	1878.873	327.4257	1744.493	309.2899	1095.465
678.0909	22.69744	37.81818	9.627784	1.363636	0.7713892	-816.6364	23.34435	687.9091	117.0124	1917.818	53.01598	1872.818	52.13238	1376
459.9565	35.10231	50.36956	4.988503	1.086957	0.4078622	-1084.174	413.2755	460.6087	173.9851	1918.435	636.6953	1714.87	544.8691	871.5652
529.5455	58.87331	74.72727	14.05244	1	0	-774	144.4589	68.63636	165.8149	1826.545	179.5562	1702.455	144.5296	1012.636
604.6667	32.26797	58.5	5.766281	1	0	-1087.833	80.94116	1005.833	521.6312	1900.833	113.5333	1952.167	62.03337	1346.167
660.5	30.93407	52.33333	4.561311	1	0	-812.5417	323.074	572.5833	271.8538	1480.583	560.4946	1568.583	595.4934	1100.458
612.4186	48.42363	46.72093	7.863148	1	0	-937.907	102.7639	522.6744	81.76334	2061.419	109.0168	1912.93	99.18022	1116.279
566.5555	42.9809	64.88889	2.997942	1	0	-1529.778	31.74474	575.4445	28.47264	1895.667	246.4341	1711.333	50.8571	974.6667
689.8	21.56293	49.6	3.039737	1	0	-957.2	35.10783	597	22.41874	1765.6	39.19745	1808.2	35.47055	1062
616.8889	52.97472	40.22222	9.658361	1.222222	0.6285394	-841.2222	127.1218	835.3333	214.9429	1834.556	96.42165	1865.889	40.93204	1228.667
690.0833	17.41388	66.33334	8.701852	3	0	0	0	0	0	0	0	1785.833	22.8029	1182.5
634.4231	152.4187	60.11538	13.78775	0.9615384	0.1923077	-1038.654	329.7003	470.0769	117.4449	1748.346	440.1382	1813.192	367.9813	1267
560.2727	29.26087	72.72727	2.733327	3	0	0	0	0	0	0	0	1872.727	35.77224	1016.909
576.6667	27.44793	52.08333	6.812468	1.041667	0.1998263	-1005.042	134.5689	480.7917	55.60049	1889.25	69.45997	1917.5	68.31911	1168.583
581.1111	28.19553	67.22222	7.420359	2.888889	0.4581228	-51.38889	211.8818	40.11111	165.3824	108.1667	445.9826	1728.5	420.0948	916.7778

Figure 2.7. Screenshot of the poly_patches feature class attribute table after extraction of the spectral attributes.

D. Generate In_park Attribute Values

Open ArcMap® and add the \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb\poly_patches feature class.

Navigate to \Spatial_info\PARK\PARKbase.gdb and add the PARKbndry feature class.

Select “Select by Location” under the Selection drop down menu. Specify the poly_patches feature class as the Target layer and PARKbndry as the Source layer. Select the “Target layers features have their centroid in the Source layer feature” option under the Spatial selection method drop down menu. Click OK.

Open the attribute table for the poly_patches feature class. Right-click on the In_park field and select “Field Calculator.” In the white window underneath “In_park =” type “Y” (with quotes) and click OK. Verify that the selected records have been populated with a“Y” value (without quotes) in the “In_park” field.

From the Table Options menu select “Switch Selection.” Right-click on the In_park field and select “Field Calculator.” In the white window underneath “In_park =” type “N” (with quotes) and click OK. Verify that selected records have been populated with “N” value (without quotes) in the In_park field.

Verify that all records have either “Y” or “N” in the In_park field.

E. Export Attribute Table to .csv Format

Open the poly_patches attribute table, if necessary. Under Table Options select Export. Make sure that “All records” is listed under Export: window.

Save the output table in the \Spatial_info\PARK\ directory with poly_patches_table_StartYear_EndYear name in the Text File format

In Windows Explorer, change the file format to “.csv.”

The table is now ready to be used in R.

SOP 3: Labeling Landscape Change Types

Revision Date	Author	Changes Made	Reason for Change

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1. Overview

This SOP explains how to use the attribute table generated by the attribute extraction models in **SOP 2: Filtering LandTrendr Results and Extracting** Attributes to run the Random Forest labeling model to classify mapped landscape change polygons by change type. The randomForest package (Liaw and Weiner 2002) is run in the R statistical software package (R Development Core Team 2011). The script for applying the Random Forest model to a .csv attribute file is provided with the protocol. The script generates a text output file containing landscape change polygon IDs, final change type predictions for each polygon, and probabilities of each polygon being classified as one of the nine change types.

All files are stored in the directories under the main project directory on GIS Specialist's workstation (C:\GIS\Monitoring\LPa01_Landscape_Change\).

2. Running the Random Forests Model

Once the landscape change polygon IDs and their associated attributes have been exported to a .csv file, the user next uploads the .csv file into R in order to run the package randomForest which is used to classify, or label, the change types.

A. Software Requirements

This SOP was written using R version 2.13.1 and Tinn-R version 2.3.7.1. Downloading and Installation instructions for these two programs can be found in the "Getting Started" section of Paul Geissler's Learn R webinar course (http://www.fort.usgs.gov/brdscience/LearnR11a-01.htm). Additional notes can be found on Tom Philippi's webpage (http://science.nature.nps.gov/im/monitor/stats/R/Installation.cfm).

Once the basic R software is installed, the user needs to open the R software and install the randomForest package by clicking on Packages/Load Packages and selecting randomForest from the list.

B. Run Model

Start R and Tinn-R. In Tinn-R open PARK_rf_dist_model.r file located in \Spatial_info\Models\R\PARK\. The script contains the R code shown in Figure 3.1:

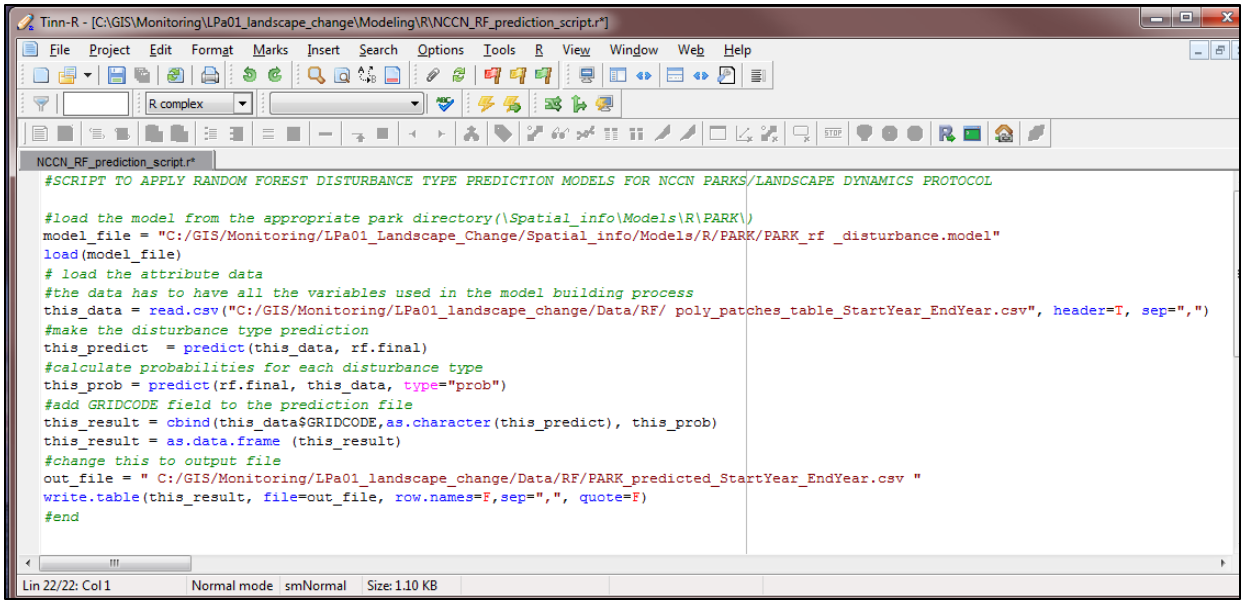


Figure 3.1. R code for applying park-specific Random Forest models to text files containing change polygon attributes.

Note that the input file containing attributes should have the same variable names as originally used to build the model, listed in Table 5, "GRIDCODE" attribute to uniquely identify the change polygon within the time step of analysis for a particular park, and an additional attribute "Agent," left blank.

C. Review Output

Open the output file in Excel to verify that all the fields were exported successfully. Table 3.1 lists the fields that should be present in the file.

Table 3.1. Fields present in the Data\R\Park\PARK_predicted_StartYear_EndYear.csv file.

Field Name	Description
GRIDCODE	Unique change polygon ID
Agent	Change category predicted by the RF model
Agricultural	Probability that polygon belongs to Agricultural category
AnnualVariability	Probability that polygon belongs to Annual Variability category
Avalanche	Probability that polygon belongs to Avalanche category
Clearing	Probability that polygon belongs to Clearing category
Development	Probability that polygon belongs to Development category
Fire	Probability that polygon belongs to Fire category
MassMovement	Probability that polygon belongs to Mass Movement category
ProgressiveDefoliation	Probability that polygon belongs to Progressive Defoliation category
Riparian	Probability that polygon belongs to Riparian category
TreeToppling	Probability that polygon belongs to Tree Toppling category

Verify that there are not missing values and that the number of output records matches the number of records in the input file.

3. Export the Random Forest Landscape Change Categories to GIS

Open an ArcMap® document and add poly_patches feature class from \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb. Right-click on the layer and open the attribute table.

Under Table Options drop down menu, select Add Field. Enter “Model_agent” (without quotes) for the field name and select “Text” for field type. Change field length to 20. Click OK.

Right click on the poly_patches feature class, select Joins and Relates and then Join. Select GRIDCODE in section 1. In section 2, navigate to and select \Data\RF\PARK_predicted_StartYear_EndYear.csv. Select GRIDCODE in section 3. Click OK.

Verify that poly_patches attribute table now contains fields from PARK_predicted_StartYear_EndYear.csv.

Right-click on Model_agent field and select “Field Calculator.” In the Fields: window, scroll down until you see PARK_predicted_StartYear_EndYear.Agent field. Double-click on the field name. This should add the field name to the white box at the bottom part of the Field Calculator window. Click OK.

Verify that Model_agent field is now populated with change categories.

Right-click on poly_patches feature class and select Joins and Relates/Remove Join(s)/Remove All Joins.

4. Generate Landscape Change Polygon Centroids

If needed, open an ArcMap® document and add poly_patches feature class from \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb.

Open ArcToolbox® and navigate to Data Management Tools\Features\. Open Feature to Point tool.

Drag poly_patches feature class from the ArcMap® table of contents to the Input Features window in the Feature to Point tool. For the Output Feature Class option, navigate to \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb and name the new feature class “patch_centroids.” Check Inside option. This will force the centroids to always be generated inside polygon boundaries. Click OK.

The centroids will be used to generate random sample of landscape change polygons to be validated following procedures described in **SOP 4: Office Validation**.

5. Literature Cited

Liaw, A., and M. Wiener. 2002. Classification and Regression by randomForest. R News 2(3), 18-22.

R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

SOP 4: Office Validation

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1. Overview

Once patches are generated and attributed with a change type by the random Forest(RF) model, the user validates the results by visually assigning a change category to all patches inside the park boundary and selected samples of patches outside of the park boundary. Additional information from spectral trajectories, aerial photos, and other external data sources are used in this validation process. These change category assignments are then compared to the types assigned by the RF model to generate accuracy matrices and classification accuracies.

To aid in validation, LARSE developed an application called TimeSync. TimeSync allows the user to view the same geographic region from each image in the image stack, while simultaneously viewing the time trajectory of spectral values for multiple indices for a chosen plot.

This SOP covers the following steps: developing inputs required by TimeSync to display graphs and image chips, conducting validation for a sample of change polygons, and generating a confusion matrix (Figure 4.1). The inputs required by TimeSync are stored inside a Microsoft Access database, a copy of which has been included with this protocol.

All files are stored in the directories under the main project directory on GIS Specialist's workstation (C:\GIS\Monitoring\LPa01_Landscape_Change\).

A. Software Requirements

NPS Alaska Pak

In addition to ArcGIS Desktop software, the user needs to install NPS Alaska Pak extension. The extension can be downloaded from http://science.nature.nps.gov/nrgis/applications/gisapps/gis_tools/8x/alaskapak.aspx. Make sure to select the version that goes with ArcGIS™ 10.x software. Follow the instructions provided on the website to complete the installation. The Theme Manager extension is not used for this protocol.

TimeSync

The TimeSync application was developed by LARSE and is included with this protocol. This SOP describes procedures for TimeSync version 3.9.8.0. The user should check for the most current version of the program before starting validation. If not already done, the executable should be unzipped and loaded into \Spatial_info\GISTools\TimeSync\ directory.

Microsoft Office

Microsoft Access and Excel are needed to contain validation plots. Both programs should be available on any NPS computer. This SOP refers to Microsoft Access version 2010.

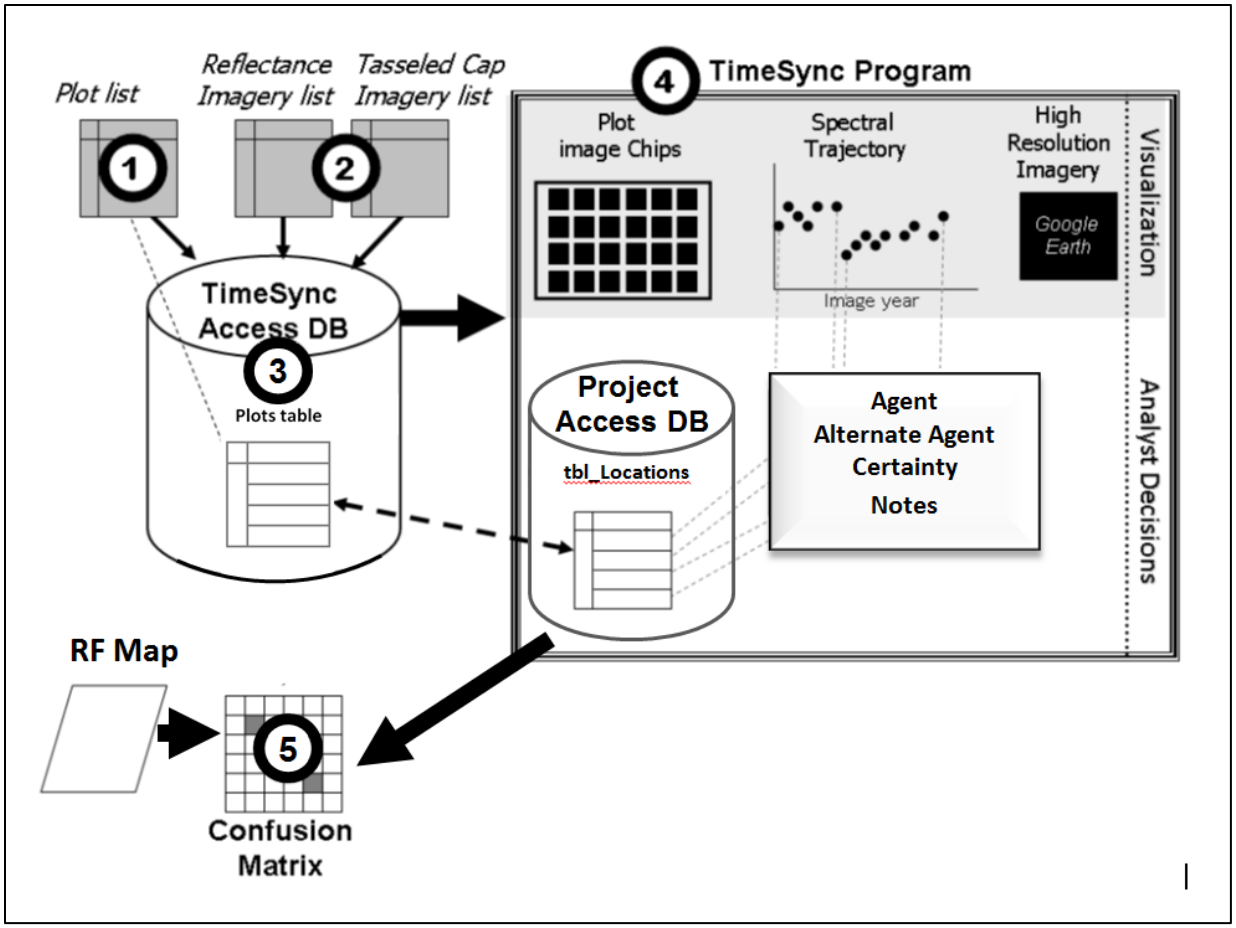


Figure 4.1. TimeSync work flow. 1) Devise plot list. 2) Update reflectance and tasseled cap imagery list. 3) Set-up TimeSync database referencing the plot list and imagery lists. 4) Determine the change category within TimeSync using a combination of Landsat image chips, spectral trajectory, and high resolution imagery in Google Earth. Document change category in the project Access Database. 5) Compare TimeSync change category results to the change category assigned by the Random Forests model using a confusion matrix.

Google Earth

Google Earth is used to view change polygons using aerial photography. The software also allows viewing of historic imagery. Currently, 1990 black and white imagery and 2006 and 2009 NAIP imagery is available for viewing. The free desktop version of Google Earth can be downloaded from http://www.google.com/earth/download/ge/. Version 6.1 was used to develop this SOP.

2. Develop Samples

A. Select Change Polygons for Validation

The protocol calls for validating all landscape change polygons inside the park boundary and a random sample of change polygons in each category outside the park boundary. The random sample is generated in GIS using the patch_centroids feature class created at the end of **SOP 3: Labeling Landscape Change Types**.

Open ArcMap and add the patch_centroids feature class from \Spatial_info\PARK\PARK_SCENE_rapid_StartYear_EndYear.gdb.

If the Alaska Pak extension toolbar did not load automatically, select Toolbars under Customize drop down menu in ArcMap® and make sure the NPS Alaska is selected.

Open the attribute table for the patch_centroids feature class. Under Table Options, select Add Field. Enter “Validate” for the field name and chose Short Integer for field type.

Under Table Options, click on Select by Attributes. Double-click on the “In_park” field and single-click on the Get Unique Values button. Double-click on ‘Y.’ Verify that the expression on the bottom window reads: "In_park" = 'Y.” Click Apply. All centroids within the park boundary should now be selected. Right-click on the Validate field and select Field Calculator. In the empty box at the bottom of the Field Calculator screen enter “1” (without quotes). Click OK. Verify that all the selected records received a value of “1” by clicking on the Show selected records button and scrolling up and down the list. Unselect selected records.

Right-click on the patch_centroids feature class and select Properties. Select Definition Query Tab and click on Query Builder button. In the bottom window type "In_park" = 'N' AND "Agent_RF" = 'Agricultural.' Only points within the “Agricultural” category that are located outside of park boundary should be selected.

> If the total number of records is less than 40, right click on the Validate field and select Field Calculator. Enter “1” in the bottom window and click OK. All records in the table should now have the value of “1” in the Validate field.
>
> If the total number of records is more than 40, click on Alaska Pak toolbar dropdown menu and select Randomize/Random Select. Verify that Feature Layer name is patch_centroids. Select Number option and enter “40.” Click Select. Verify that a number of the features were selected. Right-click on the Validate field and select Field Calculator. Enter “1” in the bottom window and click OK. Selected records in the table should now have the value of “1” in the Validate field. Unselect all the records.

Repeat the last step for all change categories in the field Agent_RF.

After the last sample has been selected, clear the Definition Query window and make sure that all patch_centroids are visible. In the attribute table, select Select by Attributes under the Table Options. Type the following expression in the bottom window: "Validate" IS NULL. Click Apply. Right-click on Validate field and select Field Calculator. Type “0” (without quotes) in the bottom window and click OK. All records that were not selected in the random selection process should now have a value of “0” in the Validate field.

At the end of this process, the user should have 40 random samples selected for each of the change categories that have at least 40 records and all observations selected for change categories with less than 40 records.

B. Devise Plot List

TimeSync requires a list of polygon centroids and associated attributes, which is loaded into an Access database table. While the TimeSync is running, the user will be able to click on one of these polygon centroids, which will prompt the TimeSync to display the associated image chips and graph the trajectory of the spectral values for indices chosen by the user. The centroids for the polygons selected for validation in the previous section will be used to create the list.

Generate X,Y Coordinates for Centroids

If needed, open ArcMap and add patch_centroids feature class from the \Spatial_info\PARK\PARK_SCENE_rapid_StartYear_EndYear.gdb.

Open ArcToolbox and navigate to Data Management Tools\Features\Add XY Coordinates tool. Open the tool and drag the patch_centroids feature class into the input features window. Run the tool and verify that the X and Y fields were added to the patch_centroids attribute table.

Export Attribute Table to .dbf Format

In ArcToolbox, navigate to Data Management Tools\Layer and Table Views\ and open Make Table View tool. Select patch_centroids for Input Table, enter "Validate" = 1 for Expression and make all fields invisible except GRIDCODE, Point_X, and Point_Y.

Open the newly added table to verify that all three selected fields transferred to the table and that the number of records in the new table matches the number of records with the value of “1” in the Validate field in the patch_centroids attribute table.

Under Table Options, select Export. For the output table, change the “Save as type” option to dBase file, navigate to \Spatial_info\PARK\TimeSync\ and name the output file “PARK_StartYear_EndYear_validation_plots.dbf.” Click OK.

Import to Excel

Open Excel and import the .dbf file created in the previous step. Change the GRIDCODE field to “PlotID,”change the Point_X field to “X” and change the Point_Y field to “Y.” Remove the decimal places from all three fields and save the file in Excel format with “PARK_StartYear_EndYear_validation_plots.xlsx” name in the same directory.

3. Update the TimeSync Imagery List

LARSE will include the NCCN reflectance and tasseled cap Landsat images to add to the existing stack. These images should be downloaded or copied to \Spatial_info\PARK\SCENE\ images\ directory. Once the files are copied, the image lists used in TimeSync need to be updated with their new file names and locations.
Navigate to the \Spatial_info\PARK\SCENE\timesync\ directory and open SCENE_refl_list.txt.

Add newly copied reflectance images in the format of: imgtype,imgyear,imgday,id,file (Figure 4.2), where
imgtype = image type (TM or ETM+)
imgyear = image year (yyyy)
imgday = image day (yyyy-ddd) ddd= julian day

id = directory path to images
file = name of madcal reflectance file

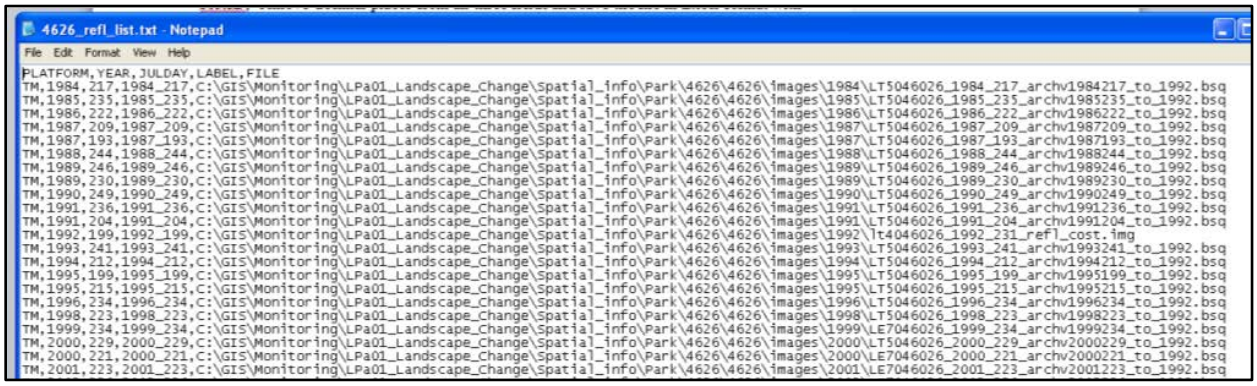


Figure 4.2. Reflectance imagery list example.

Repeat the same for the tasseled cap imagery by using SCENE_tc_list.txt and updating it with the new tasseled cap image information.

4. Set-up the TimeSync Application

A. Create Database

Each Spatial_info\PARK\SCENE\timesync\ directory contains a SCENE_timesync_template.mdb that needs to be modified to be used in TimeSync. Copy the template .mdb to Spatial_info\PARK\TimeSync\ directory and rename it to PARK_SCENE_StartYear_EndYear.mdb.

B. Populate Plots Table

Open the Access database. The database contains a number of tables that are necessary to run the TimeSync application. The only table that needs to be changed by the user is the Plots table.

Verify that the Plots table does not contain any records. Close the table. Right-click on the Plots table and select Import/Excel. Under File name, navigate to \Spatial_info\PARK\TimeSync\ PARK _StartYear_EndYear_validation_plots.xlsx. Select the append option and change the table name to “plots.” Click OK. Make sure the fields are identified correctly and click Finish. Open table “plots” and verify that the number of records added matches the number of records in the Excel file. Check that none of the fields contain missing values (Figure 4.3).

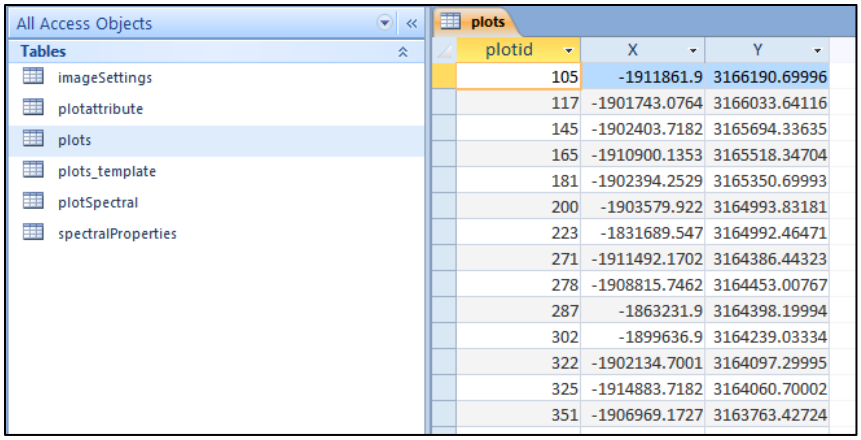


Figure 4.3. Plots table populated with polygon centroids for validation.

C. Define Image Settings

Make sure the database points to the directory containing the reflectance and tasseled cap images. Open the table named imageSettings. The Bgw_image_list field should be pointing to the\Spatial_info\PARK\SCENE\timesync\SCENE_tc_list.txt file.The Refl_image_list field should be pointing to the \Spatial_info\PARK\SCENE\timesync\SCENE_refl_list.txt file.

Leave the scalar field at the default value of 4000 (Figure 4.4)

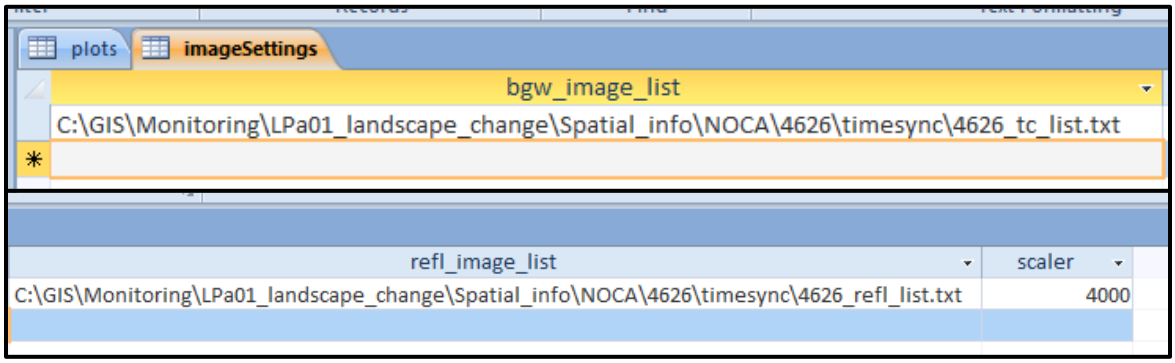


Figure 4.4. Pathways to image lists in the imageSettings table.

Close the TimeSync database.

D. Google Earth Polygon Creation

TimeSync is linked to Google Earth, which displays historic and recent aerial photography useful for the change category validation. The landscape change polygons selected for validation need to be transferred to Google Earth format (.kmz) and imported into the program showing polygon unique IDs (GRIDCODE).

If necessary, open ArcMap® and add the poly_patches feature class from \Spatial_info\PARK\PARK_SCENE_rapid_StartYear_EndYear.gdb and PARK_StartYear_EndYear_validation_plots.xlsx from \Data\Validation\Park\ directory.

Right-click on the poly_patches feature class and select Joins and Relates/Join. Choose GRIDCODE for option 1, PARK_StartYear_EndYear_validation_plots.xlsx for option 2, and PlotID for option 3. Select the "Keep only matching records" option and click OK.

Modify the poly_patches symbology by selecting no fill and a 2.0 outline in Fire Red. Label polygons using the following expression: [GRIDCODE] & "_" & [Year1]. Save poly_patches feature class as a layer file as \Spatial_info\PARK\Layers\PARK_StartYear_EndYear_validation.lyr

Add the layer file to the ArcMap® project, if it hasn't been done automatically.

Navigate to Conversion Tools\To KML\Layer to KML tool in ArcToolbox®. Open the tool, add the layer file as the input Layer and save Output File as \Spatial_info\PARK\GoogleEarth\PARK_StartYear_EndYear_validation.kmz. Enter 10,000 for Layer Output Scale. Leave all other options default. Click OK.

Obtain a copy of fire perimeters for the analysis time window from the park's fire program and convert to Google Earth .kmz file using steps outlined above. Use the fire date and name for labeling. Save the layer file as \Spatial_info\PARK\Layers\PARK_StartYear_EndYear_fires.lyr. Save the .kmz file as \Spatial_info\PARK\GoogleEarth\PARK_StartYear_EndYear_fires.kmz.

5. Lab Validation

A. Deploy Validation Components

Navigate to the \Spatial_info\TimeSync\ directory and double-click on the TimeSync.exe file. Two windows should open: TimeSync and Image Viewer. In the TimeSync window, select File/Open. Navigate to \Spatial_info\PARK\TimeSync\ PARK_SCENE_StartYear_EndYear.mdb and click OK. The plots will load on the left side of the TimeSync window. The trajectory for the first plot on the list will be generated on the right side of the TimeSync window. The tasseled cap Landsat image chips for the first plot on the list will load in the Image Viewer.

Open Google Earth. Click on File\Open and navigate to \Spatial_info\NOCA\GoogleEarth\PARK_StartYear_EndYear_validation.kmz. Click Open. The Places section of the Google Earth application will show the list of plots (expand the list, if necessary) with change polygon IDs and years of onset listed. Click on File/Open and navigate to \Spatial_info\PARK\GoogleEarth\PARK_StartYear_EndYear_fires.kmz. Open file and verify that fire perimeters were added to display.

Navigate to the current version of the project database in Data\Database\ directory. Open the database and select your user name. Open tbl_Locations. Filter the following fields: 1) Analysis_yr – limit to the three years being validated; 2) Is_selected – display only selected change polygons. You should only see the change polygons that were selected for validation.

The validation approach requires four components: (1) the TimeSync Image Viewer within which an area of user-defined size is centered around an area of interest (i.e., change polygon) and is displayed as a time series of image chips which are viewed simultaneously, (2) the

TimeSync trajectory window within which the change polygon's spectral properties are displayed as a trajectory of Landsat band reflectance or index through time in any band or index desired, (3) a Google Earth window where a recent high-resolution image of the change polygon and its neighborhood can be viewed for context, and (4) an Access database where change type determinations are entered (Figure 4.5).

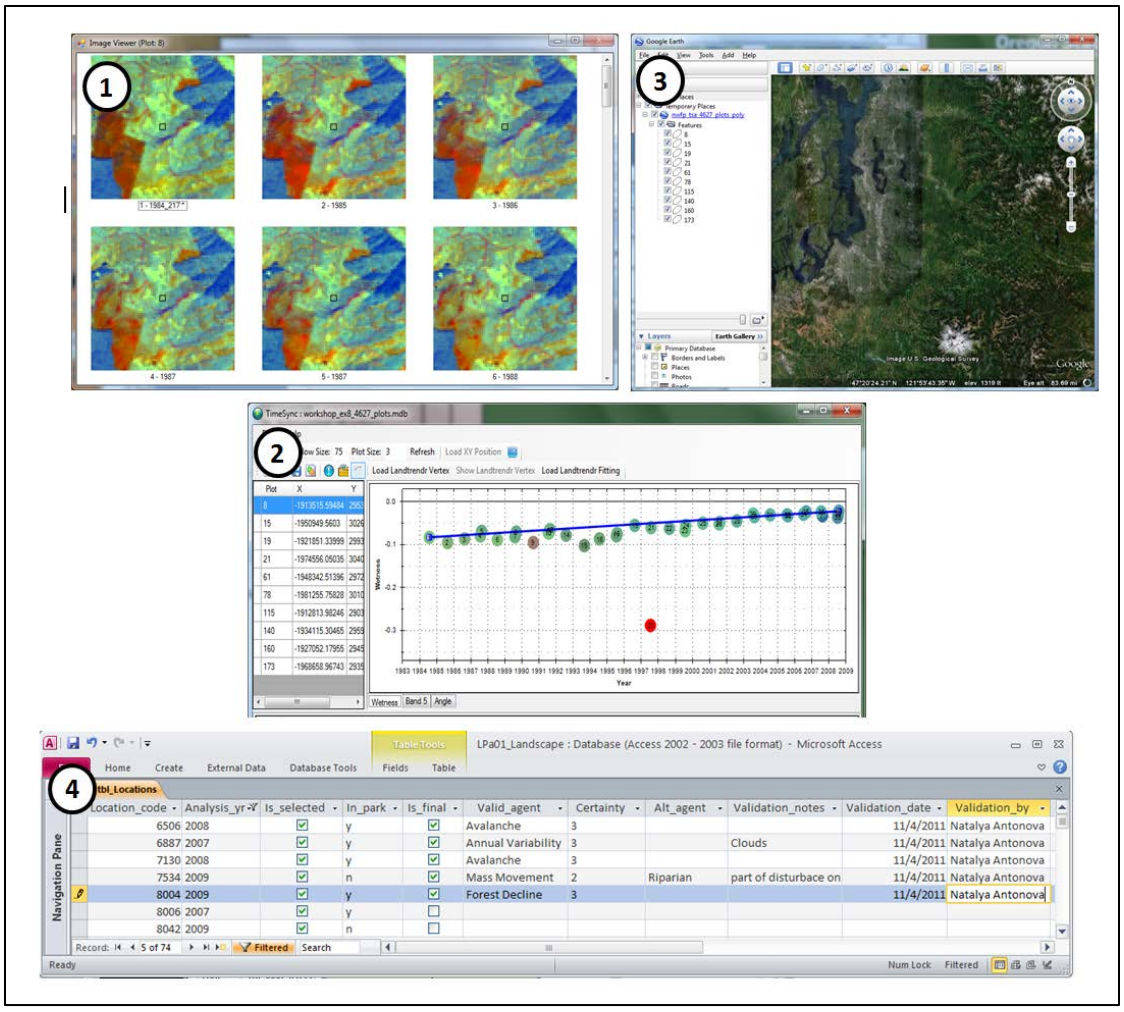


Figure 4.5. TimeSync application components. 1. Image chips from the Landsat Stack, with plot centroid indicated in the black box. 2. Trajectory of Landsat index values. 3. Google Earth. 4. Access database.

B. Perform Validation

Before performing validation, consult **Appendix A: Description of Landscape Change Types** to learn how different types of landscape changes look on tasseled cap image chips, aerial photographs and spectral trajectories. Appendix A also describes locations on the landscape or landform types where each type of landscape change is expected to be found and provides rules that the NCCN uses to distinguish landscape change categories that might exhibit similar spectral or spatial characteristics.

Landscape Change polygons displayed in the three applications used for validation (TimeSync, Google Earth and Access) are all tied by their polygon IDs. Use PlotID in TimeSync, polygon

label in Google Earth and Location_code in Access database to gather information for an individual plot. Fly to the change polygon in Google Earth by double-clicking on the polygon label. Display image chips and trajectory for a change polygon by clicking once on its associated PlotID in the TimeSync window. Use fire perimeters displayed in Google Earth to help validate fire polygons.

After determining the change category using available tools, populate Valid_agent, Certainty, Alt_agent, and Validation_notes fields in the Access database with appropriate information. Table 4.1 contains definitions for the possible entries in the Certainty field.

Table 4.1. Definitions for possible entries in the Certainty field of the TimeSync Access Database

Certainty	Certainty label	Description
1	Low	Aerial photo and spectral trajectory are hard to interpret; there is more than one possibility of an agent.
2	Medium	Landscape Change agent is difficult to interpret on the aerial photo, but spectral trajectory is consistent with the call and it's difficult to come up with an alternate agent.
3	High	Spectral trajectory and aerial photo are consistent; there is no doubt as to the agent of change.

Use the Alt_agent (alternative agent) field only if you are not certain about the landscape change type in the Valid_agent field. Make notes in the notes field describing the source of any uncertainty. The Validation_date and Validation_by fields will be populated automatically based on the user's login information. After all necessary fields are filled, check the Is_final box to indicate that the validation for a particular landscape change polygon is complete. During future validation sessions this field can be used as an additional filter to only display landscape change polygons that have not been validated yet.

6. Determine Map Accuracy Based on Aerial Photo Interpretation

A. Create Confusion Matrix for Areas Outside the Park Boundary

If necessary, open the project database in \Data\Database\ directory. Open tbl_Locations and filter the following fields: 1) Analysis_yr – limit to the three years being validated; 2) Is_selected – display only records for selected change polygons; 3) In_park – select "N." Right-click on tbl_Locations and select Export\Excel. Place the new file in \Analysis\Validation\ directory and save it as PARK_StartYear_EndYear_matrix.xlsx.

Open the Excel file and delete all columns except Location_code, Valid_agent, and Model_agent. Select the three columns and click on Insert\PivotTable. Place the table into a new worksheet.

In the worksheet with the pivot table, drag Model_agent to Row Field and Valid_agent to Column Field. Drag the Location_code field to Data Items. Excel will automatically populate the pivot table with values.

B. Calculate Classification Accuracies for Areas Outside the Park Boundary

Copy the pivot table to a new worksheet. Calculate the total classification accuracy by dividing the total number of landscape change polygons that were correctly classified (sum of values in the diagonal in the confusion matrix) by the total number of polygons and multiplying the result by 100 to convert to percent.

Calculate the user's accuracies, which represent the percent of polygons on the map that match the validation data, by dividing the number of correctly identified polygons in a given change category (diagonal) by the number claimed to be in that change category (row total). Multiply by 100.

Calculate the producer's accuracies, which represent the percent of landscape change polygons that were labeled correctly by the model, by dividing the number of correctly identified polygons in a given change category (diagonal) by the number of polygons in that are actually in that category (column total). Multiply by 100.

C. Calculate Kappa Statistic for Areas Outside the Park Boundary

Kappa or KHAT statistic is a measure of difference between the actual agreement between the reference (validation) data and the automated classifier (the Random Forest model) and the chance agreement between the reference data and a random classifier. The *Kappa* statistic is calculated using the formula below:

$$\hat{k} = \frac{observed_accuracy - chance_agreement}{1 - chance_agreement} \qquad \hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} x_{i+} * x_{+i}}$$

where

r = number of rows in the error matrix
x_{ii} = the number of observations in row i and column i (on the major diagonal)
x_{i+} = total of observations in row i (shown as marginal total at right of matrix)
x_{+i} = total of observations in column i (shown as marginal total at bottom of matrix)
N = total number of observations included in matrix

Table 4.2 shows an example of a confusion matrix with total, user's and producer's accuracies and the *Kappa* statistic.

7. Select Polygons for Field Validation

If necessary, open the project database in \Data\Database\ directory. Open tbl_Locations and filter the following fields: 1) Analysis_yr – limit to the three years being validated; 2) Is_selected – display only selected changes; 3) In_park – select "Y." Right-click on tbl_Locations and select Export\Excel. Place new file in the \Analysis\Validation\ directory and save it as PARK_StartYear_EndYear_potential_field.xlsx.

Create a point GIS layer with the same name from the .xlsx table using centroid coordinates and export to a shapefile in the Analysis\Validation\ directory under PARK_StartYear_EndYear_potential_field.shp name. Add a short integer field "Field_sel" to

the shapefile. Overlay the new shapefile with the change polygon layer and the park base layers, such as roads, trails, slope, and aerial photography.

Table 4.2. Example confusion matrix comparing TimeSync validation results and Random Forest model.

		Validation											
		Annual Variability	Avalanche	Clearing	Development	Fire	Tree Toppling	Progressive Defoliation	Mass Movement	Riparian	Unknown	**Grand Total**	User's Accuracy
RF Model	Annual Variability	30						10	1		3	**44**	68.2
	Avalanche	2	10			1		16	3	1	4	**37**	27.0
	Clearing	1	5	29	1			2	1		1	**40**	72.5
	Development				0							**0**	N/A
	Fire		3			15		2				**20**	75.0
	Tree Toppling						0	1				**1**	0.0
	Progressive Defoliation	3	2			9		144			8	**166**	86.7
	Mass Movement	3	1					1	5			**10**	50.0
	Riparian	2	1			2				3	1	**9**	33.3
	Unknown										0	**0**	N/A
	Grand Total	**41**	**22**	**29**	**1**	**27**	**0**	**176**	**10**	**4**	**17**	**327**	
	Producer's Accuracy	73.2	45.5	100.0	0.0	55.6	N/A	81.8	50.0	75.0	0.0		
	Overall Accuracy	72.17											
	Kappa Statistic	59.38											

Determine which areas of the park should be visited in the field to validate change polygons. First, use the Definition Query in ArcGIS to exclude polygons that were classified as Fire during office validation. Next, assess the number of available polygons in each remaining change category. Change categories with fewer than five occurrences should have every polygon validated. Update the “Field_sel” attribute in the point shapefile to the value of “1” for all change events in these categories. For the remaining categories, use the Select by Location tool in ArcGIS to select polygons within 0.5 kilometer of the park’s trails layer. Perform the same selection for the roads layer, but modify the Select by Location options to add selected features to the existing selection. Examine the number of polygons in each category. Update the “Field_sel” attribute in the point shapefile to the value of “1” for all polygons in categories with fewer than 10% of the total number of polygons available within that category inside the park boundary. If there are any categories that resulted in fewer than five polygons within the trails/roads buffer, use the Alaska Pak extension to randomly select additional polygons to add up to the total of five in those categories outside the trail/road buffer. For the remaining categories where the number of polygons within the trails/roads buffer exceeds the 10%

threshold, use the Alaska Pak extension to randomly select the number of polygons that would represent 10% of all available polygons in that category. Update the “Field_sel” attribute in the point shapefile to the value of “1” for the polygons that were randomly selected by the Alaska Pak extension.

Examine all polygons selected for field validation for accessibility using the park’s topographic quadrangle and slope layers. Determine if each polygon can be accessed without having to wade through a major stream or travel across slopes of more than 35 degrees. If some polygons get discarded, and there are other polygons available in that category that meet the distance from trails or roads criteria, use the Alaska Pak extension to randomly select additional polygons to replace the discarded ones. Examine the newly selected polygons for accessibility. Repeat this process until a full sample is selected. The end goal is to field validate all polygons in categories that have fewer than 5 occurrences, if accessible, and at least five but up to 10% of available polygons in the remaining categories, except Fire.

After the selection process is complete, select the point shapefile records with the value of “1” in the “Field_sel” field and export to a shapefile in Analysis\Validation\ directory under PARK_StartYear_EndYear_field_selected.shp name.

SOP 5: Field Validation

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1. Overview

Following office validation with TimeSync and aerial photography, a subset of change polygons inside the park boundary is selected for field validation. This SOP describes procedures for field season preparations, field visits and field data processing for this type of validation.

2. Permitting and Compliance

This monitoring project will be categorically excluded from further analysis under the National Environmental Policy Act (NEPA) because (a) it is not controversial; and (b) it involves nondestructive methods with negligible impacts to the environment. The following categorical exclusion applies: (6) Nondestructive data collection, inventory (including field, aerial, and satellite surveying and mapping), study, research, and monitoring activities (this is also a Departmental CE).

Within MORA, NOCA and OLYM, most of the monitoring sites will fall within designated wilderness. Therefore, aside from NEPA, if study sites are located in designated wilderness then compliance with the Wilderness Act and NPS policies regarding scientific research in wilderness must be considered. Scientific activities are an important component of wilderness stewardship and this research project will help to answer important questions that cannot be reasonably addressed in a non-wilderness setting. Therefore, this project clearly meets the minimum requirement for administration of wilderness. There will be no mechanized tools or equipment need to conduct this research, so there are no minimum tool concerns which need to be evaluated. In short, this activity will fully comply with the spirit and intent of the Wilderness Act.

3. Field Season Preparations and Equipment Setup

A. Recruitment of the Field Crew

At least two people are required to be on the field crew for safety reasons. The field crew will consist of the GIS Specialist and one intern. As a field crew lead, the GIS Specialist will be responsible for recruiting and training the intern. A local intern will be recruited by posting an internship description at the Western Washington University with NOCA being the assigned duty station for the purposes of training and data entry. To perform field validation, the GIS Specialist and the intern will travel to a designated park at the beginning of the tour of duty, spend eight to ten days in the park, camping, and then return to the duty station location. The intern does not need to have specialized experience, but should be very physically fit and comfortable spending extensive time in the backcountry.

Soon after being recruited, the intern should be sent the following:

- A written description of the internship expectations, duties, and responsibilities.
- Volunteer form.
- Volunteer handbook.
- Safety procedures.
- Supervisor contact information.
- Start date, time, and location.

- Proposed season schedule.
- Maps of each park where they are likely to perform fieldwork.
- List of camping and hiking gear recommended and/or supplied by NCCN.
- A copy of the NCCN Landscape Dynamics Monitoring Protocol.

B. Training

The GIS Specialist is responsible for training the intern, which will be conducted in July. The intern will also be encouraged to participate in parts of the seasonal training programs conducted by NOCA for other seasonal staff, which usually occurs in mid-June. Specialized training will include:

- Background information on the protocol.
- Definitions of change categories.
- Use of GPS, radio equipment and maps.
- Safety procedures, including accident forms and procedures.
- NPS vehicle operation.
- Backcountry gear and packing suggestions.

C. Inventory of Equipment and Reservations

Beginning in June, equipment will be inventoried by the GIS Specialist, including testing of breakable items such as GPS units, radios and water filters, and any needed items, including batteries for GPS units, will be purchased. Camping reservations or backcountry permits will be obtained from appropriate parks. A vehicle will be checked out and data forms will be copied on waterproof paper. Topographic maps for the year's targeted change polygons will be printed and assembled. NPS personnel knowledgeable about backcountry conditions in each park will be consulted to determine whether conditions such as washed out bridges, road or trail closures, or unusually heavy snowpack may present logistical problems.

D. GPS Loading and Preparation

The GIS Specialist will load target coordinates, change polygons with IDs and year of change onset determined from LandTrendr data, background data, and data dictionaries into the GPS units following guidelines on GPS use and GPS data handling that are provided in NCCN GPS Guidelines (NCCN 2009). The GIS Specialist will make sure that the software for downloading GPS data is available and ready for use.

4. Field Season

A. Crew Gear and Packing

The GIS Specialist will distribute items of individual gear provided by the program to the field crew. The GIS Specialist will maintain a list of checked out equipment. Personal gear can be used, but will not be replaced by NPS if damaged or lost. At the end of the field season, the crew and the supervisor will ensure that the equipment is returned and that any damaged or lost items are noted for repair or replacement. Table 5.1 provides a list of camping equipment recommended for backcountry travel in NCCN parks.

Table 5.1. Gear recommended for camping and hiking in NCCN parks.

Personal Gear*	
Large capacity backpack	Raingear - always
Compass*	Waterproof boots
Map of route*	Hat and gloves
Whistle*	Long underwear
Headlamp or flashlight (spare batteries)	Fleece jacket
Notebook, 3 pencils, 2 sharpies*	Quick dry clothes: nylon zip-off pants, polyester shirt
Hand lens* (at least one 10x for each crew)	Spare: socks, dry clothes
Bear barrel* (full of food)	Toothbrush, etc.
Water bottle: 1 bottle and perhaps an extra	Iodine capsules (in case water filter breaks)
Eating utensils (bowl, cup, fork, spoon, chopsticks, etc.)	Optional: your own tent, water filter, or stove if preferable to NPS-supplied gear
Pack cover*	Other suggestions: Bug repellant, bug net*, chapstick, sunscreen, sunglasses, hat/visor, spare shoes/sandals, hiking poles*, gators, camp clothes, daypack or field vest, lightweight long-sleeved shirt or windbreaker, parachute cord for bear wire etc., towel, bandana, personal first aid kit w/ moleskin, ace bandage, etc., hot chocolate, cards, book, chocolate chip cookies
2-3 Garbage bags* for inside pack - always	
Sleeping bag (pack in garbage bag – no holes!)	
Sleeping mat	
Group Gear (supplied by NPS)	
Scale (at office) for weighing backpack	Lighter/ matches
Water filter (recommend 1 per two people)	Cooking pot w/ handle
Stove	Tent w/ ground cloth and fly.
Fuel (2 x 22oz for 2 people for 8 days)	Trowel

*Supplied by the NPS

The following group gear will be checked out by the GIS Specialist at the beginning of the field season. The field crew is responsible for maintaining group gear and making sure that items are cleaned and dried at the end of each sampling tour. Specific equipment is maintained as follows:

- water filters - disassembled, flushed with clean water, cleaned as necessary, air dried
- tents - cleaned and dried
- first aid kits - restocked and dried if necessary
- batteries - recharged or replaced
- stoves - cleaned and tested for satisfactory burning
- cook kits - washed and dried
- fuel bottles - filled and returned to an approved storage location

Information regarding broken or lost gear, or other problems, should be included in the reports prepared by the GIS Specialist at the end of each tour and brought to the attention of the Project Lead.

Table 5.2 describes equipment necessary to perform field validation of change polygons.

Table 5.2. Equipment for validation of change polygons.

Plot Setup Equipment	
Field vest or daypack	ArcGIS maps of polygon locations
Compass	Field forms
GPS w/ spare batteries	Guide to agent types
Radio w/ spare batteries	Pen or pencil
Camera	Binoculars
7.5 minute quad or similar map	

B. Safety

Personal safety is the number one priority at all times in the field and office. At no time are staff expected to participate in operations that appear dangerous or risky. The backcountry can present a number of challenges for field crews: high altitudes, steep slopes, irregular ground surfaces, long travel times, and weather extremes (e.g. direct sunlight, rain, lightening, and rapidly changing weather). Awareness of weather, environmental conditions, wildlife, and the whereabouts of crew members is crucial to safe working conditions at high elevations. All field personnel are required to participate in an annual field safety program that covers standard safe field practices in the backcountry.

During the training period, the Project Lead will facilitate a discussion of the "Job Safety Analysis" form to explore all aspects of working safely. This form is also referred to as a "Job Hazard Analysis." Each year the intern, the GIS Specialist and the Project Lead will share their experiences about items included on the form and revise text or add new items as necessary. Two areas of emphasis in the Job Safety Analysis are vehicle use and working in the field. See **Appendix E: Job Hazard Analysis** for example form.

Vehicle Use and Safety

The Project Lead will go over vehicle use and safety with crew members as follows:

Vehicle Use

- Key drawer or board: where keys (and spares) will be kept at all times when not in use
- How to use government credit card for purchasing gas
- Other items covered by government credit card (car wash, tire repair, unexpected needs such as motor oil and windshield wipers) – NOTE: Save receipts
- Ferry travel: how to obtain reimbursement
- How to schedule if using shared vehicle

Vehicle Safety

- Safety checklist (Table 5.3)
- Location and use of vehicle safety equipment (tire gauge, jumper cables, camera, etc)
- Items to keep in vehicle (Table 5.4)
- Emergency procedures
- Procedure and equipment for changing a flat tire

Table 5.3. Vehicle safety checklist.

Check the following on your vehicle at the beginning of the field season and before each tour
Tires: pressure (do tires look low?) and tread condition
Fluids: Coolant, motor oil, transmission, and other under-the-hood fluid levels
Gas: Check that the tank is full. When traveling across park, fill the tank before leaving the last available gas station.
Lights: brake, turn signals, tail lights, headlights
Horn
Windshield (GSA pays for repairable chips)
Windshield wipers: condition
Body damage: dents or scratches
All items secure: secure items so that they are not able to fly at passengers in the event of an accident

Table 5.4. Items to keep in the vehicle.

Required gear	
Washington atlas and gazetteer	Spare tire
First aid kit	Space blanket
Fire extinguisher	Camera (disposable, in case of accident)
Flashlight, warning markers or reflectors	CA-1 Form
Car jack and lug nut wrench	Motor Vehicle Accident Report Form
Jumper cables	
Extra field gear that might come in handy	
Extra data forms	
Spare camp stove	

Road Safety

- **Seat belt.** Use is required in all government-owned or leased vehicles and is required by law in the State of Washington for driver and all passengers. Do not ride in the back of pickups.
- **Drive defensively.** Expect the other person, whether a vehicle operator or a pedestrian, to do the worst thing, and be prepared. Observe all speed regulations and traffic signs.
- **Alert and in control.** Do not drive when sleepy, taking medication, or when other personal conditions make it unsafe to drive a vehicle. Get someone else to drive or, if alone, stop driving and nap (out of public view).
- **Hands on the wheel.** Keep both hands available for driving at all times. Safely pull off to the side of the road before using a cell phone.
- **Headlights.** Always drive with headlights on to increase the visibility of the vehicle. It is particularly important when driving in fog, on dusty roads, traveling in and out of shadows, and any other low light/visibility situations. Turn lights off when parking the vehicle.
- **Conditions.** Do not operate a vehicle in an unsafe condition. Check the vehicle frequently to keep it in good mechanical condition. Lights, horn, steering, and brakes should be kept in proper adjustment at all times. Make necessary repairs as soon as unsafe condition develops. Report any unsafe conditions to your supervisor.
- **Keep the vehicle clean.** Windows, mirrors, and lights should be kept clean and free of obstructions to increase visibility. Keep the cab and driver area clean so that material is not rolling under pedals or distracting the driver.

- **Downhill.** Shift to a lower gear at the beginning of a downhill grade, if the grade is a long, steep descent. This is possible in vehicles both with manual and automatic transmissions and will help extend the life of the brakes.
- **Speed.** Adjust vehicle speed to the driving conditions. Wet, icy or snowy roads and decreased visibility require decreased speed. Be aware of speed when changing from one type of road to another, i.e. freeway to secondary highway to gravel and adjust speed accordingly.
- **Tail-gating.** Allow at least three seconds of travel distance between yourself and the vehicle ahead. Under slippery road conditions and poor visibility, allow more distance.
- **Be aware of your vehicle's idiosyncrasies.** Adjust your driving accordingly.
- **Back up safely.** Walk around your vehicle to check for hazards before backing, and use a spotter to guide you.
- **Navigation.** Do not drive and navigate at the same time. If the driver needs to look at maps and photos, he or she should stop at a safe place, then look at them.
- **Watch for animals on the road.** Most hoofed animals travel in groups, so where there is one, assume there are many, all just itching to jump out in front of your vehicle. Stop and let the animal move off the road, look for others to follow, then proceed. If you cannot stop in time to avoid hitting an animal, it is generally better to hit it than to swerve, drive off the road, or hit another vehicle.
- **Oncoming vehicles.** Be especially alert for on-coming vehicles when driving on single-lane roads. Vehicles may be moving at high speeds in a shared lane and not paying attention when coming around corners.
- **Blind curves.** Keep as far right as is safely possible on blind curves and on single-lane roads. If the curve is blind and less than two lanes wide, slow way down and be ready to take evasive action. You may also honk as you approach a blind curve on a single lane road.
- **Yield.** Yield to *uphill* vehicles on roads wide enough for only one vehicle.
- **Parking.** Park the vehicle so that it is not a hazard to other drivers. Do not park where dry grass or other potential fuels can come in contact with your vehicle's hot exhaust system.

Safety in the Backcountry

- **Clothes**. Wear protective clothing: Long-sleeved shirts, long pants, and gloves may protect you from contact with brush, rocks, and stinging insects. Trouser legs should be loose enough to avoid binding or cramping, and should not have cuffs. Hats, sunglasses, and sunblock (skin and lips) will help provide protection from sun exposure. Head nets may also be helpful during the season when insects are bad.
- **Boots.** Wear good quality boots that provide good support and traction and can be water-proofed.
- **Cross country travel**. Take your time and plan your route. Routes across brushy, irregular and steep terrain with loose rocks and down logs can be hazardous; be aware of footing at all times. Trekking poles can also be useful when travelling off trail, and can offer additional stability and balance when the ground and vegetation are wet and slippery. Walking while reading instruments is hazardous.

- **Eyes.** Be watchful of twigs and branches, which may cause eye injury. A pair of standard sunglasses can be used for eye protection when travelling off trail. Safety glasses will be provided if necessary. Be especially alert when stepping up to trees that retain their small dead twigs. Keep a sufficient distance behind the person ahead of you.
- **Travel on steep slopes**. Use caution while traveling on steep slopes of scree, talus and wet vegetation. Take your time and be aware of foot placement. Use trekking poles if necessary.
- **Travel on snow**. Snow travel, not glacier travel, may occur while accessing a site. If snow travel is expected, each crew member should be trained is snow travel and be proficient at ice axe self-arrests. Each crew member should carry an ice axe.
- **Buddy system.** Always work in crews of at least two people.

Backcountry Basic First Aid

Methods to treat common backcountry injuries with first aid kit and available backcountry equipment:

- **Ankle sprain:** Use Ace bandage wrap or triangular bandage.
- **Fractures:** There are two types of fractures, open and closed. Open fractures are a much more serious condition than closed fractures. Open fractures will have some bleeding. Control serious bleeding, treat for shock, and check for pulse of injured extremity. Remove or cut clothing from injury site, if possible gently move fractured limb to splinting position, and then splint extremity, immobilizing joints above and below the fracture site. Leave fingers and toes exposed to monitor circulation and nerve function. Keep the injury clean.
    - **Leg fracture:** Splint in place. If open fracture, bandage to stop bleeding. A splint can be made from hiking or tent poles wrapped with triangular bandage and/or rope to keep splint in place.
    - **Arm fracture**: Bandage open fracture wounds. Splint with arm to body using triangular bandage. Splint with section of trekking pole or tent pole.
    - **Hand fracture**: Check for circulation and nerve impairment; splint with ruler, pencil, or stick.
- **Joint dislocation**: Common dislocations are of the shoulder but may also happen with elbows or knees. Check for pulse in injured extremity; splint with triangular bandage. DO NOT attempt to straighten any dislocated joint (serious nerve and blood vessel damage may occur). This is a very painful injury.
- **External Bleeding** - Methods to control: direct pressure, elevation
    - DO NOT elevate extremity if there is a possible fracture, dislocation, impaled object, or spinal cord injury. Pressure points (use only if direct pressure and elevation fail): Brachial and femoral, are the most important to know.
    - NEVER remove a dressing that is in place, apply more dressing on top if needed.
- **Laceration**: Use butterfly bandages to close the wound, then dress with 4x4 sterile pads, bandage with gauze, and triangular bandage.
- **Puncture**: DO NOT remove an impaled object; dress and bandage around it, stabilizing the object. Treat for shock.
- **Hypothermia:** Keep person dry and warm, remove wet clothing, place person in sleeping bag. NEVER allow a person to remain in, or return to, a cold environment.

- **Heat exhaustion or stroke**: Cool the person, move the person to shade, treat for shock, and check vital signs.
- **Shock: Two forms to be aware of are** Metabolic (loss of body fluids) and Anaphylactic (allergic reaction). To treat, remember ABC (Check for Airway, Breathing, Circulation), control bleeding, splint fractures, elevate legs, be alert for vomiting, keep victim warm, and check vital signs often.
- **Animal attacks**: Cougar and bear, what to do: Stand up, DO NOT RUN, look as tall as you can.
- **Choking**: Perform an abdominal thrust, details will be discussed in seasonal training or first aid training.
- **Field Equipment that can be used in First-aid procedures:**
    - Trekking Pole: The c**ollapsible trekking pole can be used to splint leg fractur**es and can be pulled apart to serve as a splint for an arm fracture.
    - Bandana: Can be used as a bandage or dressing material.
    - Other: Tent poles used as splints; sleeping pad can also be used as a splint.

What to Do If Injured

- Keep a CA-1 form, a vehicle accident report form, and a disposable camera for photographing vehicle accidents in the glove box of your vehicle at all times.
- If injured, treat promptly. If you are in the front country and if immediate medical attention is required, go directly to a hospital emergency room. Try to make contact with your supervisor or the office to get instructions and assistance. Make sure the doctor fills out his/her part on the CA-1 form.
- If you are in the backcountry, contact dispatch and relay the information to the ranger division or search and rescue staff and make sure they contact your supervisor. Be prepared to describe the nature of the injuries, when the injuries happened, and your location (be as exact as possible). If the injuries are serious enough to require helicopter rescue, try to find a suitable landing location. Use your GPS unit to get the Lat/Long coordinates for the helicopter pilot and the search and rescue personnel.
- Inform your supervisor of all injuries and ask which, if any, forms need to be filled out. Supervisors must complete the accident reporting forms within 24 hours or as promptly as possible.
- Fill out federal accident forms completely with signatures. ALWAYS make a copy for your personal records. Give the completed forms to your supervisor. Have the supervisor check your entries for mistakes, fill out his/her section, and forward the completed forms to the appropriate person.
- Gather information. If you are in a multi-vehicle accident, provide the other parties with enough written information so that they can easily get in touch with you, your crew supervisor, and the office. In turn, you must get the following information from all involved parties and witnesses: names, addresses, phone numbers, vehicle license numbers, driver's license numbers, insurance company names, policy numbers, and police report numbers. If possible, do not admit responsibility without first contacting your supervisor.

Radio Use
The Project Lead and/or GIS Specialist will go over radio protocol for the assigned park. The most recent radio information should be obtained from each park's communication center. Crew members will be shown:

- How to use the type of radio assigned to them (with handout)
- How to maintain radios and batteries (if replaceable) with specifics about battery life on the shelf and in the backcountry
- How to contact dispatch
- Which repeater to use in each region of the park. A map will be provided illustrating the locations of repeaters for each park.
- Appropriate topics and terminology for radio communication
- Who to contact if radio malfunctions

Wilderness, Backcountry, and Front-Country Camping Etiquette
The Project Lead will go over "Leave no trace" camping practices, wilderness ethics, and park regulations applicable to front-country and backcountry camping. Crews are expected to read and follow posted NPS camping regulations and cooperate with NPS rangers.

C. Field Data Collection

Navigating to a Location

Change polygons that were randomly selected for field validation, as well as surrounding polygons, will be loaded by the GIS Specialist into the GPS unit. Following procedures outlined in the NCCN GPS Guidelines (GPS 2009) for a specific GPS unit selected by the Landscape Dynamics Protocol, the crew will navigate to a selected location and perform field validation.

Field Site Documentation

Landscape Change Observation Forms
While on site, the field crew will fill out the field observation form shown in Figure 5.1, using the instructions on the form. The field crew will ensure that data are entered in all fields on the form.

Landscape Change Field Assessment Card **North Coast and Cascades Network**

Park _____ **PlotID**_____ **Year of disturbance**_____ **Date** mm/dd/yy _____

Observer (lastname, firstname) __ _____ _____ **Contact #**_____

Landscape Change Category (check one): see reverse for definitions of types

Agricultural___
Annual Variability___
Avalanche___
Clearing___
Development___
Fire___
Mass Movement ___
Progressive Defoliation___
Riparian ___
Tree Toppling ___

Confidence (1-Low, 2-Medium, 3-High) _____
if your confidence was medium or low, **what other types(s) did you consider** (and why)?_____
Did you take photos? Y If so, record Image# or timestamps_____

Change Description (including Progressive Defoliation type (insect/disease) if known)_____
_____

Observation coordinates (UTMs or Degrees if known):

UTM East_ _ _ _ _ _ _ UTM North _ _ _ _ _ _ _ Datum_____

Longitude W _ _ _ degrees __ __. __ __ __ minutes Longitude N _ _ degrees __ __. __ __ __ minutes

Coordinate source(circle one): Map or GPS **Coordinate Notes** (error, unit, model, waypoint name, map used)

_____

Entered by:_____ Date:_____ Verified by: _____ Date:_____ Updated by:_____ Date:_____ Photos? Y

Instructions for Filling out Landscape Change Field Assessment Card

Park: OLYM, NOCA, MORA, LEWI, EBLA, SAJH. **PlotID:** Unique ID from LandTrendr (filled in the office if not available).

Year of disturbance: Year you believe disturbance occurred or identify from LandTrendr in the office.

Date: Date of field observation. **Observer:** name of the person(s) making the observation.

Confidence: Indicate your confidence in the choice of landscape change type. High confidence is absolutely sure and/or have pictorial evidence to support call. Medium confidence is mostly sure but perhaps there a question or another type is considered. Low confidence is unsure or possibly considering between different types.

What other types did you consider: If the confidence was low or medium, what other types were considered and why.

Landscape change type: see back side of the form for definitions.

Change description: write a word picture of the change event. Include anything you see of interest about the cause, duration, magnitude, and timing of the disturbance. Discuss % of area affected. Discuss colors and textures. Indicate if the event seems different than others of its type.

Observation coordinates: enter coordinates in UMT or Lat/Long. **Datum**: indicate datum for all coordinate formats.

Coordinate Source: indicate if a GPS unit or a map was used to derive coordinates.

Coordinate Notes: indicated any information that would be useful in determining the accuracy of the coordinate.

Figure 5.1. Field form used for field sampling of landscape change polygons.

Landscape Change Categories:

Agricultural: found predominantly outside park boundaries; characterized by annual cycles of planting, growth, harvesting and plowing and often located in a matrix of agricultural fields; no forest regrowth following clearing should be evident.

Annual Variability: changes associated with annual variability in snow cover, terrain shadows and vegetation phenology; generally found in high elevations with limited vegetation and a lot of exposed ground, topographically complex areas, or areas with homogeneous vegetation that exhibits different colors at different times of year, such as heather and Cheatgrass (*Bromus tectorum*); no physical disturbance of vegetation or ground should be visible.

Avalanche: a long, linear event that originates in snow receiving zones on ridges or high on the valley wall and typically follows drainage down slope perpendicular to the valley floor. Below tree line, paths of avalanches are well defined by vegetation boundaries. Deep debris deposits will often be observed in catchments at the terminus of a run out, such as gullies and river beds. Recent event could be characterized by scraped ground, broken trees, if forest was removed, and deposits of debris at the terminus.

Clearing: found predominantly outside park boundaries and includes complete removal of vegetation and thinning. No repeated clearing or cultivation activities should be present and vegetation regrowth should be visible. Often characterized by a regular shape. Low density rural development is also included in this category, especially if the size of clearing is a lot larger than the footprint of the structure(s). Presence of access roads is usually evident.

Development: complete removal of vegetation with no evidence of vegetation regrowth. Could be accompanied by transformation to a built landscape, with driveways, houses, and other evidence of urbanization.

Fire: presence of singed or charred, standing trees with or without foliage.

Mass Movement: a landslide or a debris flow that is distinguished from avalanches by its magnitude – there is a completely removal of vegetation and exposure of rock or bare ground. Shape is often long and linear and occurs on a valley wall, traveling perpendicular to the valley floor. Debris flows are associated with water discharge.

Progressive Defoliation: forest cover still remains, but has reduced vigor due to drought or a pathogen or both. Evidence of pathogens can sometimes be seen on individual trees.

Riparian: these changes are restricted to the valley floor where the gradient is much lower and the valley floor is wider. Typical change patches show areas where either conifer or broadleaf vegetation has been replaced with either active river channel, water or river bank with gravel and sediment. Also includes forested or open patches (wetlands) in the riparian floodplain that have been inundated either temporarily or permanently.

Tree Toppling: presence of trees that have been both broken off and toppled to the ground as a result of a major wind event or disease, such as root rot. These events are often patchy, with multiple patches present in one area. Windthrow events usually occur in areas on the landscape that are exposed to wind, either on top of ridges and knolls or along rivers.

Figure 5.1. Field form used for field sampling of landscape change polygons (continued).

Photos
The field crew will document observed change polygons with one or more images that show characteristics of the change event, i.e. fallen trees, riparian damage, debris accumulation, etc and its location on the landscape. Photo numbers and/or date stamps will be recorded in the photo log.

Incidental Observations by the Field Crew
While en route to the change polygons selected for validation, the field crew might encounter other change polygons that will be visible from their location. Often, change polygons that are hard to access on foot will be visible from a road or trail and located across the valley from the observer. The crew will use the layers loaded on the GPS unit and field maps to determine the PlotIDs of these polygons and fill out a field observation form following procedures outlined in the previous section.

Incidental Observations by Park Staff and Visitors
NCCN park staff and visitors often report changes seen while working or recreating in the parks. An observation system has been set up to take advantage of these sightings to provide an additional layer of validation for change polygons. The field observation form in Figure 5.1 can be used by park employees or visitors to report a change event. The form will be distributed to by the Project Lead to various field crews, maintenance and interpretive staff, and back-country rangers at various parks prior to the field season with instruction on how to fill it out. Upon completion, the forms will be forwarded to the Project Lead for entry into the project database.

D. End-of-Season Procedures
The field crew will be responsible for putting away the equipment and documenting anything that is damaged or missing. In addition, the GIS Specialist will prepare a brief field season report enumerating which change polygons were sampled and describing any logistic difficulties that arose and how they were addressed. The report must clearly document and explain any diversions from established protocols. Finally, it should point out any interesting observations and provide suggestions for improving the training or field season procedures for the future. These reports will be archived.

The Program Lead, Data Manager, and GIS Specialist will hold an end of season meeting each year. The purpose of the meeting will be to discuss the results of the current year, review methods, discuss data analysis, and develop recommendations for upcoming seasons. These meetings will be particularly important during the first three years, during which different parks will be analyzed, and during the ten-year review because field and analysis methods may need some revisions during this initial period.

Field Form Handling Procedures
As field observation forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content. If changes to data on the forms need to be made subsequent to data collection, the original values should not be erased or otherwise rendered illegible. Instead, changes should be made as follows:

- Draw a horizontal line through the original value, and write the new value adjacent to the original value with the date and initials of the person making the change.

- All corrections should be accompanied by a written explanation in the appropriate notes section on the field form. These notes should also be dated and initialed.
- If possible, edits and revisions should be made in a different color ink to make it easier for subsequent viewers to be able to retrace the edit history.
- Edits should be made on the original field forms and on any photocopied forms.

These procedures should be followed throughout data entry and data revision. Annually, the field observation forms are to be scanned as PDF documents and archived (see the product delivery specifications in **SOP 8: Product Delivery, Posting and Distribution**). The PDF files may then serve as a convenient digital reference of the original if needed.

GPS Data Procedures

Following field validation, the GIS Specialist will download GPS data following procedures outlined in the NCCN GPS Guidelines (NCCN 2009) and store them in the project workspace. Coordinates will then be checked for accuracy (see **SOP 6: Project Workspace and Records Management**) and uploaded into the project database.

5. Determine Map Accuracy Based on Field Validation

Following field visits, the GIS Specialist will complete an accuracy assessment of office validation results using information collected in the field.

A. Populate Project Database with Incidental Observations

The GIS Specialist is responsible for entering all field observations, both on-site and incidental, into the project database using associated database tables and forms that were developed by the Data Manager. In addition, the GIS Specialist should obtain all observation forms collected by park staff and visitors from the Project Lead and enter them into the project database.

B. Create Confusion Matrix for Areas Inside Park Boundary

If necessary, open the project database in \Data\Database\ directory. Open tbl_Locations and filter the following fields: 1) Analysis_yr – limit to the three years being validated; 2) Is_selected – display only selected records; 3) In_park – select “Y”Right-click on tbl_Locations and select Export\Excel. Place the new file in the \Analysis\Validation\ directory and save it as PARK_StartYear_EndYear_matrix.xlsx.

Open the Excel file and delete all columns except Location_code, Valid_agent, and Field_agent. Select the three columns and click on Insert\PivotTable. Place the table into a new worksheet.

In the worksheet with the pivot table, drag Valid_agent to Row Field and Field_agent to Column Field. Drag Location_code field to Data Items. The Excel will automatically populate the pivot table with values.

Calculate classification accuracies and Kappa Statistic following procedures in **Sections 6 B and 6 C**, **SOP 4: Office Validation**.

6. Determine the Final Label for the Landscape Change Polygons

In the project Access Database, determine which label will be used for reporting purposes. Use the following rules to assign the final label (type) to landscape change polygons:

- Use field validation labels for all landscape change inside the park boundary that were visited in the field;
- Use office validation labels for all landscape changes inside the park boundary that were not visited in the field;
- Use Random Forest labels for landscape change polygons outside the park boundary that have not been validated using aerial photos or field;
- Use office validation labels for landscape change polygons outside the park boundary that have been validated using aerial photos or field.

Create a query that uses the rules above to generate a table containing Location_code and Final_agent fields for import into ArcGIS™.

Open an ArcMap® document and the add poly_patches feature class from the \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb. Add the query results generated in the previous step. Create a Join between the attribute table of poly_patches feature class and the table with final agent labels. The user is now ready to generate the map and statistical products for the annual report.

7. Update the Project Geodatabase

The final step in the process is to append landscape changes generated in a given analysis time step to the feature class containing park's change polygons for the entire life of the project. Use the Append tool in Data Management Tools\General\ toolbox to transfer polygons from \Spatial_info\PARK\ PARK_SCENE_rapid_StartYear_EndYear.gdb to \Data\Geodatabase\LPa01_Landscape_Change.gdb (Figure 5.2). Navigate to the poly_patches feature class for the Input Dataset. Select the PARK_distubances feature class in the main project geodatabase as the Target Dataset. Select NO_TEST for Schema Type. Right-click on each available field name in the Field Map window and select Add Input Field. In the Add Input window that appears, select the attribute field name in the poly_patches feature class that matches the field in the PARK_disturbances feature class. For example, connect GRIDCODE attribute in poly_patches to Location_code attribute in PARK_disturbances. Make sure that the attribute that contains the final labels for the change polygons, including ones generated during the validation, is connected to the Final_agent field. Click OK. Open the PARK_disturbances feature class that just got updated, sort on Analysis_year attribute and verify that records were added to the attribute table and that there are no NULL values (Figure 5.3).

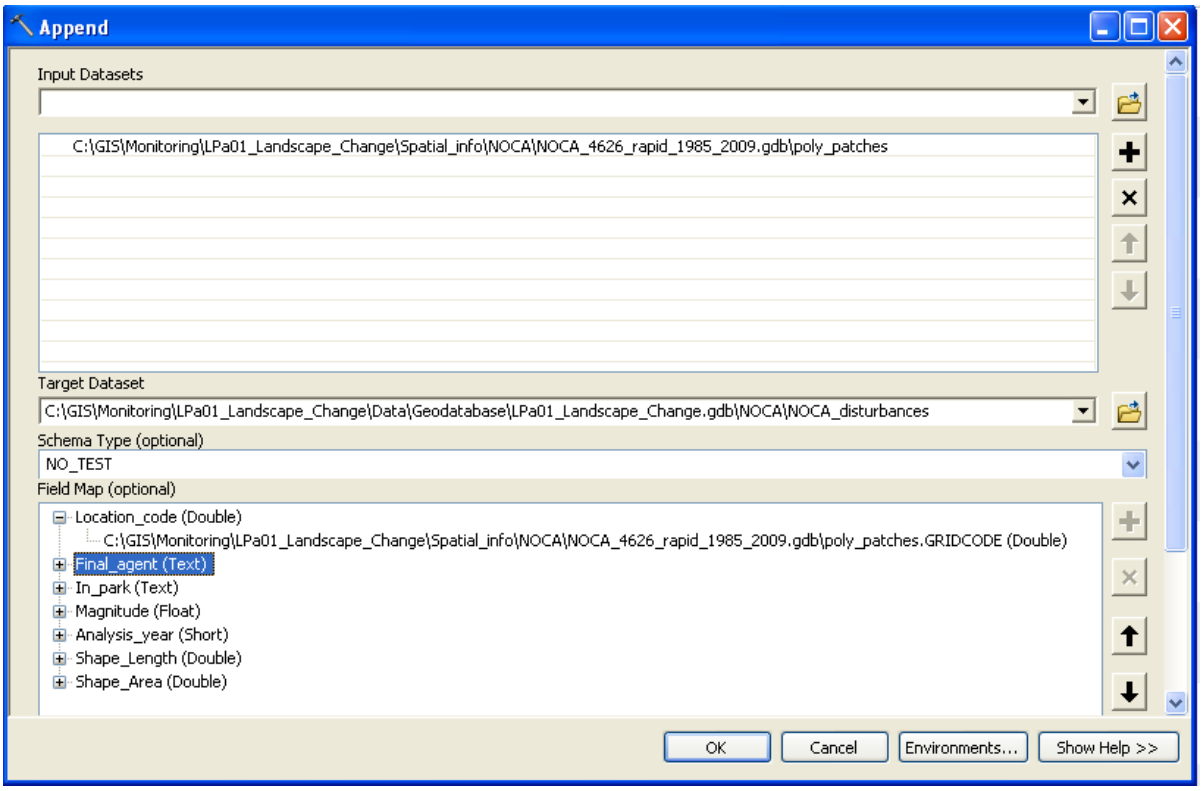


Figure 5.2. Parameters for the Append tool for transferring change polygon data to the project's main geodatabase.

\LPa01_Landscape_Change\Data\Geodatabase\LPa01_Landscape_Change.gdb\NOC

Contents | Preview | Description

OBJECTID *	Shape *	Location_code	Final_agent	In_park	Magnitude	Analysis_year	Shape_Length	Shape_Area
6675	Polygon	6825	AnnualVariability	N	40.9375	2009	1620.00001991168	28799.99426354
6689	Polygon	6839	Avalanche	N	44.64286	2009	780.000091068447	12599.99486530
6713	Polygon	6864	AnnualVariability	N	39.8125	2009	840.00012884289	14399.99713177
6794	Polygon	6950	Avalanche	N	40.21053	2009	1319.99923104048	34199.99806294
6841	Polygon	6999	Clearing	N	32.63636	2009	539.999939970672	9899.994465599
6977	Polygon	7140	ForestDecline	Y	30.66667	2009	420.000064421445	8100.007199106
7067	Polygon	7231	ForestDecline	Y	28.83333	2009	959.999804388732	16199.99339807
7130	Polygon	7296	Fire	N	97.68616	2009	8700.00007729605	877500.0189015
7135	Polygon	7301	ForestDecline	N	41	2009	720.000053294003	9900.003465579
7160	Polygon	7330	Avalanche	N	34	2009	660.00021551922	8100.007199106
7175	Polygon	7347	ForestDecline	Y	57	2009	480.000302195549	8100.010199102
7275	Polygon	7466	AnnualVariability	Y	100	2009	780.000091068447	17099.99453147
7306	Polygon	7503	AnnualVariability	Y	63.2	2009	599.999777738005	8999.999332237
7313	Polygon	7512	ForestDecline	Y	19.13793	2009	1019.9998421669	26099.99086384
7333	Polygon	7534	ForestDecline	N	78.66666	2009	720.000053294003	8100.001199112
7346	Polygon	7549	AnnualVariability	Y	35.33333	2009	599.99997774139	8099.998199069
7395	Polygon	7604	Riparian	Y	74.44444	2009	479.999902192503	8099.998199004

Figure 5.3. PARK_disturbances feature class in the main project geodatabase appended with records from the current analysis time step.

8. Literature Cited

North Coast and Cascades Network – National Park Service. 2009. GPS Data Acquisition and Processing. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm (accessed 16 May 2011).

SOP 6: Project Workspace and Records Management

Revision Date	Author	Changes Made	Reason for Change

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1. Overview

This SOP describes file naming conventions and data management for protocol files. It also describes how and where project files and records are managed by project staff. Workspace structure, naming conventions, and procedures for handling project files are included.

2. Journaling

It is recommended that an electronic text file journal be maintained to keep track of all filenames and decisions made during the steps of this protocol. This journal should be maintained in chronological order, with the date and associated filenames for each entry. Whenever a processing step is conducted, all of the relevant information about that step is entered into the journal. Enough detail should be given to fully replicate the step, including the names of all input and output files, the software module and tool used for the analysis, and all processing options (criteria selected, data types, etc.). The use of hyperlinks to other files can also be a useful feature because it provides full pathnames of files that can be used later for interpretation, even if the hyperlinks themselves become out of date because files are moved.

Additionally, the journal should be used to record important decisions and to note observations about imagery or datasets that may be useful later for error tracking or evaluation of unexplained results. Although the key processing steps leading up to any geospatial product will also be stored in the metadata, journaling allows many more details to be tracked. Most of the time, these details are not needed later, but occasionally notes recorded in the journal can provide the difference between a quick fix and starting from scratch when a problem is encountered.

3. NCCN File Workspace

NCCN has a centralized file system and project workspaces available for use by field crews and project staff at: \\inpolymfs\parkwide\NCCN. This will help avoid the problem of NCCN projects having several versions of files on different servers around the network. These folders are set up so that park and network staff members at the network parks all have read privileges throughout the directory structure. Project leads and a few other individuals associated with each project have full privileges for their project folder so they can manage their own permissions. These workspaces are intended to be a more familiar and convenient way of storing information, as an adjunct to the NCCN SharePoint site. Apart from reports and protocols (which are to be maintained in the NCCN Digital Library (a section of the NCCN SharePoint site), project leads will decide what is to be stored locally in these project workspaces as opposed to on the team SharePoint site. Examples of files kept in these project workspaces include: working files for project staff, GIS files and images, and other project records.

The NCCN file workspace is organized as follows under four main folders: Libraries, Projects, Temp, and Workspace. Project staff members will primarily be working in one or more of the project folders under Projects, and may wish to make desktop shortcuts to one or more of the project subfolders by right-clicking on the desired folder and selecting Send To > Desktop (create shortcut).

Project staff members should create a network shortcut to the project workspace by going to the Desktop in Windows Explorer and adding a new network place under My Network Places. Project staff located at OLYM will typically already have this path available to them via a mapped drive (e.g., the I:\ drive); however, they should still create this network shortcut where multiple parks are concerned for the sake of communications and consistency among parks. Performance is the main rationale for using network shortcuts instead of mapped drives at other parks.

Instructions for creating a network shortcut to the NCCN workspace:

1. Open an instance of Windows Explorer. One way is from the Start menu, go to: All Programs > Accessories > Windows Explorer. Another is to open My Documents, My Computer, or any other folder browser shortcut.
2. Navigate to the Desktop, and then to My Network Places.
3. Double-click the Add Network Place option to open the setup wizard.
4. Choose the option to specify the network location, then under network address, type in: \\inpolymfs\parkwide\NCCN
5. When prompted for a name for the network place, enter "NCCN" (or something similarly brief and meaningful).

This network place shortcut should now be available each time you log in to that particular computer, and can be accessed when navigating within most Windows software.

A. File Naming Standards for Spatial Data

File names are concatenated sequences of codes or text strings that uniquely describe a file. Descriptive code names are recommended that allow a user to immediately identify the purpose of each file. A filename usually consists of a root name with an additional component describing the file.

LARSE Image Files

Reflectance and Tasseled Cap image files received from LARSE follow the file naming conventions developed by the remote sensing group. They follow the convention:

(IMAGETYPE)(PATH)(ROW)_(YEAR)_(JULIAN DATE)_(IMAGESOURCE).(FILE FORMAT)

For example, file name “LT5046026_1985_219_archv.bsq” means that the image was acquired by Landsat 5 for path 46, row 26 on 219th day of year 1985. The file came from the Landsat archive and is in band sequential format.

File names associated with LandTrendr outputs are listed in Table 2.2.

Table 6.1. File naming procedures used in NPS processing steps of LandTrendr Data.

Product	Directory or geodatabase …\LPa01_landscape_change	File name	Product Type
Greatest Disturbance image	\Spatial_info\PARK\SCENE\Outputs\StartYear_EndYear\	LT045_nbr_SCENE_greatest_disturbance.bsq	Input
Pre-disturbance Image	\Spatial_info\PARK\SCENE\Outputs\StartYear_EndYear\	LT045_nbr_SCENE_greatest_disturbance_ftv_predist.bsq	Input
Geodatabase containing intermediate processing steps	\Spatial_info\PARK\	PARK_SCENE_rapid_StartYear_EndYear.gdb	Intermediate
Geodatabase containing base GIS data	\Spatial_info\PARK\	PARKbase.gdb	Input
Change polygons for the analysis time step	PARK_SCENE_rapid_StartYear_EndYear.gdb	poly_patches	Intermediate
Change polygons with attributes	\Spatial_info\PARK\	poly_patches_table_StartYear_EndYear.csv	Intermediate
RF Model	\Spatial_info\Models\R\PARK\	PARK_rf_dist_model.r	Input
RF change types and probabilities	\Data\R\Park\	PARK_predicted_StartYear_EndYear.csv	Final
Change polygon centroids	PARK_SCENE_rapid_StartYear_EndYear.gdb	patch_centroids	Intermediate
Validation plots	\Data\Validation\Park\	PARK_StartYear_EndYear_validation_plots.xlsx	Final
Validation plots layer	\Spatial_info\PARK\	PARK_1985_2009_validation.lyr	Intermediate
Google Earth Validation polygons	\Spatial_info\PARK\	PARK_1985_2009_validation.kmz	Final
Master Geodatabase	\Data\Spatial_info\	LPa01_Landscape_Change.gdb	Final
Change polygons	\Data\Spatial_info\LPa01_Landscape_Change.gdb\	PARK_rapid_disturbances_1985_present	Final

GIS Processing Files and Geodatabases

Table 6.1 lists names and location for files associated with various processing steps that NCCN performs on the LandTrendr. Generally, it is recommended that file names contain the name of the park for which processing is done and the associated time step recorded as start and end years. Whenever possible, the use of shapefiles and associated .dbf tables is avoided due to restrictions in the attribute field names.

Names for feature datasets, feature classes and geodatabase rasters within base, project and working geodatabases are documented in Figures D.2 and 2.3, as well as Table 2.1.

File Naming Standards

Unless otherwise specified, file names should follow these guidelines:

- No spaces or special characters in the file name
- Use the underbar ("_") character to separate file name components
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters
- Dates should be formatted as YYYYMMDD
- Correspondence files should be named as YYYYMMDD_AuthorName_subject.ext

Files with spatial information should follow the naming conventions listed above.

B. Project Workspace

A section of the NCCN workspace is reserved for this project. The recommended file structure within this workspace is shown in Figure 6.1.

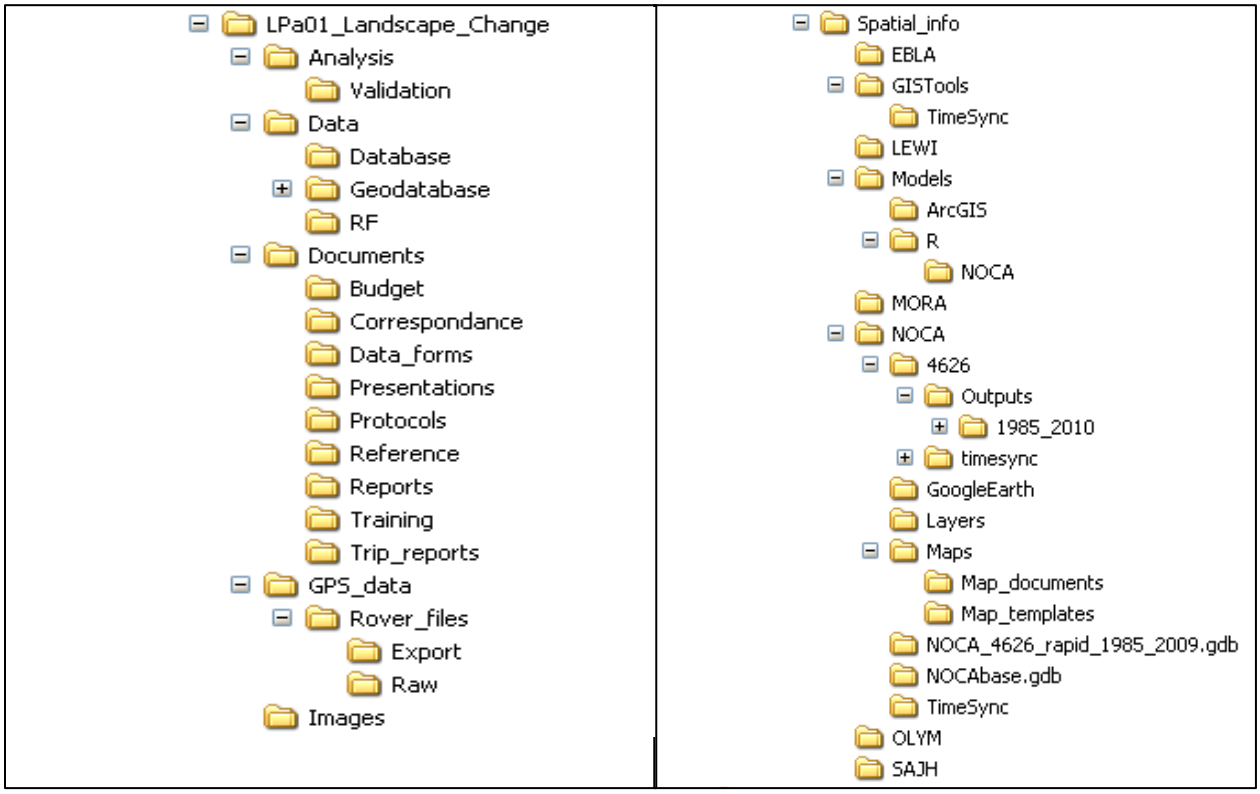


Figure 6.1. Recommended file structure for project workspace. Note: The workspace folder name includes 'LPa01', the NCCN project code.

Each major subfolder is described as follows:

- Analysis – Contains working files associated with data analysis.
- Data – Contains the front-end database application for the given analysis period. The back-end database for the project is maintained in Microsoft SQL Server. Database exports and other intermediate summary information can be stored here as well; these files are most effectively managed within subfolders named by calendar year. This

directory also contains the project geodatabase with final versions for landscape change polygons for each park and associated attributes needed for mapping and data summaries.

- Documents – Contains subfolders to categorize documents as needed for various stages of project implementation. Additional folders and subfolders may be created as needed to arrange information in a way that is useful to project staff.
- GPS data – Contains GPS data dictionaries and raw and processed GPS data files. This folder contains subfolders that organize GPS files by year. Each of these subfolders also contains the project code to make it easier to select the correct project folder within the GPS processing software. This folder will be used for any GPS files collected during occasional field validation.
- Images – For storing images associated with the project. This folder has subfolders named by calendar year to make it easier to identify and move files to the project archives at the end of each season. Photographs are not a central part of this protocol, but organizing them in this structure is useful for project records.
- Spatial info – This folder contains the majority of files associated with processing of LandTrendr data, generating change polygons and labeling change agent.
    - Park folders – base and working geodatabases and all Landsat and LandTrendr images for scenes associates with a particular park.
    - GIS Tools – ArcGIS and R models required to process LandTrendr data and generate polygons with change labels
    - Maps – Map composition files (.mxd) and map templates for reports.

C. Folder Naming Standards

In all cases, folder names should follow these guidelines:

- No spaces or special characters in the folder name
- Use the underbar ("_") character to separate words in folder names
- Try to limit folder names to 20 characters or fewer
- Dates should be formatted as YYYYMMDD (this leads to better sorting than other date naming conventions)

D. Standards for Map Creation

Maps for annual reports and ten-year reports should follow guidelines for the NPS Natural Resource Technical Report series (http://www.nature.nps.gov/publications/NRPM/), and should contain, at a minimum, a legend that identifies symbols used in the map, a scale bar, and a north arrow. Map templates are stored in \Spatial_info\PARK\Maps\ directory and should be used whenever possible to create consistent products for reports

E. Workspace Maintenance Procedures

Prior to each season, the Project Lead should:

1. Make sure that network accounts are established for each new staff member, or reactivated for returning staff members. By default, the IT staff puts new user accounts into a group that has read-only access to all files.
2. Create new folders named by year under the Images and GPS data sections.

After each season, the Project Lead should:

1. Review the workspace organization and clean up any temporary files and subfolders that are no longer needed.
2. Compare older files against the retention schedule in NPS Director's Order 19 (available at: http://data2.itc.nps.gov/npspolicy/DOrders.cfm). Dispose of files that are beyond their retention schedule if they are no longer needed. As a long-term project, many files associated with this project are likely to be scheduled for permanent retention. This makes it all the more imperative to clean out unneeded files before they accumulate and make it harder to distinguish the truly useful and meaningful ones.
3. Convert older files to current standard formats as needed to maintain their usefulness.
4. Identify files that may contain sensitive information (as defined in Section 4I of the narrative). Such files should be named and filed in a way that will allow quick and clear identification as sensitive by others.
5. Post final documents and files to the NCCN Digital Library for long-term storage. See **SOP 8: Product Delivery, Posting and Distribution**.
6. Send analog (non-digital) materials to the park collections for archiving.

SOP 7: Data Quality Review and Certification

Revision Date	Author	Changes Made	Reason for Change

1. Overview

This SOP describes the procedures for validation and certification of data in the project database. Refer also to protocol narrative sections **Overview of Database Design**, **Quality Review**, and **Data Certification and Delivery** for related guidance.

A critical part of project quality assurance is the year-end data quality review and certification. After the annual LandTrendr results are acquired from LARSE, results need to be reviewed and certified by the Project Lead before they can be used for analysis and reporting. Data validation is the process of rigorously testing data for completeness, structural integrity, and logical consistency.

Pre-built queries can check for data integrity, data outliers, missing values, and illogical values. The user may then fix these problems and document the fixes. Not all errors and inconsistencies can be fixed (e.g., missing response variable values), in which case documentation of the resulting errors and why records were not fixed is included in the metadata and certification report.

Once the data have been through the validation process and metadata have been developed for them, the Project Lead should certify the data by completing the NCCN Project Data Certification Form, available on the NCCN website.

2. Data Quality Review

The database application contains a set of queries that are run in sequence to check for structural integrity and logical consistency within the data set. Throughout the quality review, the person performing the review should remain vigilant for problems that may not be caught by the validation queries. The following quality checks are performed during the annual data quality review:

- Are all required fields populated?
- Are relationships among separate tables enforced (e.g., do child tables have related parent records)?

- Do field values match lookup domain values (for example, do values for modeled change types match the list of landscape change types)?
- Are polygon centroids and field observation coordinates within range for the indicated park?
- Are all in-park records selected for validation?
- Are there change type agents and confidence ratings assigned where Is_final = TRUE?
- Is there an alternate agent assigned where Confidence = "High"?
- Does model change agent in tbl_Polygons match the agent with the highest probability in the model probabilities table?
- Do date values make logical sense (e.g., created must be before updated, etc.)?

3. Completing Data Certification

Data certification is a benchmark in the project information management process that indicates that: 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks outlined above; and 3) they are appropriately documented and in a condition for archiving, posting and distribution as appropriate. Certification is not intended to imply that the data are completely free of errors or inconsistencies that may or may not have been detected during quality assurance reviews.

To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Lead is the primary person responsible for completing an NCCN Project Data Certification Form, available at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. This brief form should be submitted with the certified data according to the timeline in **Appendix C: Yearly Project Task List**. Refer to **SOP 8: Product Delivery, Posting and Distribution** for delivery instructions.

A. Generating Output for the Certification Report

The first page of the Quality Review Tool has a button labeled "View summary report". This button opens the formatted information for each query, the last run time, the number of records returned at last run time, a description and any remedy details that were typed in by the user. This report can be exported from the database and included as an attachment to the certification report.

SOP 8: Product Delivery, Posting and Distribution

Revision Date	Author	Changes Made	Reason for Change

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1. Overview

This SOP provides a schedule, product specifications, and instructions for delivering completed data sets, reports and other project deliverables for long-term storage (Table 8.1). Details are also provided on posting products to websites and clearinghouses, and on responding to data requests.

2. Product Delivery Schedule and Specifications

Table 8.1 Schedule and instructions for project deliverables.

Deliverable Product	Primary Responsibility	Target Date	Instructions
Certified tabular and geospatial data Data certification report Metadata interview form	Project Lead with GIS Specialist	May 30 of the same year; data are not posted to public sites until June of the second year	Refer to the section in this SOP on delivering certified data and related materials.
Full metadata (parsed XML)	GIS Specialist	October 30 of the following year	Upload the parsed XML record to the NPS Data Store [1].
Annual I&M report	Project Lead	August 31 of the following year	Refer to the section in this SOP on reports and publications.
3-year analysis report	Project Lead, Data Analyst	Every 3 years of NCCN I&M data collection, by August 31	
Other publications	Project Lead, Data Analyst	As completed	
Field data forms	Project Lead	Dec 31	Scan original, marked-up field forms as PDF files, and store in the project workspace. Hard copy originals go to the Park Curator for archiving four years after data collection.
Other records	Project Lead	Review for retention every December	Retain or dispose of records following NPS Director's Order 19 [2]. Organize and send analog files to Park Curator for archiving. Digital files that are slated for permanent retention should be uploaded to the NCCN Digital Library.

[1] The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov).

[2] NPS Director's Order 19 provides a schedule indicating the amount of time that the various kinds of records should be retained. Available at: http://data2.itc.nps.gov/npspolicy/DOrders.cfm

3. NCCN Digital Library

The NCCN Digital Library is a document management system maintained within a Microsoft SharePoint environment at: http://imnetsharepoint/nccn/default.aspx. The primary purpose of this system is to maintain important digital files – such as reports, protocol documents, and select

project images – within a content management system, and to make them available to NCCN and NPS users. NCCN users may view, post and edit documents within this system; other NPS users have read-only access to these files, except where information sensitivity may preclude general access.

To enable discovery and long-term usability of key documents, certain information about each file needs to be filled in as files are uploaded, for example:

- Document title
- Project code (e.g., "LPa01" for Landscape Change Monitoring)
- Park(s) to which the file(s) apply; multiple parks may be selected for each upload
- Document type (e.g., formal report, database, protocol, etc.)
- Date of publication or last revision
- Author name(s)
- Sensitivity: Sensitive, NPS Only, or Public. Sensitive files will not be viewable without permission.
- Description - Document abstract, additional authors and credits, special use instructions, etc.

For project staff without access to the NPS intranet, files may be sent by email or CD/DVD to the Project Lead or Data Manager for upload, along with the above information in a text file or accompanying email.

4. Park Collections

The collections at OLYM will serve as the park of record for the Landscape Change Monitoring Project. Hardcopy field forms and printouts of biennial reports, technical reports, and other publications will be filed there. In addition, other hard copy project records should be reviewed and organized on an annual basis (or at the conclusion of a project), and sent to park collections for long-term storage.

5. Delivering Certified Data and Related Materials

Data certification is a benchmark in the project information management process that indicates that the data: 1) are complete for the period of record; 2) have undergone and passed the quality assurance checks; and 3) are appropriately documented and in a condition for archiving, posting and distribution as appropriate. To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data.

The following deliverables should be delivered as a package:

- *Certified tabular data* – Back-end database containing data that has been through the quality assurance checks documented in **SOP 7: Data Quality Review and Certification**. Delivery of this item is only applicable in cases where the back-end

database is implemented in Microsoft Access. In all other cases, the Data Manager will already have access to the certified data.

- *Certified geospatial data* – GIS themes in ESRI coverage or shapefile format. Refer to NCCN GIS Development Guidelines (NCCN 2007a) and NCCN GIS Product Specifications (NCCN 2007b) for more information.
- *Data certification report* – A brief questionnaire in Microsoft Word that describes the certified data product(s) being delivered. A template form is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.
- *Metadata interview form* – The metadata interview form is a Microsoft Word questionnaire that greatly facilitates metadata creation. It is available on the NCCN website at: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm. For more information, refer to **Section Metadata Procedures**.

After the quality review is completed, the Project Lead should package the certification materials for delivery as follows:

1. Create a compression file (using WinZip® or similar software, or by right-clicking in Windows Explorer). This file should be named in accordance with general file naming standards, and the name should include the project code ("LPa01") and the year or span of years for the data being certified. For example: LPa01_2010_certification_pkg.zip.
2. Add the completed metadata interview and data certification forms to the compressed file. Both files should be named in a manner consistent with the file naming standards described in **SOP 6: Project Workspace and Records Management**.
3. Add any geospatial data files that are not already in the possession of the GIS Specialist. Geospatial data files should be developed and named according to NCCN GIS Naming Conventions (NCCN 2007c).
4. Deliver the compressed file containing all certification materials to the Data Manager by placing it in the Data folder of the project workspace and notifying the Data Manager by email. If the Project Lead does not have network access, then certification materials should be delivered as follows:
    a. If the compressed file is under 9.5 mb in size, it may be delivered directly to the Data Manager by email.
    b. If the compressed file is larger than 9.5 mb, it should be copied to a CD or DVD and delivered in this manner. Under no circumstances should products containing sensitive information be posted to an FTP site or other unsecured web portal.

Upon receiving the certification materials, the Data Manager will:

1. Review them for completeness and work with the Project Lead if there are any questions.
2. Check in the delivered products using the NCCN project tracking application.
3. Notify the GIS Specialist if any geospatial data are delivered. The GIS Specialist will then review the data, and update any project GIS data sets and metadata accordingly, and file those products in the project workspace.
4. Notify the Project Lead that the year's data have been successfully reviewed and processed. The Project Lead may then proceed with data summarization, analysis and reporting.
5. Develop, parse and post the XML metadata record to the NPS Data Store.

6. After a holding period of two years, the GIS Specialist will upload the certified data to the NPS Data Store. This holding period is to protect professional authorship priority and to provide sufficient time to catch any undetected data quality problems.

No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared. Only products that are intended for public/general-use may be posted to public websites and clearinghouses – these may not contain sensitive information.

6. Instructions for Reports and Publications

Annual reports and trend analysis reports will use the NPS Natural Resource Publications templates, which are pre-formatted Microsoft Word template documents based on current NPS formatting standards. Annual reports will use the Natural Resource Technical Report (NRTR) template. Trend analysis and other reports may require the Natural Resource Report (NRR) template if they include management implications or other content requiring an additional level of peer review. These templates and documentation of the NPS publication standards are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.

The procedures for biennial reports, technical reports, and publications are as follows. (Note: This is optional for field season reports, which are intended to be internal communications only.)

1. The Project Lead or Data Analyst formats the document according to the NPS Natural Resource Publications standards.
   a. Formatting according to NPS standards is easiest when using the report template from the very beginning, as opposed to reformatting an existing document.
   b. When creating the file, use appropriate naming standards (described in this document). If creating the document in SharePoint (e.g., the NCCN Digital Library), attribute the file as a draft; otherwise and add "DRAFT" to the file name.
   c. Open the document and add "DRAFT" to the header or document watermark as appropriate.
2. The document should be peer reviewed at the appropriate level. For example, I&M biennial reports should be reviewed by other members of the project work group. The Network Program Manager will also review all biennial reports for completeness and compliance with I&M standards and expectations. Before sending the document for review, rename the document by adding a date stamp to the end of the file name using the YYYYMMDD format.
3. Upon completing the peer review, the Project Lead should acquire a publication series number from the appropriate regional or national key official. Instructions for acquiring a series number are available at: http://www.nature.nps.gov/publications/NRPM/index.cfm.
4. The Project Lead should finalize the document:
   a. Ensure that the publication/version date (last saved date field code in the document header, if used) and file name (field code in the document footer, if used) are updated properly throughout the document.
   b. Remove the word "DRAFT" from watermarks, document headers, and file name.

c. Remove any previous date stamp from the file name.
d. If the document has been developed and maintained in SharePoint (e.g., the NCCN Digital Library), update the document attribute to “Final”.
e. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
f. Create a PDF version of the document and upload the final file and PDF copy to the NCCN Digital Library for long-term storage.
g. Store both the Word document and PDF copy in the appropriate section of the project workspace (see **SOP 5: Project Workspace and Data Management**).

5. Notify the Park Curator and Data Manager that the report is available, and send a printout to the Park Curator to add to the host park collections.
6. The Data Manager (or a designee) will create a bibliographic record and upload the PDF copy to the NPS Data Store according to document sensitivity.

7. File Naming Standards

Prior to delivering or uploading digital products, files should be named according to the naming conventions appropriate to each product type.

A. Reports and Publications

- No spaces or special characters in the file name.
- Use the underbar (“_”) character to separate file name components.
- Try to limit file names to 30 characters or fewer, up to a maximum of 50 characters.
- Dates should be formatted as YYYYMMDD.
- As appropriate, include the project code (e.g., “LPa01”), network code (“NCCN”) or park code ("LEWI"), and year in the file name.

Examples:

- LEWI_LPa01_2010_Biennial_report.pdf
- LEWI_LPa01_2010_Field_season_report.doc
- LEWI_LPa01_2010_Certification_report.doc

Other Files

General naming standards as described in **SOP 5: Data and Workspace Management** apply to all deliverables. When delivering files to the Digital Library, file names should be modified as needed to include the project code (e.g., “LPa01”), network code (“NCCN”) or park code, and year as appropriate (e.g., LEWI_LPa01_2010_cert_package.zip). Specific standards are described in **SOP 8: Revising the Protocol** for protocol documents.

8. Product Posting

Once digital products have been delivered and processed, the Data Manager or a designee will post them to or otherwise update the following applications to make them generally available:

1. The NPS Data Store is an internet clearinghouse for documents, data and metadata on natural and cultural resources in parks. It is a primary component of the NPS Integrated Resource Management Applications (IRMA) portal (http://irma.nps.gov). Full metadata records will be posted to the NPS Data Store as they are created; data sets will be posted after a two-year hold to protect professional authorship priority and to provide sufficient time to catch any undetected quality assurance problems. For reports and other publications, an online record is created after first verifying that one does not already exist. The digital report file in PDF format is then uploaded.
2. NPSpecies is the NPS database and application for maintaining park-specific species lists and observation data, and is a component of the IRMA portal (http://irma.nps.gov). Species observations will be extracted from project data sets and uploaded into NPSpecies.
3. NCCN Web Site is maintained by NCCN staff as part of the NPS Inventory and Monitoring web site (http://science.nature.nps.gov/im/units/nccn) to describe our program, the vital signs selected for monitoring, and to highlight certain products and information derived from inventory and monitoring work at NCCN. The site has both internet and intranet components. Select products such as biennial reports and technical reports will be posted to the web site.
4. These applications serve as the primary mechanisms for sharing reports, data, and other project deliverables with other agencies, organizations, and the general public.

9. Holding Period for Project Data

To protect professional authorship priority and to provide sufficient time to complete quality assurance measures, there is a two-year holding period before posting or otherwise distributing certified project data. This means that certified data sets are first posted to publicly-accessible websites (i.e., the NPS Data Store) approximately 24 months after they are certified (e.g., data collected in June 2010 and certified in February 2011 becomes generally available through the NPS Data Store in February 2013). In certain circumstances, and at the discretion of the Project Lead, data may be shared before a full two years have elapsed.

Note: This hold only applies to raw data, and not to metadata, reports or other products which are posted to NPS clearinghouses immediately after being received and processed.

10. Responding to Data Requests

Occasionally, a park or project staff member may be contacted directly regarding a specific data request from another agency, organization, scientist, or from a member of the general public. The following points should be considered when responding to data requests:

- For all Inventory and Monitoring projects in NCCN, NPS is the originator and steward of the data, and the NPS Inventory and Monitoring Program should be acknowledged in any professional publication using the data.
- NPS retains distribution rights; copies of the data should not be redistributed by anyone but NPS.

- The data that project staff members and cooperators collect using public funds are public records and as such cannot be considered personal or professional intellectual property.
- No sensitive information (e.g., information about the specific nature or location of protected resources) may be posted to the NPS Data Store or any other publicly-accessible website, or otherwise shared or distributed outside NPS without a confidentiality agreement between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared.
- For quality assurance, only certified, finalized versions of data sets should be shared with others. In exceptional cases where a provisional data set needs to be shared with others prior to certification:
    - Any accompanying communications should clearly indicate that the data set is provisional and subject to change according to our quality review process.
    - File names and the media it is sent on should be clearly labeled as containing provisional data not for distribution.

The Project Lead will handle all data requests as follows:

1. Discuss the request with other Park Biologists as necessary to make those with a need to know aware of the request and, if necessary, to work together on a response.
2. Notify the Data Manager if s/he is needed to facilitate fulfilling the request in some manner.
3. Respond to the request in an official email or memo.
4. In the response, refer the requestor to the NPS Data Store and the IRMA portal (http://irma.nps.gov), so they may download the necessary data and/or metadata. If the request cannot be fulfilled in that manner – either because the data products have not been posted yet, or because the requested data include sensitive information – work with the Data Manager to discuss options for fulfilling the request directly (e.g., writing data to CD or DVD). Ordinarily, only certified data sets should be shared outside NPS.
5. It is recommended that documents and presentation files be converted to PDF format prior to distribution. This is to maximize portability and to reduce the ability for others to alter and redistribute files.
6. If the request is for data that may reveal the location of protected resources, refer to the next section in this document about sensitive information.
7. After responding, provide the following information to the Data Manager, who will maintain a log of all requests in the NCCN project tracking database:
    a. Name and affiliation of requestor
    b. Request date
    c. Nature of request
    d. Responder
    e. Response date
    f. Nature of response
    g. List of specific data sets and products sent (if any)

11. Freedom of Information (FOIA) Requests

All official FOIA requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the park FOIA representative(s) of the park(s) for which the request applies.

12. Special Procedures for Sensitive Information

Products that have been identified upon delivery by the Project Lead as containing sensitive information will normally be revised into a form that does not disclose the locations of protected resources – most often by removing specific coordinates and only providing coordinates that include a random offset to indicate the general locality of the occurrence. If this kind of measure is not a sufficient safeguard given the nature of the product or the protected resource in question, the product(s) will be withheld from posting and distribution.

If requests for distribution of products containing sensitive information are initiated by the NPS, by another federal agency, or by another partner organization (e.g., a research scientist at a university), the unedited product (i.e., the full data set that includes sensitive information) may be shared only after a confidentiality agreement has been established between NPS and the agency, organization, or person(s) with whom the sensitive information is to be shared

13. Literature Cited

NCCN – National Park Service. 2007a. GIS Development Guidelines. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

NCCN – National Park Service. 2007b. GIS Product Specifications. USDI National Park Service. Internet document: http://science.nature.nps.gov/im/units/nccn/datamgmt_guide.cfm.

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SOP 9: Revising the Protocol

Revision Date	Author	Changes Made	Reason for Change

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1. Overview

This SOP describes how to make and track changes to the NCCN Landscape Change Monitoring Protocol, including its accompanying SOPs. Project staff should refer to this SOP whenever edits are necessary, and should be familiar with the protocol versioning conventions in order to identify and use the most current versions of the protocol documents. Required revisions should be made in a timely manner to minimize disruptions to project operations.

2. Peer Review

This protocol attempts to incorporate the best and most cost-effective methods for monitoring and information management. As new technologies, methods, and equipment become available, this protocol will be updated as appropriate, by balancing current best practices against the continuity of protocol information.

All edits require review for clarity and technical soundness. Small changes to existing documents – e.g., formatting, simple clarification of existing content, minor changes to the task schedule or project budget, or general updates to information management SOPs – may be reviewed in-house by project and NCCN staff. However, changes to data collection or analysis techniques, sampling design, or response design are usually more significant in scope and impact and will typically trigger an outside review to be coordinated by the Pacific West Regional Office of the National Park Service.

3. Document Life Cycle

Protocol documents may be maintained as separate files for each component (e.g., narrative, SOPs, appendices in separate document files) or unified into a single document file. During its life cycle, each document file can be classified in one of six life cycle stages:

1. Draft documents – Documents that have been drafted or revised but have not been reviewed and approved yet.
2. Review documents – Draft documents that have been sent out for peer review or administrative review.
3. Active documents – The current, reviewed and accepted version of each protocol component in Microsoft Word format. These documents have been reviewed and approved at the appropriate level, and are currently implemented for active monitoring projects.
4. Inactive documents – Older versions of approved protocol components that are no longer in active implementation.
5. Archived documents – Comprehensive set of active protocol components plus older, inactive versions of approved protocol components in Microsoft Word format. These are stored as read-only and have a date stamp to identify their approval date. The history of the protocol versions through time should be entirely traceable from within the document archive.
6. Distribution copies – PDF versions of approved, date-stamped protocol components, used to post to websites or otherwise share outside NPS.

Protocol documents are stored in the project workspace in separate subfolders named for each life cycle stage, except for inactive documents which are filed together with date-stamped copies of active documents in the archive folder. See **SOP 5: Data and Workspace Management** for additional details about the project workspace.

4. Document Versioning Conventions

Rather than using a sequential numeric versioning convention, date stamps should be used to distinguish document versions because they are more intuitive and informative than version numbers. Date stamps are embedded within the document header, and also included in the document name.

A. Document Header

Within each document, the upper right section of the document header should show the date that the document was last saved. By using save date instead of current date, printouts and document previews will show the correct version number. The following is the field code to be used within the header to indicate the version number:

SAVEDATE } \@ "MMMM d, yyyy"

B. File Naming Conventions

All documents *except for active documents and draft documents* should include the last edit date as a suffix, using the YYYYMMDD format so that documents will sort by date rather than month or day (e.g., NCCN_ Landscape_Protocol_DRAFT_20120430.doc for the review draft on 4/30/2012).

Active documents and draft documents that have not been shared with others (as review documents) should not include the date because – unlike documents in other life cycle stages – they are not "point in time" document snapshots. By omitting the date stamp from these documents, they can more easily be distinguished from review drafts and archive or distribution copies. Draft documents should clearly contain the word "DRAFT" in the file name.

Note: General file and folder naming conventions are described in **SOP 5: Data and Workspace Management**; these should be followed when naming protocol document files.

5. Revision Procedures

Proposed changes to protocol components should be discussed among project staff prior to making modifications. It is especially important to consult with the Data Manager prior to making changes because certain types of changes may jeopardize data set integrity unless they are planned and executed with the continuity of the data set in mind. Because certain changes may require altering the database structure or functionality, advance notice of changes is important to minimize disruptions to project operations. Consensus should be reached on who will be making the agreed-upon changes and in what timeframe.

Note: A change in one document also may necessitate other changes elsewhere in the protocol. For example, a change in the narrative may require changes to several SOPs; similarly

renumbering an SOP may mean changing document references in several other sections of the protocol. The project task list and other appendices also may need to be updated to reflect changes in timing or responsibilities for the various project tasks.

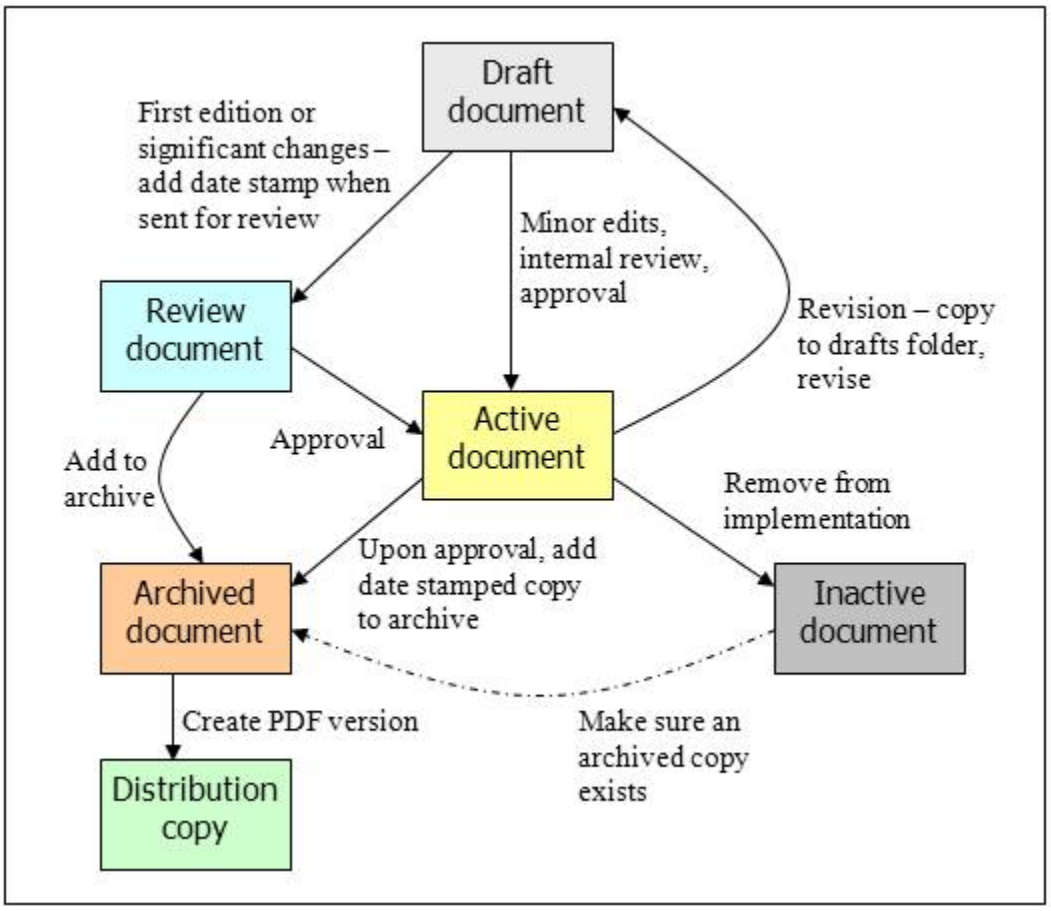


Figure 9.1. Process for creating and revising protocol documents. Boxes represent document life cycle stages, and connecting arrows indicate procedures.

The Project Lead is the primarily responsible for making edits and ensuring document review at the appropriate level. The process for creating and revising protocol documents is shown in Figure 9.1, and outlined below:

1. Create the draft document in Microsoft Word format. If modifying an existing document (usually an active document), copy the document to the draft document folder, remove any date stamp from the name. Add "DRAFT" to the file name. Open the document and add "DRAFT" to the header or document watermark as appropriate.

2. Track revision history. If modifying an existing document, document all edits in the Revision History Log embedded in the protocol narrative and each SOP. Log changes only for the section of the document being edited (i.e., if there is a change to an SOP, log those changes only in the revision history log for that SOP). Record the date of the changes (i.e., the date on which all changes were finalized), author of the revision,

describe the change and cite the paragraph(s) and page(s) where changes are made, and briefly indicate the reason for making the changes.

3. Document review. Circulate the changed document for internal review among project staff and cooperators. If the changes are significant enough to trigger peer review (as defined above), create a review document by adding a date stamp to the end of the file name using the YYYYMMDD format, copy the file to the archive folder, and submit the document for peer review according to current instructions.

4. Finalize and archive. Upon approval and final changes:
   a. Ensure that the version date (last saved date field code in the document header) and file name (field code in the document footer, if used) are updated properly throughout the document.
   b. Move the approved document to the active folder. Remove the word "DRAFT" from watermarks, document headers, and file name. Remove any previous date stamp. This is now an active, implemented document.
   c. To avoid unplanned edits to the document, reset the document to read-only by right-clicking on the document in Windows Explorer and checking the appropriate box in the Properties popup.
   d. Create a copy of the file and add the revision date to the end of the file name using the YYYYMMDD format. Move this copy to the archive folder.
   e. Inform the Data Manager so the new version number can be incorporated into the project metadata.

5. Create distribution copies. As needed, create a PDF version of the archived document to post to the internet and share with others. These PDF versions should have the same date-stamped name as the archived Microsoft Word file. Post the distribution copy to the NCCN Digital Library and forward copies to all individuals who had been using a previous version of the affected document.

6. Remove from implementation. If it is decided that a document needs to be removed from implementation – either because it is no longer necessary (e.g., an unneeded SOP), or because it has been superseded by a more recent version – this can be easily done by removing the document from the active document folder, after first checking that a copy of that version already exists in the archive folder.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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