DRAFT

Study Plan

Development of a Long-term Ecological Monitoring Program at Denali National Park and Preserve

(SIS #5001243)

Vegetation

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Executive Summary

The objectives of the vegetation component of the Denali Long-term Ecological Monitoring program over the next two years (1999 and 2000 field seasons) are to develop, test, and describe ground and remote-sensing techniques to quantify vegetation characteristics and changes over time throughout the Park using scientifically and statistically sound methods suitable for assessing landscape scale pattern and decades-long changes.

To achieve this, a hierarchical, systematic grid system will be tested as the framework for both extensive and intensive vegetation monitoring. A grid is being proposed to (1) eliminate the bias associated with selecting plots in homogeneous vegetation types, (2) have the sampling points based on a fixed geographical point, and (3) ensure sampling throughout the Park. Based on the vegetation types present at each sampling site, estimates can be made of the area of that type in the Park.

We plan to pattern the grid design after the Forest Health Monitoring (FHM) and/or the Forest Inventory Analysis (FIA) programs being run by the US Forest Service. We anticipate five levels in our hierarchy: (1) base grid, (2) extensive sites, (3) intermediate sites (corresponds to grid scale of FHM), (4) intensive sites, and (5) research or tactical sites. The base grid will be 'sampled' only with remote-sensing or parameters that are present in a GIS, such as the Denali browser. This grid forms the base from which all non-special sites are selected systematically. Extensive and intermediate sites will address strategic issues, usually exemplified by vegetation composition and structure parameters, sampled systematically throughout the Park in perpetuity. Intensive sites will be selected non-systematically (probably) from the base grid to address specific issues / studies, but will be part of the strategic long-term monitoring. Process oriented parameters (growth and reproduction) will be sampled here. Research or tactical sites can be selected from the base grid for specific issues but may need to follow a different design. Parameters sampled should overlap with the strategic points so that results may be interpreted in a landscape context. This sampling may be short-term. A final grid scale will be suggested by scientific, economic, and political issues: correlations among adjacent points, how long it takes to do one site, how many sites are needed for reasonable precision, and what scale may fit with an existing network.

We may need to modify some of the FHM design to adequately address issues associated with LTEM, particularly Denali. In particular, we anticipate testing modified cover methodologies to address issues of reproducibility and flexibility for wildlife habitat. Nested quadrats and nested systematic point techniques are being considered. We will also investigate linking with other networks besides FHM, particularly other subarctic and arctic networks, where appropriate.

Field tests will be used to evaluate time it takes to do a site based on existing FHM (or FIA) protocols or with our modifications and how the observer observations compare. The techniques will be compared both in terms of number of sampling units needed for a given level of precision as well as for the power of detection for a given sample size. Sampling efficiencies of the methods will be compared for species composition and for species area curves to determine how many sampling units to use within a site and how many sites are needed. Year 1 will focus on testing the protocols in several sites with different scales of pattern to take a first cut at how a plot should be sampled. Year 2 will focus on how many plots should be taken throughout the Park for a given sampling adequacy or the power for a given sample size. Models with be developed from data collected over the next two years to help understand vegetation responses over time to perturbations such as fire, flood, foraging, mining, and other human use. The final product will include documentation of the field techniques and justification, the grid design and justification, and flowcharts or decision matrixes to help future users adapt techniques to changing issues and technologies.

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1 Introduction

The National Park Service recognized the need to detect and document resource changes and established a prototype Long-term Ecological Monitoring Program in 1991 at the national level. Denali National Park and Preserve (DENA) was chosen for the pilot program for subarctic ecosystems. Sampling of some vegetation parameters was initiated 1992 and has continued through 1998, but this was never intended to be a complete sampling program (Densmore et al. 1998). The next two years (1999 and 2000 field seasons) on the vegetation program will strive to develop a scientifically and statistically sound park-wide sampling program that is consistent with the Denali Strategic Plan (Denali National Park and Preserve and USGS Biological Resources Division 1997) and with selected national and / or international networks such as the Forest Health Monitoring (FHM) (Mangold 1998) or Forest Inventory Analysis as performed in Alaska, which is similar to FHM design (USDA Forest Service 1998).

“The purpose of the Long-term Ecological Monitoring Program at Denali National Park and Preserve is to develop broadly-based, scientifically-sound information on the current status and long-term trends in the structure and function of the park's ecosystems to:

1. Improve management decision-making on park resource preservation concerns that are primarily local and regional in nature;

2. Increase our basic understanding of ecological dynamics in the taiga and tundra ecosystems of the Subarctic Biogeographic Association in interior Alaska;

3. Enhance national and global monitoring networks by representing a naturally-functioning and intact subarctic site.” (Denali National Park and Preserve and USGS Biological Resources Division 1997)

The Strategic Plan also differentiates between “strategic” monitoring, which “provides basic knowledge about the status and trends of park resources. It answers questions that have a major influence on park ecosystems, are multi-generational or long-term in nature, and are on a large spatial scale. Tactical monitoring answers very specific questions, has a limited life span, and is usually carried out at a small spatial scale. Strategic monitoring is designed to continue in perpetuity. In some instances, monitoring that begins as a tactical activity will eventually be incorporated into the LTEM Program.” (p. 4 in Denali National Park and Preserve and USGS Biological Resources Division 1997)

More details of the Strategic Plan and how this proposed design for LTEM addresses those issues are in Appendix A for reference.

This document presents the study plan for the next two years for the vegetation component of the Long-term Ecological Monitoring program (LTEM). It will focus on a hierarchical sampling design to address Park-wide issues as well as more local issues. The sampling design will be able to detect spatial variation within the Park as well as changes over time on a decades-long scale. It will acquire information needed for management purposes and to help understand ecological distributions and processes. It will provide data that are suitable for including in national and global networks. We feel the proposed design provides a framework suitable for monitoring terrestrial vegetation in other National Parks in Alaska especially since Denali contains a diversity of plant communities with various scales of pattern.

In order to provide unbiased Park-wide information in a manner that specific information can be interpreted in a landscape context, a systematic grid will be tested with a hierarchical design to address multiple scales of information. Several large-scale systems are already in use mostly by the Forest Service to monitor or to inventory vegetation, especially forest communities. The Forest Inventory Analysis (FIA) has been in operation for several decades and plots are located throughout Alaska, including Denali National Park. A new program called Forest Health Monitoring (FHM) system has been implemented in the lower 48 and will be coming to Alaska sometime, possibly in 2001. This program developed in response to effects of acid rain in the northeast. FHM is oriented more toward forest health whereas the FIA is oriented more toward complete vegetation analysis. FHM is designed to estimate changes over short time intervals (2 to 4 yr) rather than in estimates of changes for small geographic areas (< 2 million acres) although it can be adapted to more intensive spatial monitoring (FHM web page). These designs have been used and accepted nationally, and we feel it appropriate to follow their framework but adapt them to our specific objectives. More information on FHM is provided in Appendix B. In contrast, LTEM is focusing on decades-long changes manifested at multiple landscape scales: local, regional, and global. However, shorter time intervals may be of interest for certain applications in LTEM.

2 Objectives

The objectives of the vegetation component of the Denali Long-term Ecological Monitoring program over the next two years (1999 and 2000 field seasons) are to develop, test, and describe ground and remote-sensing techniques to quantify vegetation characteristics and to document changes over time throughout Denali using scientifically and statistically sound methods and experimental design suitable for assessing landscape scale pattern and decades-long changes. More specifically, they are to:

1. Develop, test, and describe methods to document spatial and temporal patterns of vegetation composition, structure, and processes on a Park-wide basis. Composition and structure parameters will include parameters such as cover by species whereas process parameters will include parameters such as growth and reproduction of white spruce.

2. Develop and describe a hierarchical sampling design that is Park-wide and can accommodate both extensive (strategic) and intensive (strategic and tactical) issues. This will include recommendations for spatial scale and frequency of sampling, but this cannot be fully tested in 2 yr.

3. Integrate with other LTEM components by soliciting comments regarding suitability of parameters we are collecting for their studies and providing them with the data.

4. Produce a document(s) describing the protocols and sampling design and their justifications as well as any information needed to change these protocols as needed (adaptive management). Where appropriate it will also document parameters not proposed for monitoring and why.

5. Suggest methods of quality control, including training. These will ultimately depend on what Park personnel are available to work on LTEM and whether personnel are shared on a statewide basis.

6. Stratify the Park on a large scale, such as ecoregions, and also identify areas of management (e.g. access) concern and/or ecological interest (e.g. fire or other disturbance recovery) where more grid

points should be utilized. This will probably follow the stratification being used for the present mapping project but may have other factors..

7. Collect and/or identify study locations in the park for data and plot locations from previous studies (e.g USFS, Joan Foote, Fred Dean, Les Viereck). These points will be located in a GIS, and selected sites will be resampled to identify change.

8. Develop models for vegetation succession following fire, flooding, mining, and human usage and for interactions with abiotic (climatic and soils properties) and biotic factors (wildlife interactions). Suggest methods of quality control. However, these may ultimately depend on what Park personnel are available to work on the LTEM.

3 Methods

3.1 Overall Design

A hierarchical, systematic grid system will be tested as the framework for the LTEM vegetation component A grid is being proposed to (1) eliminate the bias associated with selecting plots in homogeneous vegetation types, (2) have the sampling points based on an unchanging geographical point, and (3) ensure sampling throughout the Park. Based on the vegetation types present at each sampling point, estimates can be made of the area of that type in the Park. Documenting vegetation change on a vegetation map would require relocating boundaries of a type, which could be cumbersome. Documenting vegetation change on a grid requires redocumenting the vegetation characteristics of that point and assigning a new vegetation classification, if appropriate, which is relatively easy to do.

Spatial scales like that proposed for the FHM (27 km) and used for the Statewide Forest Inventory in the early 1980s (40 km) are too sparse to provide adequate information about species composition an dother ecological parameters in the Park.. Spatial scales of 1-2 km may be too dense to be able to field sample in a 5-yr period, depending upon the resources available. By using a hierarchical sampling scheme, a fairly dense grid (e.g. 1 km) could be established, but it would probably exist only in GIS form and be 'sampled' by remote sensing techniques – probably satellite, but airborne may be used for special situations. We anticipate four levels of ground sampling: extensive, intermediate, intensive, and possibly research (Table 1). “Extensive” sites would be located throughout the Park (maybe 1/5 of base grid), and general vegetation composition and structural characteristics would be measured on the ground. “Intermediate” plots would be a subset of the extensive plots that would have all the parameters of the extensive plots plus some that may be too expensive to do on the entire grid – perhaps tissue chemical analysis. “Intensive” plots would be those that could be a subset of the remote-sensing grid and would generally be located for specific purposes: e.g. change in position of treeline or access road areas. Additionally, there will be “tactical” or “research” sites that could be sampled within the LTEM base grid but may need to be more intensive or specifically located for certain characteristics. These research sites are probably beyond the scope of the main LTEM monitoring but we will look at trying to begin implementation of one set of intensive plots as an example to work out initial glitches.

The FHM design involves sampling all ground points during the first year and dividing the points up into four panels (every 4th point). During year 2, points on Panel 1 and 1/3 of those on Panel 2 would be sampled. During year 3, all points on Panel 2 and 1/3 of those on Panel 3 would be sampled, and so on. This takes 5 yr to complete the initial analysis and one complete cycle of 4 yr of monitoring. The 4-yr monitoring cycle is then continued. This results in all points being sampled at least every 4 yr, and 1/3 of them being sampled in consecutive years. This provides a grid that is systematic both in space and time. The same geographic area is sampled every year. In many vegetation types in Alaska, little change may be expected in 2 yr so this would help continuously revalidate the amount of sampling needed and reproducibility of sampling, but this degree of resampling seems intensive for LTEM purposes.

FHM spatial scale is somewhat on the sparse side while the every 4-yr sampling cycle may be more frequent than needed for LTEM purposes. Switching to a 5-yr (or 10-yr) cycle may make the sampling frequency more in tune with what is needed on most sites and allow more points to be sampled resulting in a denser grid. However, the 5-yr cycle may not fit in well with the hexagonal geometry of FHM. The number of FHM grid points is expected to be small (about 31) relative to the total number of grid points in the Park (possibly>200). If those points need to be kept on the FHM cycle, then they could be dealt with separately. The USFS has acknowledged that grid adaptations may be needed for Alaska. I also understand that the FIA plots are on 5- or 10-yr remeasurement cycles so the USFS needs to figure out how to mesh the FIA and FHM designs. In other words, the details of these designs are still being worked out.

Additionally, some catastrophic (locally or regionally) disturbances such as fire or floods may occur in certain areas. As part of the strategic plan's goal to understand ecological processes, more frequent monitoring may be needed in some of those sites. These may require research-level or intensive plots and be resampled more frequently.

Some parameters, such as phenology, berries, or cone production, will need to be sampled at specific seasons or across seasons (Table 2). These parameters can be recorded on the extensive plots sampled during the appropriate season(s), but it may be desirable to have more detailed observations on the same sites every year. Those sites would probably be selected for specific reasons.

The grid scale recommendations will be made on what is economically feasible given the amount of sampling needed at each point, sampling adequacy, similarity of adjacent grid points (vegetation, topography), or suitability of the scale for another sampling design, like the USFS FIA grid. Unless some outside force like the FIA grid suggests a particular solution, we will look at correlations between adjacent points based on proposed vegetation map (which doesn't exist yet) or existing land cover maps. Another approach may be to calculate average major and minor axes of polygons or average area and size the scale appropriately. This will probably be done using ArcView.

3.1.1 Base Grid

The “Base” or “Remote sensing” grid will be the densest grid, and all the points are expected to be 'sampled' only by GIS associations or by some remote sensing means. However, this grid will also form the basis from which all other point selections will be made. It will enable us to select sites for intensive or research plots closer to the area of concern than the extensive plots would permit. The parameter for these points will probably be the vegetation type based on the cover class map being developed by NRCS

/ NPS / EarthSat. By nature of their location in the Park in GIS, the points will have that class, as well as many other features (such backcountry region or ecoregion), associated with them. As management areas of concern are delimited, they will also have that attribute associated with them.

3.1.2 Extensive Sites

The extensive sites will be the focus of the general sampling within LTEM and is intended to be strategic (providing basic knowledge about the status and trends of park resources) (Denali National Park and Preserve and USGS Biological Resources Division 1997). It is anticipated that it will have a couple hundred plots (Table 1). Parameters to be measured here will include:

1. Cover of all plant species by height class (vascular plants by species, lichens and mosses by genera, species if possible).
2. Density of selected woody species (tree species, tall shrub species, selected low shrub species - see description of density parameter for more details)
3. Height and dbh of tree species.
4. Basal area of tree species.
5. Fuel loading and downed woody debris.
6. Phenological state of selected species.
7. Berry production - if use photographs (could use double sampling between extensive and intermediate sites).
8. Wildlife usage signs - droppings, browsing, bird singing, carcasses, burrows, squirrel or marmot sounds..
9. Depth of duff.
10. Shade over streams (place holder for input from aquatic folks).
11. Possibly cover and condition of selected lichen and/or moss species that are indicative of a particular issue, such as air quality. That is, we may not be able to identify all mosses and lichens on a site, but field workers should be able to identify a few indicator species. Cover and possibly condition of these will be recorded.

Parameters measured on extensive sites will typically use low cost measurements that can be done at almost any time of the growing season (Table 2). Low cost measurements that may need to be done at certain times or frequently will need to be sampled on the intermediate, rather than extensive, sites. We will solicit input or request data from other components as needed to develop models (Table 3).

3.1.3 Intermediate Sites

The intermediate sites will focus on parameters that may be too expensive to measure on all extensive sites, but which need to be measured on systematic sites throughout the Park and are part of the strategic measurements (Table 1). These may include:

1. Some of the FHM parameters.
2. Tissue samples for air quality.
3. Browse or other forage production (may be better for intensive sites because of expense).
4. Berry production - if harvest berries.

5. Cone production - possibly - but may be better suited for intensive or research plots.

Intermediate sites may include parameters that might be easily sampled but must be done during critical time periods (Table 2), or ones that require frequent re-measurement may need to be in intensive sites.

3.1.4 Intensive Sites

Intensive sites will be selected from the base grid in response to certain issues (although some may have to be located at denser locations than that), like growth and reproduction of white spruce or road access issues, or monitoring after a disturbance. Parameters to be measured here will be those specific to the issue at hand plus the relevant extensive site parameters. It is anticipated that intensive plots will measure enough of these extensive parameters that are relevant to the intensive objective, that results from the intensive sites can be extrapolated to the extensive sites.

3.1.5 Research or Tactical Sites

These will be somewhat like intensive sites in that they are selected from the base (remote-sensing) grid or other specific locations. These will probably involve specific issues that may evolve in response to a particular concern and may have a relatively short duration compared to LTEM (Denali National Park and Preserve and USGS Biological Resources Division 1997). They may need sufficiently intense or technical measurements that they may need to be done outside the realm of LTEM, but they should measure some of the same extensive measurements so extrapolations can be made as necessary. These sites may be used to study cause and effect relations that might be hypothesized from correlations established by the extensive LTEM sites.

3.2 Grid Design

Since the National Park Service at the national level may be leaning toward following the FHM pattern, we will look at the FHM grid and intensify from there to determine a suitable grid scale. To maintain the unbiasedness of these plots, the preferred mechanism of placement is at the center point (as I understand it today 5/22/1999). Under some circumstances, the points should be viewed more as cells. If an existing site from some past, unbiased study (such as FIA or Statewide Forest Inventory plots) exists in a cell, then that site can be continued to be monitored as part of FHM. Whether plots established for some reason, like post-burn or moose browse, can be used as part of official FHM grid is being questioned because it biases the results (we're checking on this). These sites could be used as part of the Denali LTEM grid system if it was decided that the gain from past knowledge outweighed any bias associated with these site selections. We anticipate using some USFS inventory study locations from 1982-1983 (these are definitely legitimate as FHM plots) as well as moose sites from the mid 1980s (these could be part of Denali system, but may not be suitable for FHM).

3.3 Site Location and Marking

We intend to follow protocols setup by FHM, FIA, or LTER (Long-Term Ecological Research), depending upon which is most appropriate for the location and parameters, for site location and permanent marking.

Since the USFS has been inventorying and permanently marking plots for a couple decades in Alaska, we are assuming that they have worked out most of the kinks in the system, and should have no need to revise these, except perhaps to be consistent with low-visibility desires of NPS. The final protocols will be consistent among sites, but because of our potential modification of some sampling protocols, we may need additional markers.

3.4 Vegetation Composition and Structure (extensive, intermediate sites)

Overall the vegetation composition and structure will be the workhorse parameters interacting with numerous other LTEM components. It will provide information for wildlife habitat and changes that may result from perturbations or stressors. It will use information from soils and meteorology to help explain present spatial distributions of plant species and communities. This will help understand (and potentially predict??) changes in vegetation composition associated with local, regional, and global changes. During the 1999 field season ground methodologies will be tested from the FHM and FIA protocols and compared with some modifications that we are considering to better address the LTEM objectives. Emphasis in 1999 will be establishing the ground protocols (length and point spacing on transects, size of quadrats), determining how long it takes to do these sites in various vegetation types (forest, shrub, herbaceous), and how much local (within-site) variability exists. In 2000, we will focus more on how many sites are needed to achieve the desired precision / power throughout the Park. The FHM cover protocols are still being tested at the national level, and some questions still exist about the techniques.

3.4.1 Cover

Cover is the vertical projection of vegetation on the ground surface, like a shadow, and is always ≤ 100%. Where plant species overlap, the cover values cannot be numerically added to obtain the cover value for a composite category, such as low shrubs. The vertical distribution of cover is also relevant to wildlife habitat. Numerous methods of measuring cover exist but usually involve ocular estimates, line intercepts, or points. Ocular estimates may have observer error, especially over a number of years. Line intercepts are very good in vegetation where plants may cover substantial area, but may be extremely tedious in meadows or grasslands with many small plants. Points, on the other hand, are easy to do – what lies above a point – and are easily adaptable to various scales of pattern. The point technique, however, may miss minor species, but these can be included through a species list in the area, especially a belt transect alongside the transect. Minor species are rarely sampled adequately anyway, so even though other techniques may have a value of 5% or 10%, all that is really known is that the species is present. Systematic points have been found to be more efficient than random points because the time to locate points is much smaller (pers. obs.).

Where there is a small area to be sampled, the transect could be shortened. Point frames are a small version of systematic points. Where the scale of pattern is small, the points can be located closer to each other and the transect shortened (e.g. 10 cm in meadow), and where individual plants are larger, the spacings can be increased (e.g. 2 m in a pinyon-juniper stand). Longer transects may be desired in these areas. However, a preliminary study in Alaska on low shrub and forest sites near Healy resulted in 20-m transects with 50-cm intervals (40 points/transect) being the most efficient to adequately sample vascular vegetation within 20% of the mean with 80% confidence (Helm 1985). We will investigate nesting the transects (shorter transects, closer points within part of a longer transect with sparser points) to address multiple scales of pattern associated with trees or shrubs and understory. It is anticipated that herbaceous or dwarf shrub communities may not have multiple scales of pattern resulting from overstory species, but some soil or hydrologic condition may result in multiple scales.

To record cover data at systematic points along the transect, a transect is stretched, then every 50 cm (or other systematic spacing), all plants “covering” that point are recorded in order from the canopy crown to the ground mosses and lichens and litter. Overstory is obtained through a rifle sighting scope mounted vertically on a staff while understory is obtained by dropping a “pin” (sharpened welding rod) to the ground. Each species is counted only once per point (and height class if height classes are used). Height classes are also recorded for each point. This type recording allows us to know what plant species were in overstory or understory and general structure of vegetation. The cover for each species per transect is determined by counting the number of hits per species, dividing by the number of points per transect, and multiplying by 100%. Additionally, each species is classified by life form (tree, dwarf tree, tall shrub, low shrub, dwarf shrub, forb, graminoid), and the percentage cover calculated for each life form. Because of species overlap, the percentage cover of individual species cannot be simply added to determine the cover of the life form. Additional categories can be formed at any time in the future as more is learned about the ecosystems and what combinations of plant species may be important. Cover percentages can be determined for those categories decades after the data were collected. This type calculation cannot be done with ocular estimates.

The cover data will be recorded by height strata :

Code	Height	Name
1	0-20 cm	Dwarf shrub, seedlings
2	20-150 cm	Low shrub
3	150-300 cm	Tall shrub, dwarf tree
4	300-400 cm	Some woody plants may still be browsable in this category if dbh<4cm (but may use this class for density only and not cover)
5	4m - 8m	Small trees
6	8-16 m	Intermediate trees
7	>16 m	Tall trees

These breaks (at least through the start of the trees) are based roughly on the classes used for the Alaskan Vegetation Classification (Viereck et al. 1992). However, for specific wildlife (including birds and small mammals) values, some other breakpoints may be more appropriate. We will solicit comments from those people and incorporate them as appropriate. The densities will probably be done by height class also for wildlife habitat values.

Ocular estimates of cover in 12 1-m^2 plots are used in FHM. This sized plot is usually extremely small for a forested community, especially one with canopy gaps. Plots tend to fall under trees or in gaps, and each type may have its own species composition. Transects will encompass this variability. If differentiating the understories in gaps vs crown areas is needed, then the quadrats would be a more appropriate method, or perhaps multiple scales of transects as proposed in the nesting design..

For cover estimates by height category, we propose to test the systematic point technique in at least four categories of vegetation: needleleaf forest, broadleaf forest, low shrub, and herbaceous. We hope to do two sites in each, preferably three sites. We will test the technique with various lengths and spacing at these four scales to determine an appropriate transect length and point spacing for the various scales of pattern. We anticipate testing the following transect lengths and point spacing:

	Distance between points (cm)					
Transect Lengths (m)	10	25	50	100	200	500
5	x	x	x			
10		x	x	x		
20		x	x	x	x	
30			x	x	x	x

If some of these become too time consuming or are obviously inappropriate, we will stop testing that combination in that vegetation type unless it appears to be the optimal combination in all the other scales of pattern tested. I have used 20 m transects with 50 cm intervals for many years in a number of vegetation types. However, 30 m transects were more appropriate in floodplain stands which had large cottonwoods along the Susitna River. Shorter 10-m transects may be more appropriate for meadows or tussock tundra. We are investigating the idea of nesting transects to see if one technique can be used in all types.

Assuming something near a 20-m transect is optimal, the intention is to line up the cover transects on the fuel loading transects of FHM, which are only 18 m. Using the FHM design, we will test how many transects are needed per site to achieve a certain level of sampling adequacy. Do we need all 12 transects of the FHM design, or are 4 (for example) transects adequate? The 1-m^2 plots of the FHM design will also be tested since we anticipate that question will be raised. Systematic points and 1-m^2 plots will be compared both for community composition / similarity and for species area curves. The objective is to determine whether we need as many transects as FHM has or whether we are better off collecting less data at a site but on more sites. We will also test nested quadrats to evaluate species area curves (Roland 1999).

For example, plants suitable for moose browse are frequently taken as those sized 0.4 to 2 m or 2-4 m with dbh< 4 cm (the latter can be bent by moose to reach them). Densities of woody plants, especially willows, will take this into account. More important than the density and the cover of these species is their production at the right height, but production would be too expensive to measure on extensive plots.

Crown class will be reported for each species.
1 Open grown (isolated trees)
2 Dominant (received sunlight from above and sides)
3 Codominant (received sunlight from above but not the sides)
4 Intermediate (barely reaching main canopy)
5 Overtopped (below general level of canopy)
6 Subordinate (under overtopped)
7 Ground (lowest level).

If systematic points are used, this will be reported as a general observation through the site since the order of the species hit will also help indicate a species position in the crown, although not completely. If the 1-m^2 plots are used then it will be reported for each plot. This may only need to be reported for herbaceous species as the crown class will be recorded in the stand plot.

At the outset, we anticipate sampling all of these parameters on the extensive sites. If it is unrealistic to sample all these items in one day per site with a 2-person crew, then selected parameters will be sampled only on the intermediate sites. We anticipate that the intermediate sites will correspond to FHM protocols.

3.4.2 Species Density and Condition

Density is the number of stems of individuals per unit area. We will probably confine density measurements to those of tree species and selected shrub species such as alder and willows. (Sprawling species, such as *Vaccinium uliginosum*, that are better characterized by cover or another parameter will not be included here.) Density is related to number of individuals and would be a more direct reflection of recruitment and mortality whereas cover is related to both number and size of individuals.

Densities in FIA and FHM are generally recorded by mapping trees in circular plots and obtaining the counts from that information. Protocols used in Rock Creek in the early stages of Denali LTEM were developed from the Bonanza Creek Long-Term Ecological Monitoring (BNZ LTER) protocols. Circular plots have less boundary error than rectangular plots but encompass less variability than rectangular plots of the same area. Square plots are intermediate between circular and rectangular plots. Plots with straight sides (rectangular, square) are usually easier to mark in forested sites in the field. Circular plots may be easier when trunks would not interfere with using a radius tape to mark the perimeter.

We will test the FIA/FHM methods of determining density in the course of evaluating their complete protocols. Because the FIA/FHM methods actually map the trees (distance and azimuth from the center), the field implementation of the circular plots is not as difficult as it would be if stems were just being counted in a circular vs rectangular plot. This mapping and following the trees through their life cycle and ultimate decomposition allows true observations on life histories.

We will also consider coring a subset of these trees to determine an initial age structure for the site and past growth rates. Whether the vegetation field people should count the rings or whether they should be contracted to someone with capabilities of measuring widths and incorporating data into larger picture (e.g. Glenn Juday) is something that should be determined.

3.4.3 Down Woody Debris and Fuel Loading

Downed woody debris and fuel loading relates to stand health, may provide habitat characteristics for seedling establishment or wildlife usage, and potential fire issues that may be a concern near development. The fire folks within Denali are considering adding something to LTEM on this. We will interact with them concerning the general FHM design and provide them with the methods used by USFS Alaskan FIA (USDA Forest Service 1998) or FHM (Mangold 1998). Past FirePro studies have used various techniques so there may not be historical reasons to maintain certain methodology here, but that will be considered if appropriate. FIA and FHM use similar methods. This may be a candidate for Intermediate level sites if we feel we do not need this extensively.

3.4.4 Duff Depth

Duff depth will be determined for small mammals and for fire. This will be the depth of the highly decomposed surface organic matter. Small mammals overwinter in the duff. Duff and its moisture content can affect fire behavior and impacts on vegetation. These are the types of measurements where we will solicit input from the other components to be sure we are measuring the desired parameter in a meaningful way. (On intensive plots, we may want to collect duff samples and determine moisture content, as per Fire-Pro techniques. Since this is somewhat destructive and involves laboratory processing (drying), we may not want to do it on extensive plots. Or qualitative estimates could be provided in the field.)

3.4.5 Phenology

Phenology, including snow-free ground, is needed to determine the spatial and temporal availability of snow free sites for wildlife movement and foraging as well as the availability of certain foods, like berries, later in the season. It can be assessed by remote sensing, will be reported on extensive plots, and may be done in more detail on intermediate or intensive plots. (In addition to presence of snow, crustiness may be important as this would affect the ability of wildlife to forage through the snow. I'm not sure if this is discernible on radar or not and whether this should be left to the snow and wildlife people, but I'm putting a comment here so it does not fall through cracks. Snow depth and crustiness may also be factors in small mammal overwintering sites.) This information may also be useful for season of pollen production.

The dominant phenological state as well as the most advanced phenological state of selected species in the cover plots/transects will be recorded. Selected species will include tree and tall shrub species, willows, berry-producing species (*Vaccinium* spp., *Shepherdia canadensis*, *Empetrum nigrum*, *Rubus*, and other species that may be suggested), and herbaceous species like *Equisetum* and *Hedysarum* that are also used by bears (Table 4).

3.4.6 Wildlife Usage

General observations will also be made on signs of wildlife usage in the area. Some specific measurements that are being considered include pellet group counts and percentage utilization (percent of twigs that have been browsed). Actual browse productivity studies would probably be limited to intensive or research plots because of the expense, but parameters like diameter-at-point-of-browsing (dpb) could be determined on intermediate plots. Increased dpb may reflect increased wildlife pressure on plants in given years or regions of the Park. This would probably be confined to specific plant species of concern, like willows. These will be discussed with wildlife investigators before implementing to target parameters that will be of use to them. The parameters can be measured in annular plots, microplots, subplots, or transects. If clipping is needed, that would be confined to annular plots. It is anticipated that any clipping studies would be too expensive for this scale and possibly not of use to the wildlife people unless they were developing carrying capacity models.

3.5 Vegetation Processes (intensive sites)

3.5.1 White Spruce Growth

This may be a candidate for intermediate and intensive plots. It is suggested that the protocols or a modification that were used in Rock Creek and patterned after the Bonanza Creek LTER be used here also. It is anticipated that this will include sites throughout the Park, perhaps the FHM plots. Intensive plots will also be selected from the remote-sensing grid (that is, the densest grid) within the areas where treeline advance is a concern. The plots addressing treeline will be in transects (perhaps zig-zagged) across the gradient. This will probably involve at least two, preferably three, transects to take into account variabilities. On each transect or gradient, at least one site will be in 'mature' white spruce stand, one in transition, and two or three in the shrub communities - at increasing distance from the trees to allow for monitoring this over a long period of time. If herbaceous communities can be found along this same transect, then sites should be established there also to monitor shrub colonization.

Dendrobands will be considered to measure growth. In addition to these dendroband readings, all the extensive plots will have at least some dbh's measured. These can be remeasured every 5 yr or whatever cycle is determined. However, the dbh tape method will be subject to some error in re-placement of the dbh tape, even when marked with a nail.

Location of all trees and their sizes in these plots will be mapped so that the growth, recruitment, and mortality can be monitored over time.

At least one site in each major ecoregion. If these are read every year, as they have been in the past, then it might be desirable to locate them in readily accessible locations, but have at least a few in remote regions.

In addition to the intensive plots, tree cores could be taken in the extensive plots during the first reading. Tree cores could be brought back and analyzed in a laboratory for age and growth rates. Ages of some white spruce might be able to be determined in the field because of their visibility and separation, but it might be desirable to bring them back for growth rate analysis.

3.5.2 White Spruce Reproduction

White spruce reproduction is measured by the number of cones produced per tree, the number of seeds (viable and nonviable, counted separately) seeds produced, and numbers of seeds in seed traps. The seed trap data are really intermediate between the reproduction and regeneration. It is a measure of seed deposition in the area, which is most likely from the local spruce trees, but may reflect influx from elsewhere. Similarly, seed produced by local trees may be dispersed elsewhere. However, Zasada (1983) reported that most white spruce seeds were dispersed within 100m. Light seeded species, such as aspen and poplar, tend to disperse much farther and seem to leave a seed shadow near their origin (pers. obs.). Protocols used here can probably follow the protocols established in Rock Creek and adapted from the BNZ LTER. We may want to check with BNZ personnel to determine if they have changed anything over time.

We would like to establish at least one site in each major ecoregion. If these are read every year, as they have been in the past, then it might be desirable to locate them in readily accessible locations, but have at least a few in remote regions. These sites must be accessed at least twice a year: once to count cones and put out seed traps in fall and once to collect seed traps in spring.

The techniques used will be modified from the Rock Creek design based on experience and input from other sources.

3.5.3 White Spruce Colonization

White spruce colonization (tree line advance) is assessed by seed fall in the area, colonizing seedlings, and their survival, growth, and ultimately reproduction (this IS long-term monitoring). The seed fall can be assessed by seed traps. Seedling colonization, establishment, and growth is measured as part of the extensive plot measurements anyway. If it were desired to only document the changes in tree line, the extensive plots are already measuring the desired parameters. It is only if we want to relate the treeline advance to white spruce growth or reproduction that we need the other measurements.

3.5.4 Berry Production

Berry production is being collected primarily to relate to bear population data. In the past, data were collected only in high productivity areas, and it was done by fruit collection (Densmore et al. 1998). Data were highly variable and were not believed to provide a good representation of berry production (Densmore et al. 1998). Berry data is typically characterized by high variability, both spatially and temporally (year-to-year).

We propose to develop a method of sampling berries more efficiently and sampling this at all relevant extensive sites sampled when berries are present. A double sampling technique will be investigated during 1999 using digital photographs (or real photos later scanned in) taken at the sites. A protocol would need to be established for exactly how to take the photos. The digital image would be analyzed for spectral image related to the berries (dark blue for blueberries when ripe, red for buffaloberry, and black or very dark blue for crowberries) and an index developed. Software such as MuliSpec may be used for this. Berries would be collected from the site and the photo index related to the actual production or category. The model must be validated with imagery and berries collected from plots not used to develop the model. This may not work until the berries are ripe, since the green berries may not be distinguishable from the leaves. Other indicators would also be investigated.

If this works, we anticipate that the photos would be taken at all extensive plots, and the berry collections would be done only at the intensive or intermediate plots. It may be that once a relation is established, that we only need to report the index for each plot each year. Our assumption is that the bear investigators probably need an indication of whether a site / year is highly productive, average, or poor. Hence, the exact number or weight of berries is not critical for long-term monitoring. The food value of the selected berries has already been reported (Densmore 1998?).

3.5.5 Air Quality

Air quality effects on vegetation may result from such perturbations as Arctic haze, local and regional industrial development, and road usage (dust and other contaminants). Some of these may impact other resources before they impact vegetation. For instance, Arctic haze may result in acidification of streams and have a direct effect on aquatic invertebrates (pers. comm. Andrea Blakesly commenting on something an investigator stated at an air quality meeting). Any direct impacts should be picked up by the community composition monitoring as well as the visual condition of those plants. However, air quality may also be manifested by an accumulation of certain contaminants. For instance, Gough and Crock (1991??) measured metal accumulation in *Hylocomium* and *Peltigera aphthosa* surrounding an old power plant at Healy. A literature search will be continued identifying specific species and contaminants that might be appropriate for monitoring on an intermediate scale. It is expected that analysis of tissue samples may be more appropriate for intermediate and/or intensive sites than extensive sites because of the cost. Certain sporocarps of fungi may also be indicators of poor air quality. If these fungi are symbiotic mycorrhizal fungi, then this could ultimately affect plant communities.

Factors affecting air quality, such as fires and volcanic eruptions, may have direct effects on vegetation – like consumption or burial. Deposition from smoke and ash would also have some effect. These would be indicated by condition of plants.

3.5.6 Soils

FHM protocols include soils measurements. Initially a soil pit is dug but thereafter soil cores are taken. Soils are not expected to change as rapidly as vegetation, but vegetation succession will result in different plant species and different litter qualities which will affect soil parameters. Global change may also alter soil properties, especially temperature. Potential parameters include pH, extractable nutrients (N, P, K), CEC (cation exchange capacity), and total C and N. Hobos may be installed on the FHM plots that are revisited in consecutive years or it may be desirable to select a few sites throughout the Park that are revisited every year to obtain longer-term data. That will allow soils temperatures to be monitored on a 3 year-round basis. This is put here mostly as a place holder. The soils and possibly meteorology studies need to be integrated here somehow.

3.6 Remote Sensing

Some variables, such as phenology or snow-free areas, will be monitored by remote sensing in conjunction with ground truthing. The feasibility of this will depend on platforms available for use and a number of other factors which were outlined in Helm and Roland (1999) and which are included in Appendix C for completeness. It is anticipated that most remote sensing needs will use optical and infrared wavelengths, and these are fairly standard. Radar seems to provide useful information where vegetation structure is involved – like forest vs non-forest – or where moisture condition (abundance, frozen or liquid, permafrost) is discriminatory. With this in mind, the anticipated applications are for phenology, wetland, and permafrost (thermokarsting) applications as well as general succession (herbaceous to shrub to forest and potential loss of associated bear habitat).

3.6.1 Phenology

The objectives of any phenology observations appear to be to determine (1) when ground becomes snow free, (2) when spring food is available after greenup for wildlife, and (3) when berries are ripe for bears to fatten in preparation for winter. It has already been established that NDVI (normalized differential vegetation index) using AVHRR data can provide information on general greenup and senescence at a scale of about 1 km. This may be close to the scale of our base grid system and is probably adequate for general monitoring but it may need to be calibrated for events critical to our needs. The images could be used in association with the Denali browser.

One issue that might be important is that some small sites (<1 pixel) may become snow free before others. Although small, they may be critical for early season foraging by wildlife. Although this patchiness would be < 1 pixel in size, hopefully it would alter the signature sufficiently that the pixel(s) could be classified as partially snow free or thin snow. This issue will have low priority for the time being.

Some data on snow-free sites may need to be collected on the ground or fly-over by aircraft for calibration. For instance, we see the changes in the images, but do we know what the patterns actually represent.?? The aircraft flyover is suggested as a quick way of obtaining a lot of visual information when the Park road may not be open yet.

Berry production will be a little more challenging. We need both spatial and temporal distribution of berries. We anticipate that productive berry patches are smaller than 1 km and hence spatial distribution is probably not obtainable with AVHRR. However, AVHRR can provide the temporal signal for when berries should be ripening (when tied in with ground-truthing data). Some berries may overwinter. These are probably best assessed on the ground after or during late stages of snow melt. This may be before most of the sampling for the summer has started. Berries produced during the growing season will be assessed as part of the extensive plots using some type of double sampling, photos of plots are being considered at this point. The signatures (percent of pixels in a certain range of histogram) of these images would be calibrated with actual berry collections on intermediate or intensive (maybe tactical) plots.

We would need to work with the LTEM data manager to determine the best method of storing the data such that year-to-year analyses could be done. It is anticipated that incorporation in GIS database would permit easy visual comparison among years. Analysis on a pixel by pixel basis could be done to determine on what date each pixel (or group of pixels) reached a certain phenological state or to determine what phenological state each pixel was in on a certain date.

The same types of issues would be needed for other wildlife food, although in most cases it is merely the time of greenup for desired species. The species are indicated in Table 4. The species selected for moose food were based on earlier studies (Van Ballenberghe et al. 1989), which was based on June through August samples (fecal analysis, direct observation) along the first 30 km of park road in the frontcountry portion of the Park. It is not clear if these diets (dominated by diamondleaf and other willows) would also be valid in winter or in other portions of the Park, especially the western portion where there are more lakes. In areas where there is more aquatic habitat or herbaceous species, the moose diets may differ as they do on the Kenai Peninsula relative to Denali. Also other studies have noted the use of aspen bark (Miquelle and Van Ballenberghe 1986). The list in Table 4 is intended to be a starting list. Species and important states can be added or removed, based on improved knowledge or lack of resources to deal with it.

Actual field observations will record the most advanced state of the selected species (without spending a lot of time looking) and the predominant phenological state of the selected species. Phenological states will include the following (unless this is changed for compatibility with another system): bud swelling, bud break, leaf expansion, flower bud, flowering, fruit beginning to form, fruit ripe, leaves senescing, leaves fallen.

Additionally, we will investigate the use of radar to see if it can provide other insights. It can penetrate certain types of snow. This might be useful to distinguish certain winter habitats, e.g. hard-packed snow or ice distinguished from light, dry snow that an animal may be able to penetrate easily.

3.6.2 Wetlands

Floating bogs or other wetland vegetation may be difficult to distinguish on optical imagery. However, certain radar wavelengths may be reflected by the surface vegetation while others penetrate the vegetation. Comparison of these images allows one to delineate floating vegetation. This may be useful for tracking of changes in pond sizes over time or the extent and type of wetland vegetation.

3.7 Statistical Analyses

Initial data analysis will be by a nested or hierarchical analysis of variance. Each circular plot within a site will be characterized by a vegetation type. Each site may have multiple vegetation types. The first level will be the ecoregion (3 in Park), the second level will be the sub-ecoregion (13 in Park), and the third level will be the vegetation type (Level IV or V of Alaskan Vegetation Classification). Fourth level will be the sites and the actual sampling units will be the circular plots. Initially, plots will be established in relatively pure types to evaluate the techniques under relatively simple circumstances. Ultimately, the statistics for a vegetation type will be taken from all the subplots (circles or transects) that fall within that vegetation type throughout a region. However to determine how many circular subplots and transects are really needed within a site, we are setting up the first test sites in comparatively simple vegetation, that is most of the circular subplots will be in one vegetation types. In addition to statistics with respect to vegetation type, they will also be calculated on a regional basis or any landscape category – whether it be vegetation type or sites with particular slopes, aspects, and soil types in the different ecoregions.

The determination of adequacy of sampling will be based on using the mean square at each level as the variance term in the formula:

$$\hat{n} = \frac{(st)^2}{20\%}$$

where s is the standard deviation, t is a 2- (1-) sided t-value with df (degrees of freedom) corresponding to at least the number present in the sample, up to 30 (which is similar to that for infinity). 20% is the half-width of the confidence interval and may vary with the parameter being tested. Suggested specific goals for the most important parameters are indicated in Table 5. We will determine the number of samples needed. If it appears unrealistically large, then we will calculate the power of a number that appears reasonable. If the power is not sufficient, then alternative means of sampling will be considered or the meaning and value of the parameter will be reconsidered.

It may be more realistic to select a couple key parameters and focus on those rather than completing a table such as Table 5. For instance, concerns have been expressed about the succession of herbaceous vegetation to shrub communities and ultimately to forest with the associated loss of bear habitat (F. Dean). We should sample enough circular subplots at a site and enough sites that we should be able to detect those changes – perhaps a change in woody plant cover of 20%. The 20% was chosen somewhat arbitrarily. We need to interact with the bear investigators to determine if there is some woody plant cover percentage where the habitat is degraded for bears, perhaps a threshold or a range of percentages.

3.8 Quality Control and Data Storage

Several levels of quality control will be considered. Ultimately, we hope to use field data recorders. They can be programmed to only allow certain values for parameters, such as cover percentages must be between 0 and 100%. Hopefully, programs could be developed that would also perform checks that the data collected are consistent with the vegetation type reported. Training of the field workers from one year to another should be incorporated in the program as well as some type of double checking by an experienced person. Whether this is done at the Park level or ultimately at the regional level when all the parks have implemented LTEM should be an NPS decision.

Hopefully, we can work with a data manager on these quality controls as well as on efficient means of data storage. Cover data can be bulky. It may be that a program or query needs to be developed to retrieve some of the data.

3.9 Specific Issues

3.9.1 Changes in White Spruce Treeline

Changes in treeline will be addressed potentially in three ways: (1) extensive sites throughout the Park to monitor changes in stand structure, (2) intermediate sites that will have more detailed measurements such as growth and reproduction of white spruce, and (3) intensive sites that will be selected in the areas where treeline appears to be advancing along the road corridor. We may decide that any data collected besides the extensive data should be done only in intensive plots, or that maybe the 'intensive' parameters should be less intensive and measured only in the intermediate plots. This will depend on how long it takes to do different measurements and resources available for implementation of LTEM. The extensive plots will have cover data, densities, and sizes of trees. The intermediate plots will have dendrobands to monitor tree growth and may have cone counts. This might entail scheduling the relevant intermediate plots to be sampled at the appropriate time of year. The intensive site measurements would include all those associated with growth and reproduction of white spruce: dendrobands (or substitute), cone counts, and seed counts (cones and traps) although we may want to consider limiting the seed counts to the traps.

The intensive sites would be selected from the base grid points in the areas of interest along the road corridor. Ideally, we would like three transects or belts of at least three, preferably five, intensive sites per transect. One will be in a forest community, one in a current transition zone, and three at increasing distances into the non-forested zone. By locating three at increasing distances into the shrub community, changes in treeline can be monitored for decades, and the rate of colonization compared. If the number of sites were reduced, it would be the number in the non-forested communities. The forested and transition sites are needed for comparisons. The selection of sites along transects is suggested to minimize other variabilities but the sites could be selected anywhere from the base grid in the area of interest.

Observed changes can be related to meteorological conditions as well as the growth and reproduction of white spruce in the nearby forested areas. We might want to consider inserting soil temperature-measuring hobos at 50-cm depths (depth used by NRCS) in at least one of these transects to monitor temperature differences. Hobos can store one year of temperature data but may be subject to freezing damage by air temperatures. Hence, they must be buried.

3.9.2 Spatial and Temporal Variation Near Human Impacted Areas

This can be assessed around existing areas. Baseline sites can also be installed in areas in anticipation of road or other development. These issues can draw from the overall extensive data but more sites may be needed in certain areas. A study site could be located anywhere within a grid cell. Specific issues that this will address will be developed in conjunction with NPS personnel and could include road development. Sites could also be paired – some near present or future disturbances and others at a distance (but other factors as similar as possible) so changes could be compared.

3.9.3 Air Quality

This has already been partly described under the vegetation processes (intensive or intermediate sites). Locating plots throughout the Park before air quality has become a major issue will allow baseline data to be acquired. That way temporal and spatial patterns that may develop over time as a result of development can be picked up. Based on the estimate that there may be about 31 intermediate sites (almost 10 per year based on a 4- or 5-yr cycle), tissue samples could probably be obtained at those locations.

Vegetation responses to air quality changes will require inputs from the air quality component. Accumulations of elements in certain plant species have been documented (Gough and Crock 1990; Crock 1992). Additional literature review needs to be done.

3.9.4 Bear Food and Habitat

Bear cub populations are believed to be declining due to lower berry production – food availability when adults are putting on weight for winter hibernation. Also bears depend on herbaceous foods. Plant succession seems to be replacing herbaceous vegetation by shrubs and ultimately by trees. The berry production study is directly aimed at bear food. The general vegetation composition and structure data can address the successional issues. If done appropriately, the phenology data should address availability of Equisetum and Hedysarum early in the season because of their importance.

Additionally, there has been concern about herbaceous vegetation used by bears advancing successionally into shrub communities, and the shrub communities advancing into forested communities. This general change in plant communities over time is addressed in Section 3.10.6. A threshold for when these changes become significant for bears could be developed by the bear investigators. Adequacy of sampling issues could then focus on being able to identify those thresholds, as discussed earlier.

3.9.5 Spatial and Temporal Changes in Plant Species Distribution

This study will document the distribution of plant species throughout the Park and perform gradient analyses to better understand their distribution. It will also document the distribution of rare species in the Park as well as distribution of introduced species with respect to human use and how this has and will change. This should provide management with information on how to mitigate for human impacts (Roland 1999).

3.9.6 Spatial and Temporal Changes in Plant Community Distribution

Successional models will be developed for various disturbances such as fire, flood, and mining. See below. These will be used to help park managers understand the changes that vegetation may undergo when subjected to certain disturbances.

3.10 Models

At this point a conceptual vegetation model is best dealt with in several pieces, like the frame-based models (Starfield 1997). There will be several successional models: glacier (north and south sides), flood, mining, revegetation, thermokarst, fire, trampling, overuse by animals (probably very coarse scale at this point), and air pollution. It is anticipated that the fire model may be the most detailed (hopefully) and most useful. Hopefully, it will include not just plant community succession, but also fuel loading information, so that fire managers will have a model to work with. Or if there is already a fire model (in either Denali work or Joan Foote's work), perhaps the vegetation data may provide more details for the model. Flood and mining would probably be similar unless metals affected colonization on mining sites. In order to keep the models simple, we will use categorical data where appropriate. Chances are we do not know the signficance of interactions at a finer scale.

3.10.1 Post-fire succession

Data concerning fire succession are expected to be found in existing studies (Buskirk 1976; Viereck and Schandelmeier 1980) and also from additional data collection. It is anticipated that this model, especially, can profit from re-reading plots, such as the FirePro plots.

3.10.2 Glacial recession, floodplains, mining

Glacier succession model on north side will be based on Viereck (1966). South side glaciers may have a different sequence in some cases. Flooding and mining may follow a similar sequence and may be depend on elevation, geology, soils, slope and aspect. Some of this material may be available in the literature, but additional observations and probably data may be needed. Revegetation model would be based on documented revegetation in the Park (Densmore 1994; Karle and Densmore 1994).

3.10.3 Climate

Vegetation changes correlated with meteorological data will be modeled based on changes in temperature, moisture, and air quality. Some of this may follow a model developed for interior Alaska (Starfield and Chapin).

3.10.4 Wildlife - moose, bear, caribou, sheep, wolf

For interactions with animals, ideally the population densities of the respective animal species in region with the food in question and the amount that they eat in a day could be input to a carrying capacity model. Based on the amount of material taken and the amount left, the plant response to browsing/grazing, a carrying capacity model could be developed. However, it is doubtful that we know that much about the animal - plant interactions. Therefore, this will probably be treated on a cursory level, where the input is a usage category (heavy browsing, light browsing), and the output would be a general plant (range) condition response. For instance, moderate browsing of feltleaf willow would likely lead to moderate production (which is browsed each year so no net growth), while heavy browsing for 10 yr may lead to a decline in the plant survival. At least for moose, some of this material could be obtained from re-reading Joan Foote's plots and moose studies performed in the Park (Miquelle et al. 1986; Miquelle and Van Ballenberghe 1986; Miquelle and Van Ballenberghe 1988; Molvar 1992; Molvar et al. 1993). Moose affect vegetation succession, and plant productivity may affect moose populations. The moose - vegetation interactions may differ in different parts of the Park. For instance, in the front country area where many of the previous studies were conducted is dominated by woody species in the mountains. In other portions of the park, other plant species, especially herbaceous species near wetlands, may be more important, but we need to obtain that data from the moose researchers. In places where food habits are not known, we can pay particular attention to the plant species being browsed and the degree of utilization as well as other signs of wildlife usage.

For bears, although they consume plant parts, like berries, it is not anticipated that they affect vegetation, at least not as obviously as moose do. So bear - plant interactions are more likely to be vegetation inputs into a bear model.

Caribou food studies are expected to be found in existing park studies (Boertje 1979c; Boertje 1979a; Boertje 1979b; Boertje 1984; Boertje 1990). There are circumstances under which caribou could affect the plants and vice versa so this would be a plant model with inputs from and outputs to the caribou model.

We will continue to consult with the various wildlife investigators when building these models and interact with the NRCS/NPS mapping team as they are building wildlife habitat information into their mapping.

3.11 Priorities

There is a lot of work that we feel needs to be done in the next 2 yr. Since the prior vegetation LTEM work did not address many of the upscaling issues, we are leaning heavily on other networks for protocols. In addition to the extensive sampling, there are multiple levels of more detailed sampling as well as models to construct. In some respects we are trying to compress almost 8 yr of work into 2 yr. Hence, some of these items will be done in more detail and higher quality than others. We intend to address all issues and have everything at least started. Items 1-4 will be the most critical.

1. Grid design and extensive site sampling, including sample sizes. This has to be first and foremost at this point.
2. Quality control and data storage. Although some of this is internal to the vegetation program, this should be done in conjunction with Denali personnel (LTEM data manager), and presence/absence of that person may affect the level at which this can be addressed.
3. Intermediate sites. This will probably be patterned after the FHM/FIA sampling, modified appropriately if needed
4. Documentation of protocols and decisions that went into them.

5. Intensive and tactical sites. By their nature, they are somewhat open-ended and will depend on issues. These should involve Denali personnel input for specific management issues; e.g. road access.
6. Remote sensing applications. This technology may be changing constantly and there are people at the regional level that can assist if this does not get done in the detail desired. For longer term implementation, it may require somewhat at the regional level doing this for all the parks in Alaska.
7. Models. These are also somewhat open ended and are expected to evolve over time.

4 Deliverables / Products

Final protocols will contain:

1. Grid design and justification..
2. Sampling design for plots/transects within each site and justification along with some general idea of cost/benefit (which things were expensive to measure for the amount of useful information obtained).
3. Methodology for permanently marking location.
4. List of parameters to be collected and justification (usage within LTEM).
5. Methods for collecting ground level data and acceptable values.
6. Methods for data analysis (hopefully, we can develop some tools here)
7. Suggestions for quality control and training (some of this may be beyond the scope of this study as it may involve interactions with USFS or dictates from national level of NPS).
8. Flowcharts or decision matrix or background information where modifications may need to be made in some protocols as things are learned over time (such as change in remote sensing technologies).
9. A series of models concerning vegetation interactions with other components - climate, moose, bear, caribou, sheep, wolves, air quality. Fire, floodplain, and mining succession.
10. Glossary of vegetation terms.
11. Documentation for all decisions where appropriate, so that people in the future do not have to reinvent the wheel.

By the end of the project we should have documented.

On-ground parameters

1. Definition of what it is.
2. Why it is being measured (e.g. hiding cover for voles)
3. How it is being measured (e.g. binoculars, dropping pin, etc).
4. What values are acceptable (quality control, e.g. cover is between 0 and 100%)
5. What adequacy-of-sampling criteria were placed on it, if any.
6. How it is included in the overall design (this may be the same for all)
7. Frequency of sampling (may be same for most)
8. Season of sampling, if needed (e.g. berries in late July, early August).
9. If we think that something may need to be changed as more data are acquired, then a flowchart or decision matrix of what to consider (this may not be needed on most things).

Remote sensing (This is really a parameter measured by remote sensing rather than ground-sampling)

1. Selection of imagery.
2. What it is being used for
3. Why it was selected
4. How to use it (perhaps an ArcView application may be needed for landscape analysis. This may be beyond the scope of what we can do and may be better done by the ASO GIS support team.)
5. Flowchart or decision matrix or some kind of documentation on what may need to be considered if changing imagery as technology develops. This is probably more important here than for the parameters.

All of the above will be due at the end of the project: March 31, 2001. Intermediate deliverables will consist of:

An Annual Progress Report for the prior fiscal year suitable for NPS Annual Administrative Report is due December 15, 1999, and 2000.

Another summary concerning the prior summer's work, results, and plan for the second summer will be due April 15, 2000. This is not intended to be a full-scale report, but rather here-is-where-we-are and here-is-where-we-are-going type of report and may be a series of annotated lists.

5 Schedule

5.1 Field Season 1999 Objectives and Tasks

5.1.1 Goals of 1999 Field Season

1. Test preliminary protocols to determine
    a. What is doable in one day?
    b. How many transects/circles of FHM are really needed at one location for 'adequate' sampling?
    c. Are we better off taking more data at one point (1 full day's work) or taking less data and doing 2 points in one day? (Final 'answer' may be driven by economics/logistics of being moved by helicopter at mid-day.)
    d. How far apart should grid points be - both in terms of sampling variability on landscape and economics of being able to do it year after year?
    e. How frequently should they be resampled - FHM is 4 yr but 5 yr may be more doable and allow a denser grid?
    f. How many points do we need throughout the park? (This is a composite of several of the above questions.)
    g. How much variability is there between observers? Can the same observer resample and achieve similar results?

2. Relocate old plots (USFS, Joan Foote's, Fred Dean, Les Viereck) to look at changes for modelling
    a. At least identify what type of vegetation is there now and whether it appears different from the last reading.
    b. Re-read some of the plots to determine the amount of change since they were last read. This may be either by original techniques or new preliminary protocols, probably depending on arbitrary reasons. Original techniques allow for true comparison. However, if we were to incorporate the plots in the new design, then it would make sense to start using the new design. It may be that we use some of each technique. New protocols need to be tested so we might as well test them at old points. The USFS plots are especially useful for this since they were originally based on a grid system and not selected for a particular purpose.

3. Determine better methods of sampling old parameters:
    a. Cover by height class.
    b. Evaluate methods of cone sampling.
    c. Evaluate methods of berry sampling.
    d. Phenology.

5.1.2 Tasks

Prior to the start of field season (or perhaps overlapping somewhat):

We need to complete finding locations of known prior vegetation sampling plots and enter in ArcView:
    Has been done for most of USFS plots and Joan Foote plots.
    Fred Dean has points on map and these may need to be converted to lat/long.

Les Viereck's plots need to be located and lat/long locations obtained.
Locate the FHM plots.
Evaluate in ArcView a grid size finer than the FHM plots.

We also need to solicit input from other LTEM investigators to determine if our methods appear to be collecting appropriate parameters in a meaningful way for their component.

Check with the Park to find out what types of permanent markings are allowed and whether the FHM/FIA marking techniques are acceptable.

Attend USFS training (Anchorage and Wisconsin, if possible) using FIA and FHM techniques.

The following outlines the field season techniques:

Field test the FHM methodology for extensive or intermediate sites

- Use their methodology verbatim to start but also add other parameters such as signs of wildlife usage, duff depth, etc. We will need to have a more explicit list before we actually start.
- Use systematic points along the 18-m down woody material transects to evaluate cover by height class.
- Perform this test in at least one of each of the following general vegetation types: open white spruce forest, deciduous forest (maybe paper birch), low shrub, and herbaceous. These are selected to represent a range of scales of vegetation patterns within a plot. Tweak the system as necessary.
- Initially this will be done with two people, and both will do all observations to check for observer variability. The same person can also go back and read the same plots a couple days later.
- After it is felt that the major kinks are out of the system, have at least one other observer, preferably a couple, read the plots or a new set of plots to check for observer variability.
- Perform some preliminary data analysis to assess whether the transect length and point spacing seem reasonable for the vegetation types being sampled. Adjust as needed. (My guess is that they may not need adjusting so any comparisons along these lines may have a low priority.)
- Continue sampling on another set of four sites.
- Initial sites can be collected along the road system, especially in the front country area, including Rock Creek. Since there will be kinks in the system, there is no need to waste helicopter time on this. The initial sites may not correspond to any existing or future sites so we don't trample potential sites during training.
- Before the end of the summer though, some sites should be taken on USFS Tanana sites and Joan Foote sites to evaluate change from existing data. Some sites should also be taken in successional sites for model building.

Evaluate grid spacing or site placement with respect to special issues.

- Some of this can be done in ArcView prior to the field season, but we need to look at sites for the treeline studies and management applications, especially road access. Is an intensive grid (subset of base grid) adequate for these or will we need to select sites?

Expand the white spruce growth and reproduction study to sites in other parts of the Park.

- This may be a matter of setting up a couple FHM sites (or close to those sites) this year with the dendrobands, cone counts, seed counts, seed traps. More can be set up next year. Since 1998 was an excellent seed year, 1999 may be a poor year so it may be difficult to establish how many sampling units are needed in each site. Most importantly, we need to evaluate how to set up the various components within the FHM site design. We may also look at alternative methods of sampling some of these parameters, such as cone counts.

Evaluate different methods of counting cones.
Compare counts of cones on photos with actual counts of cones.
Must be done as cones are ripening before the squirrels get them.

Evaluate different methods of berry production.
Use digital photo images to develop an index to berry production.
Collect berries and see if a regression could be developed between actual berries and index developed from photos. It may be that only a general idea of berry production is needed - good, so-so, or poor.

Evaluate different methods of observing phenology.
We already know that AVHRR data can be used for general phenological observations.
Do these data need to be calibrated with on the ground information - both for greenup and for berry maturity?
Dave Douglas is continuing some work along these lines, but if we decide this is the way to go, do we need to initiate some mechanism of transfer? This might be appropriate for a LTEM remote sensing specialist. {This is more a question of where are we and should be reworded in final version of study plan.}

Begin evaluating remote sensing for some applications such as phenology and wetlands.
This may carry over into the next field season.

5.2 Winter 1999-2000

5.2.1 Goals

1. Assess data variability and quality by following techniques.
   a. Calculate number of observations needed to adequately sample the parameter within a site and between sites within major vegetation types (Level IV? Of Viereck) within a region. As a first cut, 'adequately sampled' will mean that cover of the dominant growth form is sampled within 20% (absolute, not a percentage of the mean) with 67% confidence. (2/3 of the time when that population is resampled, the calculated mean will be in the confidence interval). This may seem coarse at first, but when we look at variabilities, tighter confidence may require more observations than are economically reasonable. This should just be regarded as a starting point.
   b. Construct species area curves within sites as well as within vegetation types within strata and across entire park (if desired). At what point do we feel that we have encountered an adequate percentage of the species?

2. Start working on protocol documentation.
   a. Field sampling techniques.
   b. What statistics are required - may need to develop some application tools for Park or investigate commercial packages.
   c. What imagery needs to be used and how. May need more time for radar imagery applications since it is so different from optical interpretations.

3. If decide to use computer for field sampling, then make selection and set it up.

4. Make results available to other investigators and see if we are sampling their favorite parameter adequately and in a manner suitable for what they are doing. Encourage feedback.

5.3 Field Season 2000

1. Continue fine tuning system if needed.

2. Test protocols on a larger scale by establishing sites throughout the Park.

3. If using a computer for field data entry, then test the programs for it.

5.4 Winter 2000-2001

1. Analyze data and see if it meets adequacy of sampling for local and regional scales. Determine number of sampling units needed per site (but may have to remain standard with FHM) and number of sites needed for some a given level of adequacy of sampling. Or determine power for the number of samples collected by necessity of the grid design.

2. Distribute data to other users and see if it meets their needs.

3. Complete protocol documentation. Ideally much of the actual techniques would have been written the prior winter (although I may be dreaming about getting that much done) and this year could be devoted to documenting the scale and reasons why. By the end of the project we should have documented.

4. Remote sensing (This is really a parameter measured by remote sensing rather than ground-sampling)
   a. Selection of imagery.
   b. What it is being used for
   c. Why it was selected
   d. How to use it (perhaps an ArcView application may be needed for landscape analysis. This may be beyond the scope of what we can do and may be better done by the ASO GIS support team.)
   e. Flowchart or decision matrix or some kind of documentation on what may need to be considered if changing imagery as technology develops. This is probably more important here than for the parameters.

5. Quality control
   a. Acceptable values for parameters both absolutely and in context. For instance, cover must be between 0 and 100% inclusive. Tree cover in a closed forest site must be at least 60%. (or close to it. Sometimes sampling might result in a value somewhat lower because of variability.)
   b. Some method of quality control - multiple people sampling, having a supervisor independently check, etc. This would probably need to be developed closely with the Park in terms of what personnel are available. Or when all the parks have started doing this, then maybe someone at the regional level can oversee this. Some parks may just barely have someone to sample, never mind having someone different check.

6. Complete models
    a. Develop based on data and literature
    b. Document
    c. Sensitivity analysis if time permits

Different form of schedule

5.1 Field Season 1999

May - Jun 1999	USFS training Phenology observations Solicit input from other LTEM investigators concerning the appropriateness of the vegetation parameters we are collecting for their components. Visit SAR to learn more about radar applications (or in fall if this doesn't work out).
Late Jun-early Aug 1999	3 wks - test extensive protocols on small scale, include some remote sites, 1 wk - revisit old plots where desirable - esp. USFS sites, Joan Foote, Les Viereck Test for reproducibility by different observers or same observer over time. Plant identification of new or uncertain species is on-going.
Late Jul-early Aug 1999	Test new berry protocols (Dot - digital imagery signatures)
Mid - late Aug 1999	Test new cone counting protocols (Carl - photos of trees) or postpone until next year Place seed traps in new sites or postpone until next year

5.2 Winter 1999-2000

Sep 1999	Make sure data are complete, photos labeled, etc. Start processing cones and other samples that may need to be processed.. Arctic Science Conference
Oct-Dec 1999	Data reduction (calculate means, SE of most of data) Administrative report due 12/15/1999. Continue considering how data should be stored and accessed. Work with Denali LTEM data manager if present. Continue with literature reviews. Consider data loggers or hand held computers and programs for field (This could actually be started earlier, but we won't have time to implement anything for the 1999 field season, so it is on back burner until after field season.)
Jan 2000	Check to see what still functions after Y2K has struck.
Jan-Apr 2000	Calculate sampling adequacy, power, etc Develop regressions for double sampling

Make as many decisions as possible about protocols - primarily small scale (how many transects needed per site, etc.)
Start developing models, if they weren't already started in fall
Develop schedule and plans for field season
Begin documentation of protocols that seem reasonably set
Obtain data recorder and set up programs.

5.3 Field Season 2000

May-Sep 2000	Implement protocols on a larger scale. Sample throughout the Park to determine number of sites needed or to justify a lower power. Test berry and cone (and other types of double sampling) protocols again (validation with data from a different year) Resample some sites from first year.

5.4 Winter 2000-2001

Oct-Dec 2000	Data reduction, sample analysis. Administrative report due 12/15/2000 Calculate estimated sample sizes, power. Continue documentation
Jan-Mar 2001	Complete documentation and models.

6 Budgets

to be inserted

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Table 1. Parameters to be measured as part of the vegetation component of the Denali LTEM, and which type of plots they would be measured / recorded on. (Tentative ideas)

	Strategic - general			Probably Strategic	Tactical
	Base	Extensive	Intermediate	Intensive	Research
Method of site selection	Overall grid	Systematic subset of base grid	Systematic subset of extensive sites	Subset of base grid selected for certain issues	Selected for specific issues but prefer base grid site
Guesstimated number of plots and grid scale	1000s (maybe every 1 km)	200-400 (maybe every 5-15 km)	20-40 (maybe every 27 km)		
Any GIS (Denali Browser) data	x	x	x	x	x
Vegetation type	x	x	x	x	x
Cover		x	x	x	x
Density		x	x	x	x
Basal area (dbh)		x	x	x	x
Tree age (cores, initially)		x	x	x	x
Tree condition		x	x	x	x
Downed woody material		x	x	x	x
Duff		x	x	x	x
Duff moisture			x	x	x
Berry production (photos)		x	x	x	x
Berry production (pick)			x		
Phenology	x	x	x	x	x
Cone counts			x	x	x
Seed production			x	x	x
Seed fall			x	x	x
Seedling colonization		x	x	x	x

Depending upon how long it takes to perform measurements, some of the extensive site parameters may only be sampled on intermediate or more intensive sites. Parameters sampled on intensive and tactical sites may be specific to that study but will sample enough of extensive-site parameters so that data may be extrapolated if desired.

Table 2. Timing of measurement of parameter. (Tentative ideas)

Parameter	Any time	Anytime after greenup	When berries mature or almost mature	When cones ripe, before squirrels get them	Spring after snowmelt	All times
Any GIS (Denali Browser) data	x	x	x	x	x	x
Cover		x				
Density	x	x				
Basal area	x	x				
Tree cores	x (only need 1st time)					
Tree condition	x	x				
Downed woody material	x	x				
Duff	x	x				
Duff moisture	x	x				
Berry production-photos			x			
Berry production-pick			x			
Phenology	x	x				x
Cone counts				x		
Seed production				x		
Seed fall				x	x	
Seedling colonization	x	x				

Table 3. Parameters to be measured as part of the vegetation component of the Denali LTEM, and which other components they link to. (f=from, t=to) (Tentative ideas)

Parameter	Meteorology	Glaciers	Air Quality	Forest Health/ treeline	Succession	Charismatic megafauna	Birds	Small mammals	Development	Aquatic habitats	Fire Mgmt
Any GIS data											
Cover	f	f	f/t	t	t	t	t	t	f/t	t	t
Density	f	f	f/t	t	t	t	t	t	f/t	t	t
Basal area	f	f	f/t	t	t	t	t	t	f/t	t	t
Tree age	f			t	t		t?		f/t		t
Tree condition	f	f	f/t	t	t	t	t	t	f/t	t	t
Downed woody material				t	t						t
Duff				t				t			t
Duff moisture											t
Berry production-photos						t					
Berry production-pick						t					
Phenology	f/t	f/t	f/t	t		t	t	t	t		t
Cone counts	f/t		f/t	t	t?			t			
Seed production	f/t		f/t	t			t	t			
Seed fall					t?						
Seedling colonization					t						

f=from - parameter needs information from other LTEM component for spatial or temporal model. t=to - vegetation component passes this information to other components for their use.

Table 4. Selected species for phenological observations and justification. (Tentative ideas)

Species	State important for LTEM	Justification
Buffaloberry (*Shepherdia canadensis*)	Ripe berries Overwintered berries	Bear food going into hibernation and coming out of hibernation.
Blueberry (*Vaccinium uliginosum*)	Overwintered berries Ripe berries	Bear food coming out of hibernation and going into hibernation
Crowberry (*Empetrum nigrum*)	Overwintered berries Ripe berries	Bear food coming out of hibernation and going into hibernation
Horsetail (*Equisetum*)	Greenup	Bear food
Hedysarum	Greenup	Bear food
Diamond leaf willow (*Salix planifolia pulchra*)	Greenup	Moose food
Richardson willow (*Salix lanata*)	Greenup	Moose food
Feltleaf willow (*Salix alaxensis*)	Greenup	Moose food
Low blueberry willow (*Salix novae-angliae*)	Greenup	Moose food
Resin birch (*Betula glandulosa*)	Greenup	Moose food, also as a general indicator of phenology because of its prevalence
White spruce (*Picea glauca*)	All states, esp. cone maturation	Treeline, climate change, squirrel food
Black spruce (*Picea mariana*)	All states, esp. cone maturation	General knowledge for tree growth
Balsam poplar (*Populus balsamifera*)	Greenup, seed dispersal	General knowledge for tree growth, moose food in some areas, hayfever alert
Aspen (*Populus tremuloides*)	Greenup, seed dispersal	General knowledge for tree growth, moose food in some areas, hayfever alert
Paper birch (*Betula papyrifera*)	Greenup, seed dispersal	General knowledge for tree growth, moose food in some areas, hayfever alert
Alder (*Alnus crispa*)	Greenup, seed dispersal	General knowledge for tree growth, moose food in some areas, hayfever alert
Snow-free sites (or shallow snow)	Snowmelt	Indicator of when snow may not be impeding movement and availability of forage

Table 5. Tentative goals for precision / power of sampling on a Park-wide basis. (May just incorporate in text rather than a table. Don't want to be too confining at outset.)

	Precision	Confidence	Power
Any GIS (Denali Browser) data			
Cover	20%	67%	80%
Density	20% of mean		
Basal area			
Tree age	na		
Tree condition	na		
Downed woody material	na		
Duff	na		
Duff moisture	na		
Berry production-photos	na		
Berry production-pick	na		
Phenology			
Cone counts			
Seed production			
Seed fall			
Seedling colonization			

Appendix A - Denali Strategic Plan

This is a list of the Guiding Principles, Specific Objectives, and Priority Monitoring topics from the Denali Strategic Plan and how this plan of study addresses those issues.

Guiding Principles

The following principles reflect our basic assumptions about what we are trying to do, and provide more specific guidance about how we will go about it. All long-term monitoring activities will be evaluated against these guiding principles, which set standards for a fully successful program.

1. The program will attempt to develop linkages between ecosystem condition, and management needs and actions. To the extent possible, the program will anticipate the causes, mechanisms and indicators of human-induced change.

2. The program will be grounded in an interdisciplinary scientific approach based on a conceptual ecosystem model and integrated in its strategies.

3. The program will recognize the significant contributions that Denali, as a pristine, subarctic terrestrial site, can make to understanding large-scale ecological processes.

4. Program design will reflect the hierarchy of ecosystems at multiple spatial and temporal scales.

5. The program will use adaptive management. It will be regularly evaluated and revised based on new information and techniques.

6. The program will be managed on a sustainable basis, and will include or ad only those elements that can be supported over the long-term. Realistic assumptions about the availability f financial and operational resources to support the program will be used.

7. Program participants will be cognizant of its role as a prototype. Mechanisms for documenting and transferring lessons learned in developing the program will be encouraged.

8. Methods used will be repeatable, statistically sound, and readily implemented. They will be low-impact and consistent with park values.

How these plans addresses these Guiding Principles: By assessing not only species composition but the structure of the sites and health of the various species, indicators can be provided to Park managers regarding ecosystem condition (GP 1). Hopefully, the successional data and other data can provide some hints as to what management decisions may be appropriate. Some sites will be located specifically to address management concerns about development (GP 1). We have discussed with workers in a number of disciplines what parameters they would need from the vegetation data, and we will continue to interact with them to be sure we are collecting appropriate parameters (GP 2).

By introducing a Park-wide grid and multiple levels of sampling for separate objectives, we address the issues of the hierarchical nature of ecosystems at multiple spatial and temporal scales (GP 3, 4). By documenting our decisions and background information and providing flowcharts or decision matrixes based on existing knowledge, hopefully we can facilitate adaptive management to modify the program as knowledge is gained and needs may change (GP 5, 7). Methods will be tested to determine how much plots per site and sites are needed to adequately assess key parameters. Techniques and sample sizes will be adjusted until a scientifically and statistically sound methodology that is economically feasible is achieved (GP 6, 8).

Specific Objectives:

- Document the ranges of natural variation in key ecosystem processes and structural elements;
- Develop information that can be used to identify cause and effect relationships;
- Discriminate natural change from that which is human-induced;
- Obtain information useful in predicting change prior to undesirable environmental effects;
- Provide control sites and benchmark data for comparative ecosystem research;
- Share resource status information, monitoring methodologies and program development strategies with NPS and other entities;
- Provide information upon which management responses are based when pre-determined thresholds of resource condition are reached.

By measuring a number of ecosystem structure and function parameters throughout the Park, we will be documenting the natural variation for many features. These studies may document correlations between certain elements of vegetation structure and function and human activity (local, global, and regional) that can result in hypotheses concerning cause and effect. However, we believe that more detailed studies and possibly experiments may be needed to document cause and effect and separate human-caused from natural changes. Once models have been developed and data have been collected over time, predictive relations may be developed. Most of the extensive sites are expected to have little impact by human activity and so would provide control sites for comparisons. By the very nature of patterning the design after other networks and soliciting inputs and providing outputs to other LTEM workers and networks, we will be sharing resource status information. This design should be able to provide managers the information they need, or the design can be modified. However, either the threshold information needs to be provided by the managers or enough of a description of the issue that the vegetation workers can tease that information out of the data.

Priority Monitoring Topics

- Document meteorological patterns, particularly those affecting the timing and length of snow-free season.

- Provide early warning of changes in air quality, particularly visibility, due to local contamination, regional development and global influences.

- Detect changes in water quality of streams and lakes due to visitor use, park development, resource extraction activities and global influences.

- Detect changes in the productivity (including fish, primary producers and benthic invertebrates) of streams and lakes due to park development and resource extraction activities.

- Document patterns of glacial activity in response to global warming, and develop predictive capabilities of the effects of surges or recessions on mountaineering, other park uses, and downstream resources.

- * Detect significant changes in the structure, composition and distribution of major vegetation communities due to regional and park development, and global influences.

- * Monitor fire regimes (frequency, intensity, location, and areal extent) to evaluate the effects of fire management strategies on pant succession and habitat quality.

- * Detect changes in the distribution, behavior or population dynamics of animal species highlight in the park's enabling legislation, such as grizzly bears, moose, caribou, Dall sheep, wolves, swans and other waterfowl, in response to changes in habitat quality, park use or harvest.

- Provide early warning of changes in distribution, abundance and productivity of species of national/international concern, such as neotropical migratory land birds.

- Detect changes in the occurrence of deformities, population abundance or distribution of species, such as the wood frog, sensitive to contaminant deposition in air and water.

- Document trends in the abundance and productivity of animal species representative of all trophic levels.

- * Detect changes in distribution, abundance or productivity of umbrella, keystone and indicator species, such as grizzly bears, golden eagles, salmon, arctic ground squirrels, microtines, and merlin.

- * Discern changes in biodiversity, including introduction or loss of species, due to habitat fragmentation/loss, park and visitor activities, and regional development.

- * Detect trends in abundance and distribution of rare and native species and of introduced non-native species due to access, development and visitor activities.

The topics in the list that are relevant to vegetation are starred. Several of them involve wildlife habitat, which we are making specific efforts to measure. Input from wildlife researchers and managers will be solicited along the way to be sure that we are measuring the appropriate parameters with suitable methods. The distribution of the plant communities throughout the park and their relation to development will be one of the most obvious results of this monitoring. Biodiversity and distribution of native and introduced species are also being measured on the extensive plots.

Appendix B - Forest Health Monitoring

The Forest Health Monitoring (FHM) grid system is based on a hexagonal grid with four plots within each hexagon (cell). Generally the sampling scheme would be centered in the cell, but if prior plots, e.g. Forest Inventory and Analysis plots, exist in the cell, then the existing plot location may be used for FHM. The sites within FHM are systematically assigned to one of four panels (every 4th point). It was originally designed to monitor damage by acid rain in the northeast US, but is now being expanded throughout the US.

The first year all plots are sampled. During the second year, plots in the second panel plus 1/3 of those in the first panel are sampled. During year 3, plots in the third panel plus 1/3 of those in the second panel are sampled, and so on At the end of 5 yr, all plots have been sampled at least 3 times: once in the initial year, once in consecutive years, and once 3 yr after a prior reading. A complete cycle takes 12 yr -- 4 yr for a simple cycle and 12 yr to run three of the simple cycles so that all plots have been read in consecutive years at least once. Reading plots in consecutive years was desirable to assess crown damage from various causes (particularly acid rain in the northeast), but there was concern about plot damage from revisiting the plots too often. This design is a compromise between those concerns. Consecutive year readings where vegetation changes slowly can help reinforce how much year-to-year variation there might be with some parameters.

Within each cell are four plots arranged with one plot in center and three surrounding plots (Figure 1). Each nest of plots contains the following components:

Lichen plot (120 ft radius) centered on subplot 1 (circumference passes through centers of other three subplots) - macrolichens on woody plants
Annular plot (58.9 ft, 17.95 m outer radius with inner radius of 24.0 ft or 7.32 m) - destructive sampling
Subplot (24.0 ft, 7.32 m radius) - tally of living and dead trees >= 5 in dbh, quick survey of plant species present
Microplot (6.8 ft, 2.07 m radius) - ocular estimate of cover by life form of understory species including regeneration trees (tree seedling and sapling), fuel loading
Three 1-m^2 quadrats (1m x 1m) - cover by species and height class
Off-frame sites - ozone reference plots selected for certain conditions within the cell.
Three 17.95-m transects - down woody debris (We will probably use these transects for systematic point sampling.)

There are eight categories of data collected for FHM:

1. Forest mensuration
2. Crown condition classification
3. Damage and catastrophic mortality assessment
4. Photosynthetically Active Radiation (PAR) indicator (not implemented in 1998)
5. Vegetation structure (not implemented in 1998)
6. Ozone bioindicator plants
7. Lichen communities
8. Soil measurement and sampling.

This material was adapted from the FHM manual (Mangold 1998) and http://willow.ncfes.umn.edu/fhm_fact/list.htm.

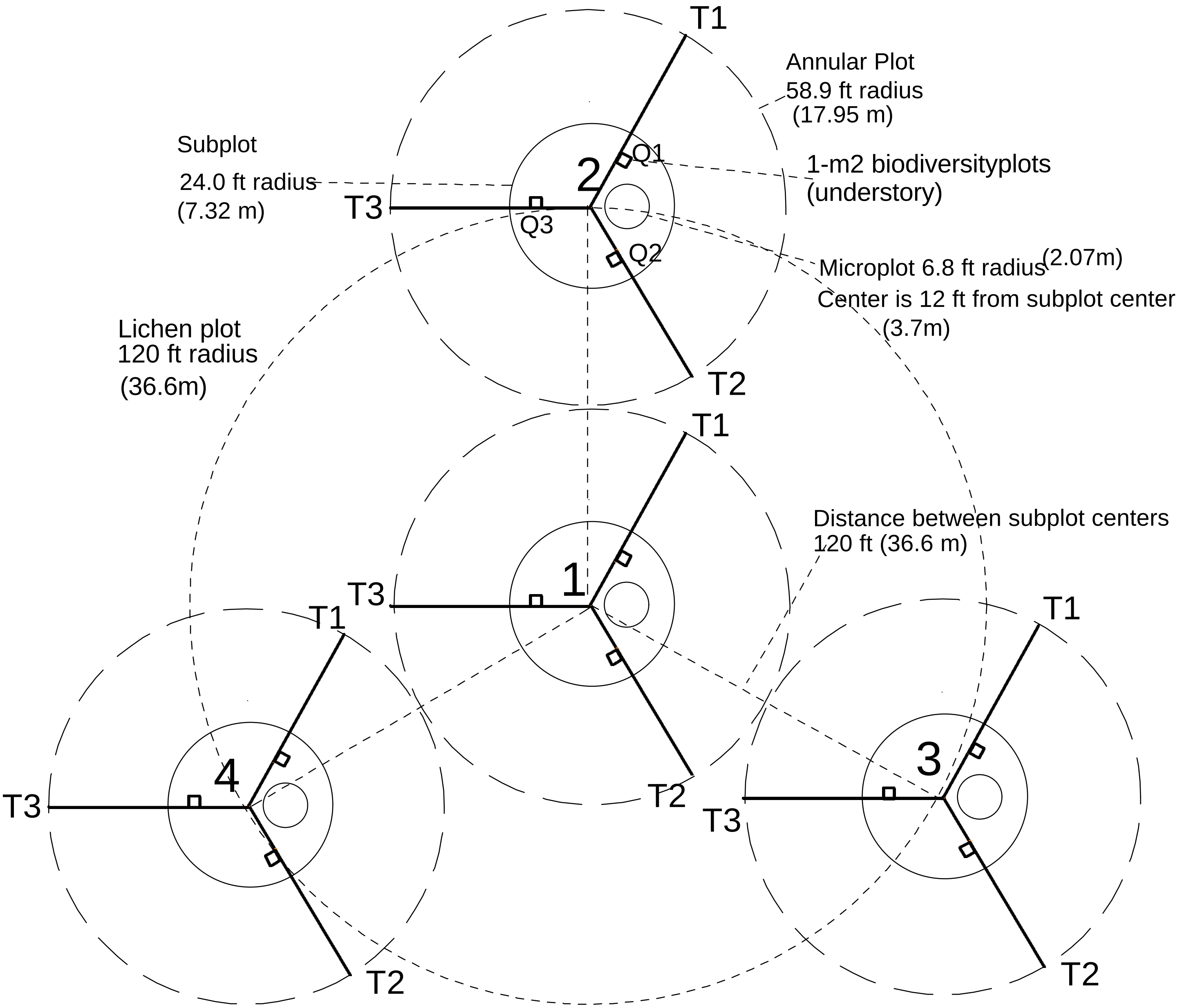

Figure 1. Diagram of Forest Health Monitoring site. (Mangold 1998).

Appendix C - Remote Sensing

Table C-1. Summary of electromagnetic energy spectrum.

Category	Band (μm unless indicated otherwise)
Optical	
Photography	0.3 -1.3 approx
UV	<0.4
Visible	0.4- 0.7
Blue	.45-.52
Green	.52-.60
Red	.63-.69
Near Infrared	.76-.90
SWIR	1.55-1.75
SWIR	2.08-2.35
Thermal	3.0-20. (general) ; or 10.4-12.4 (Landsat?)
Multispectral encompasses all the above	.3 to 20
Radar bands	Wavelength (other)
K-band	.6mm
X-band	
C-band	5.65cm
L-band	23 cm
P-band	

Summarized from Kaupp and Guritz (1998) and other sources.

The longer wavelengths may penetrate some types of vegetation. Table 9 summarizes the most common SAR (Synthetic Aperture Radar) platforms and their characteristics although there are others. Table 10 has the more detailed characteristics for RadarSAT.

Raw data needs much processing to be useful while the level 1 archive does not require as much processing but does require some. Terrain and radial corrections must be provided. The Alaska SAR Facility (ASF) has developed a number of tools and made them available on their web site. However, they are mostly available for UNIX systems at this time.

Table C-2. Platforms supporting optical sensors and their characteristics. (Data from assorted web pages, brochures)

Name	Landsat	AVHRR (NOAA)	DMSV (airborne)	CAR-TERRA	LISS (Linear Imaging Self Scanning Sensor)	LISS	WiFS
Platform	Landsat	Weather satellite	Airborne	Satellite (IRS?)	IRS-1A&B	IRS-1C 1995	
Ground resolution	30m	1 km	1m to 6 m	180m	72.5m, 36.25	5.8 m, 23.5m,	188 m
Repeat cycle	16 days at equator	couple days	selected		22 days at equator	24 days at equator	5 days at equator
Time between adjacent swaths (revisit)			-			5 days	
Size scene (swath)	185 km	2400km	-	810 km	148 km, 146 km	70 km, 142 km	774 km (810 km)
Bands (wave-length)							
	Blue (.45-.52)	Blue	Blue		Blue (.45-.52)		
	Green (.52-.60)	Green	Green		Green (.52-.59)	Green (.52-.59)	
	Red (.63-.69)	Red	Red	Red (.62-.68)	Red (.62-.68)	Red (.62-.68)	Red (.62-.68)
	Near IR (.76-.90)	IR	IR	Near IR (.77-.86)	Near IR (.77-.86)	Near IR (.77-.86)	Near IR (.77-.86)
	SWIR (1.55-1.75)	temper-ature				SW Infrared (1.5-1.70)	
	SWIR (2.08-2.35)					Panchromatic (0.5-0.75)	
	Thermal (10.4-12.4)						
Availability (potentially)	“always" if satellite is functioning		scheduled	routinely available for select areas or requested by customer			
Source	EROS?, GI?	GI?	Private contractors	Space-Imaging			
Launched		1st in 1978	scheduled			Dec 28, 1995	
Country	USA			India			

Table C-3. Characteristics of radar platforms.

Characteristic		ERS-1/2	JERS-1	RadarSat	AirSAR
SAR					
	Frequency	C-band	L-band	C-band	
		5.65 cm	23 cm		
	Polarization	VV	HH	HH	
	Swath	100 km	75 km	50 to 500km	
	Resolution/looks	30 m /4	30 m /4	30m/4 - 100m/8	
	Incidence angle	23 deg	35 deg	20-50+ deg	
	Orientation	Right	Right	Right	
	Onboard storage	None	10 min	15 min	
Orbit					
	Inclination	97.5 deg	98.5 deg	98.6 deg	Airborne
	Altitude	785 km	568 km	768 km	
	Repeat cycle	35 days	41 days	24 days	
	Time between adjacent swaths	3 days			
	Type	Sun-synchronous	Sun-synchronous	Sun-synchronous	
Mission					
	Launch	Jul 1991, Apr 1995	Feb 1992	Nov 1995	scheduled
	Design lifetime	3 yrs +	2 yrs +	5 yrs +	
	Status	Both active	Died Oct 1998	Active	
Other instruments		Radar altimeter Wind/wave scatterometer Along track scanning radiometer	Optical sensor	None	
Other Comments			Longer wavelength than ERS1,2; therefore better penetration; steeper angle means less distortion		

Adapted from Kaupp and Guritz (1998).

Table C-4. Characteristics of RadarSAT that make it more flexible than other radar platforms. (Kaupp and Guritz 1998)

Operational Beam Mode	Beam Position	Incidence Angle	Nominal Resolution (m)	Nominal Area (km)	Number of Processing Looks
Fine			10	50 x 50	1 x 1
	F1	37-40			
	F2	39-42			
	F3	41-44			
	F4	43-46			
	F5	45-48			
Standard			30	100 x 100	1 x 4
	S1	20-27			
	S2	24-31			
	S3	30-37			
	S4	34-40			
	S5	36-42			
	S6	41-46			
	S7	45-49			
Wide			30		1 x 4
	W1	20-31		165 x 165	
	W2	31-39		150 x 150	
	W3	39-45		130 x 130	
ScanSAR Narrow			50	300 x 300	2 x 2
	SN1	20-40			
	SN2	31-46			
ScanSAR Wide			100	300 x 300	2 x 2
	SW1	20-49			
Extended Position			25	75 x 75	1 x 4
	H1	49-52			
	H2	50-53			
	H3	52-55			
	H4	54-57			
	H5	56-58			
	H6	57-59			
Extended Low			35	170 x 170	1 x 4
	L1	10-23			