Soils Supplement

SOIL QUALITY MONITORING:
A Review of Methods and Trends in the Northern Region

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This report describes the conclusions of a task force of soil scientists from representative National Forests in the Northern Region. They were given three charges: 1) to review, and develop if necessary, site level soil monitoring methods for both qualitative and quantitative monitoring along with recommendations; 2) to develop guidance for selecting benchmark soils and practices for monitoring; and 3) to develop a rapid assessment technique for coarse scale monitoring. A consistent approach to monitoring, as well as adherence to scientific methods was emphasized.

I. SOIL MONITORING METHODS

Listed below are monitoring methods being applied on five representative National Forests in Montana and Idaho. All the transect methods are based on Howes, Hazard, and Geist (1983). Each National Forest applies methods that are appropriate for the area and accomplish the intended objective -- to determine the effects of various management practices on soil quality and long-term soil productivity. Soil and site parameters that are monitored are described in Forest Service Handbook 2554, Soil Quality Monitoring (R-1 Supplement 2500-99-1, 11/12/99). These parameters include *compaction, erosion, displacement, rutting, severely burned soil, soil mass movement, and organic matter [both fine woody debris (FWD) and coarse woody debris (CWD)].*

The following methods are applied to both recent and past activities. It is not unusual to observe recent and past activities in the same activity area. The past activity review is used in the NEPA stage to ascertain existing cumulative effects. The results of the recent activity reviews are used in NEPA documents for projected cumulative effects.

100 Foot Transect: observations of soil impacts, including erosion, rutting, displacement, burned soil, fine woody debris (FWD) and coarse woody debris (CWD) are made at one foot intervals along 100 foot transects that are selected randomly using standard statistical techniques. The number of transects per unit varies between 3 and 16, depending on the size and shape of the unit being evaluated. Soil compaction is evaluated at 10 foot intervals along the transect using one of the following methods:

Bulk density core samples, saran coated clods, or the sand cone method.

A shovel test which includes an estimation of penetration resistance and an observation of soil structure. The use of penetrometers is an alternate to this method. Core samples or other laboratory techniques are used to calibrate shovel or penetrometer estimations of compaction.

Infiltration test, correlated with soil structure.

Pace / StepTransect: transects are made from one side of a harvest unit to the other. The transect generally follows the contour of the slope, which is usually perpendicular to the activity. At every or alternate steps observations of soil impacts are made. One to five transects are made across the unit depending on the size and shape. It should be noted that this is not a statistically accurate method; it is intended for a general estimate of soil impacts.

Traverse: this is a random walk though the unit making visual observations. This method is used to determine if further sampling is warranted.

Evaluation of Methods Used on Forests

All five Forests correlate field methods with standardized procedures for compaction and infiltration. Standard methods for compaction (bulk density) are sand-cone, core, or saran-coated clod.

All definitions in FSM 2554 are used on all Forests. These definitions may be collapsed to a binary system (detrimental vs. non-detrimental) to enable more rapid sampling. This collapse process is consistent across Forests.

We recommend the continued use of existing methods and definitions. All Forests evaluated appear to be applying the methods correctly and consistently to meet the objectives of soil quality monitoring. The consistent application of these methods will continue to be emphasized. We also recognize that no one method is universally applicable; the selection of methods needs to be appropriate for the landscape and the objectives of monitoring.

II. *MONITORING BENCHMARK SOILS AND MANAGEMENT PRACTICES*

Soils and site factors form the basis for site capability and contribute to the effects of management activities but, based on monitoring results, we feel that harvest and site preparation methods have a stronger influence on soil quality and productivity.

Some soil properties are important across the Region. The western Montana and Idaho forests are generally more productive and have surface soils largely composed of weathered volcanic ash. This masks other soil properties related to compactibility.

Eastern Montana forests have more variable surface soils due to the absence of volcanic ash. Soil displacement is a significant factor. Soil productivity is lower due to lower precipitation and thinner surface soils.

The cushioning effect of organic materials (duff, litter, and slash) is significant relative to soil protection. The amount of organic material on a site influences the effectiveness of harvest methods in protecting soil productivity. Sites with lower amounts of organic material are more vulnerable to soil damage than are sites with higher amounts.

Stratification of monitoring based on ecological units may have some merit but first an assessment based on data entered into SOLO needs to be done. It would also be desirable to summarize and compare the effects of various harvest and site preparation practices on soil quality and productivity.

III. *RAPID ASSESSMENT TECHNIQUES FOR COARSE SCALE MONITORING*

An emerging soils issue is the cumulative effects of past logging on soil quality. Pre-project monitoring of existing soil conditions in western Montana is revealing that, where ground-based skidding and/or dozer-piling have occurred on the logged units, soil compaction and displacement still are evident in the upper soil horizons several decades after logging. Transecting these units documents that the degree of compaction is high enough to be considered detrimental, i.e., the soils now have a greater than 15% increase in bulk density compared with undisturbed soils. Associated tests of infiltration of water into the soil confirm negative soil impacts; the infiltration rates on these compacted soils are several-fold slower than rates on undisturbed soil. Further evidence of detrimental compaction is the alteration of the soil structure from friable fine granular structure in undisturbed soils to high strength, platy structure that breaks apart with difficulty and is noticeably higher in density. Understory vegetation height and canopy cover is usually lower in compacted areas and plant species composition may be different. Transecting indicates that these conditions are widespread. Typically, 30 to 60 percent of a unit will have detrimental compaction.

The effects of extensive areas of compacted and/or displaced soil in watersheds along with impacts from roads, fire, and other activities are cumulative. A rapid assessment technique to evaluate soil conditions related to past logging in a watershed is based on a step-wise process of aerial photo interpretation, field verification of subsamples, development of a predictive model of expected soil conditions by timber stand, application of this model to each timber stand through GIS, and finally a GIS summarization of the predicted soil conditions in the watershed. This information can then be combined with an assessment of road and bank erosion conditions in the watershed to give a holistic description of watershed conditions and to help understand cause/effect relationships. The information can be related to Region 1 Soil Quality Standards to determine if, on a watershed basis, soil conditions depart from these standards. Watersheds that do depart from Soil Quality Standards can be flagged for more accurate and intensive field study during landscape level and project level assessments. This process is essentially the application of Soil Quality Standards at the watershed scale with the intent of maintaining healthy watershed conditions.

Evaluation Factors and Assumptions

Evaluation factors used in the predictive model include the following:

Slope from GIS

Harvest year from TSMRS

Fuel treatment (determines if site was dozer-piled or not) from TSMRS

Silvicultural system group from TSMRS
Group 1 – 80 to 100% canopy removal (clearcut, seed tree, and shelterwood systems)
Group 2 – 60 to 80% canopy removal (shelterwood with reserves, shelterwood prep)
Group 3 – 20 to 60% canopy removal (improvement, commercial thin, group selection, sanitation salvage)

NOTE: Other more direct evaluation factors such as logging system, volume removed, and site preparation would have been more desirable to use. Unfortunately, those fields were not mandatory in TSMRS and were often not populated. The selected factors were mandatory fields in TSMRS.

Ground-based logging systems produce substantially higher levels of soil damage than skyline, cable, or helicopter systems. Cable, skyline, and helicopter systems have similar levels of soil impacts and these levels typically are less than 5% detrimental soil damage on an areal basis. Increased levels of canopy removal are associated with increased levels of soil damage in most cases. The following assumptions are made in order to determine which logging system was used on a site:

Dozer-piled sites used a ground-based system
If the site was not dozer-piled, slope was less than **, and the site was logged prior to 19**, a ground-based system was used
If the site was not dozer-piled, was logged after 19**, and slope was less than 40 percent, a ground-based system was used
If the site was not dozer-piled, was logged after 19**, and slope was greater than 40 percent, a skyline, cable, or helicopter system was used
If slope was greater than **, skyline, cable, or helicopter systems were used

** to be determined on each Forest.

Prior to the early 1980's, ground-based logging equipment tended to operate on steeper slopes than they do now. This shift may coincide with implementation of Forest Plans in the 1980's or some other factor to be determined locally. The period when this occurred can be determined through a query of TSMRS in conjunction with GIS.

This procedure can be applied to the timber stand data base for silvicultural systems groups and yarding methods in combination with slope estimates from GIS. A 3 x 3 matrix will be produced having 3 silvicultural system groups versus 3 yarding methods, for a total of 9 matrix cells, some of which may not be applicable. Estimated soil damage classes will be assigned to each matrix cell using the following method.

Analysis Procedure

In conjunction with the Soil Quality assessment, there should be separate watershed assessments of road effects using the latest version of the Water Erosion Prediction Project (WEPP) model and streambank erosion. The concensus of a small group of watershed specialists is that all three assessments should be done in the same watersheds. These watersheds should be selected based on their occurrence in subsections or Landtype Association groups in the planning zone.

1) Using aerial photos, sample harvest units within each ecological unit in the watershed. These units will be photo-interpreted for estimates of soil damage. Experience has shown that skid trails even several decades old often are evident on the 9 x 9 inch color resource photos. Each unit will be associated with a cell of the 3 x 3 matrix of silvicultural system group (Groups 1,2,3) versus yarding/fuels treatment method (ground-based; ground-based plus dozer-pile; skyline/cable/helicopter) to determine estimated soil damage related to these combinations. A minimum of 5 to 10 samples for each combination per ecological unit should be photo-interpreted.

2) Concurrent with the photo-interpretation assessment, field sampling should also be conducted to verify and calibrate the photo-interpretations. Field sampling needs to be done on the same units being assessed by photo-interpretation and should also cover all the ecological units. The number of field samples needed should be based on the degree of correlation between the photo-interpreted data and the field data. The field transecting should be done using a rapid assessment of soil conditions.

3) Adjust aerial photo estimates using the field data as the photo-interpretation proceeds.

4) Based on the revised aerial photo estimates of percent soil damage, develop rules for use with GIS/TSMRS that assign soil damage classes to the various combinations of silvicultural system group and yarding system for each ecological unit.

5) Apply these rules using the timber stand data base and GIS, based on slope, silvicultural system group, and yarding/piling method so that all timber stands are assigned the appropriate predicted soil damage value. Unmanaged watersheds can be rated as appropriate (for the most part, no detrimental soil damage).

6) Summarize this data using GIS and the results of step 5 to determine weighted average estimates of soil damage for all watersheds across the planning zone.

7) Relate estimates of soil impacts by watershed to Soil Quality Standards.

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APPENDIX A

SOIL MONITORING TRENDS FOR REPRESENTATIVE NATIONAL FORESTS IN THE NORTHERN REGION

The following gives detailed soil monitoring data compiled from five Region One National Forests. These are based on interviews with Forest soil scientists. *Ecological Characteristics* are general descriptions giving the landscape and management context for each Forest. *Timber Activities* are summaries of the kinds of timber management activities common on each Forest. Activities are only the most common. Others may occur. *Monitoring Methods* refers to specific methods used to monitor soil productivity after timber management activities. *Monitoring Frequency* provides a summary of the level of monitoring related to sale activity on the Forest. *Recent Results* is a summary of important results in the last few years. *Trends* indicate the perceived direction of soil productivity maintenance based on Forest data. *Emerging Issues* lists new concerns that will probably impact monitoring efforts in the future.

Forest: IDAHO PANHANDLE NATIONAL FORESTS

Ecological Characteristics: The average annual production of wood on suitable lands is 63 cubic feet. Last year sales were about 86 million board feet. Soils are developed in an average of 17 inches of volcanic ash over a variety of substrates. The volcanic ash is critical for production. All volcanic ash soils are compactible.

Timber Activities (including Harvest, Fuel Abatement, and Site Preparation): Of the available lands, about 25 percent is tractor, feller/harvester logged; 25 percent is helicopter logged, and 50 percent is logged by cable systems. Upper slope limit on tractor skidding is 35 percent. Tractor harvest operations presently utilize 100 foot trail spacing, except where roads converge at landings; feller bunchers with and without processing heads and harvesters are used primarily on small diameter timber sales, this equipment in the past has operated both on and off slash mats. The present recommendation is to operate on slash mats. These operations use 60-70 foot spaced skid trails and utilize swing skidding or forwarder operations. Some feller buncher and cable yarding operations are also used. Broadcast burning and grapple piling on slash mats are the most frequently used slash disposal methods. Primary prescriptions are seed-tree or shelterwood

Monitoring Methods: Two levels are practiced. "Intensive" monitoring uses *100 ft., randomly placed transects (five to twelve)*, evaluating disturbance modes (displacement, organic material retention [fine and coarse woody debris], erosion, burning, and puddling.) Compaction is evaluated using core bulk densities every 10 feet. The other elements are noted and recorded every foot along the 100 foot transect. *"Walk through"* monitoring uses the same transect method, but using a spade to evaluate compaction. Soil monitoring results are in databases used for planning and monitoring.

Monitoring Frequency: Four sales were monitored last year. A total of 15 cutting units were monitored. A total of about 35 sales have been monitored. Efforts are made to monitor a sale per district per year and those sites where new equipment is used. All are "new" sales, meaning areas have not been disturbed by previous logging operations. The soil scientist has been formally monitoring sales since 1984. Additional monitoring may be completed if new equipment is used or on request by resource specialists or managers.

Recent Results: Compaction is the most documented problem. Problem areas include skid trails spaced too close together and where dispersed skidding is allowed (non-winter operations), or where travel is allowed on soil without slash mats. In some cases, burning when organic layers are dry has resulted in significant soil damage, particularly on south and west aspects. Less than 10 percent of the units monitored exceeded soil productivity limits

Trends: The trend is towards lower disturbance levels as Timber Sale layout becomes more efficient at prescribing methods.

Emerging Issues: Retention of organic materials is becoming an important issue. Too little downed woody debris is currently being left on site. Cumulative effects are important where harvest occurs on previously-cut sites.

Forest: KOOTENAI NATIONAL FOREST

Ecological Characteristics: The average annual production of wood fiber on suitable lands is 58 cubic feet. The average volume for the last five years is 85 million board feet. The soils are developing in glacial till or residual soils. Four to 14 inches of volcanic ash overlies the parent materials. There are some areas where ash is mixed with the substrate material. Volcanic ash is absent on 20-25 percent of the area. Almost all of the underlying bedrock is Precambrian Belt metasediments. The volcanic ash is critical for production. All volcanic ash soils are compactible.

Timber Activities (including Harvest, Fuel Abatement, and Site Preparation): About 50 percent of managed lands are tractor ground. Out of available lands, 50 percent is tractor-logged, 45 percent forwarder systems, and five percent cable. Upper slope limit on tractor skidding is 40 percent. Feller-bunchers are used, with processing heads to distribute slash. Feller-bunchers operate on a "slash mat" of material stripped from trees. Tractor or rubber-tired skidder (RTS) skidding uses 60 to 70 ft. spaced skid trails with little activity allowed off trails. Timber is accessed by directional felling and cable pulling methods. Broadcast burn is often used for hazard abatement and site preparation. Grapple piling is allowed if on a slash mat. Primary prescriptions are seed-tree, intermediate, shelterwood, or sanitation salvage. Soil moisture level must be less than 18 percent for harvest to proceed using ground-disturbing methods. Higher soil moistures have been allowed in some cases with forwarders operating on slash mats.

Monitoring Methods: Two levels are practiced. "Intensive" monitoring uses *step transects (one to four per cutting unit)* depending on size and shape of the harvest unit. Each step represents a monitoring point. Transects are placed in a systematic manner, on the contour, to most efficiently monitor the direction of activity in the cutting unit. All disturbance modes (compaction, displacement, erosion, burning, and puddling.) are evaluated. A general observation is also made of the organics. Soil clods for bulk density were used to calibrate field methods. *"Walk through"* monitoring uses the same transect method, but uses a random walk through the unit to evaluate disturbance levels while using a spade system (calibrated to compaction tests). This method is also used to determine if a more detailed look is needed for the unit. Soil monitoring results are in databases used for planning and monitoring. These are linked to spatial data. The soil scientist has been formally monitoring sales since 1985 and informally since 1977.

Monitoring Frequency: There were 15 sales monitored last year for a total of 30 cutting units. A total of 75 sales have been monitored, with a total of 150 cutting units. A total of 355 transects have been completed with over 80,000 transect points. The total area involved in the monitoring units is about seven percent of the total harvest area. Additional monitoring may be completed if new equipment is used or on request by resource specialists or managers.

Recent Results: All sales last year were within standards. In the last five years no units have been over fifteen percent and of 88 monitored units and only one has been over ten percent. The main disturbance mode has been soil compaction. Ninety-five percent of sales were in areas not previously harvested.

Trends: The trend is definitely downward. With more operations involving forwarders and excavators, being more cognitive of operating on an organic mat, doing winter operations, etc., the soil resource is definitely benefiting. Winter logging is increasingly used. Soil disturbance is also gradually lessening as operators and administrators become familiar with these methods.

Emerging Issues: Retention of organic materials is becoming an important issue. Too little downed woody debris is currently being left on some sites. Cumulative effects are important, especially as harvest begins to occur on previously cut sites.

Forest: FLATHEAD NATIONAL FOREST

Ecological Characteristics: Production of wood is 60 to 100 cft. per year. Last year sales were about 20 million board feet. Soils are developed in five to seven inches of volcanic ash over a variety of substrates. There are many areas where ash is mixed with substrate material. The volcanic ash is critical for production. All soils are compactible.

Timber Activities (including Harvest, Fuel Abatement, and Site Preparation): About 50 percent of lands are tractor ground. Upper slope limit on ground-based systems is 45 percent. Feller-bunchers or forwarders are used, but only some machines have the processers to trim slash. Feller-bunchers seldom operate on a "slash mat." Tractor or rubber-tired skidder (RTS) skidding uses 60 to 75 ft. spaced skid trails with minimal activity allowed off trails. Piles are generally next to skid roads. Excavators are used for piling and site preparation. These systems have been shown to cause little soil disturbance. Timber is accessed by directional fell methods. Broadcast burn is often used for site preparation. Primary prescriptions are seed-tree or shelterwood. Soil moisture level must be less than 18 percent for harvest to proceed using ground-disturbing methods. Allowed soil moisture may be higher using excavators.

Monitoring Methods: Three levels are practiced. "Intensive" monitoring uses *100 ft., randomly-placed transects (seven to ten)*, to represent the cutting unit, evaluating all disturbance modes (compaction, displacement, erosion, burning, and puddling.) *"Zig-zag-toe count"* monitoring uses the same transect method, but using a randomly oriented, continuous transect through the unit and using a spade system (calibrated to compaction tests.) A binary system of classification is used for this method. *"Walk through"* is a random look at the unit to determine if further transecting is warranted. Soil monitoring results are in databases used for planning and monitoring. The soil scientist has been formally monitoring sales since 1983 and informally since 1977.

Monitoring Frequency: There were two sales last year, and both were monitored with a total of 15 cutting units. A total of 30 sales have been monitored. Candidate units are selected using "sensitive" landtypes during the planning process. Additional monitoring may be completed if new equipment is used or on request by resource specialists or managers.

Recent Results: Compaction is the primary disturbance mode. Sales using feller-bunchers without processers (on no slash mat) sometimes exceed soil protection standards. Other sales fall within standards.

Trends: Trends are towards lower levels of soil disturbance. Use of forwarders and excavators, winter logging, and designated skid trail is partially responsible for this trend. Harvest levels are decreasing to the point where monitoring can occur on nearly all sales.

Emerging Issues: Retention of organic materials (fine organic material and large woody debris) is becoming an important issue, especially in broadcast burned areas. Use of excavators has increased residual organic material left. Cumulative effects will soon become important as harvest begins to occur on previously cut sites.

Forest: <u>BITTERROOT NATIONAL FOREST</u>

Ecological Characteristics: Production of wood 20 to 80 cft. per year. Last year sales were about 5 million board feet. Roughly fifty percent of the soils have 5 to 7 inches of volcanic ash surface, in some areas this ash layer is mixed with the substrate. The volcanic ash is critical for production. All soils are compactible. Most present projects are in dry ponderosa pine or Douglas-fir community types.

Timber Activities (including Harvest, Fuel Abatement, and Site Preparation): About 15 percent of lands are appropriate for tractor-based systems. Slope limits on ground-based systems are 35 percent. Feller-bunchers are used, with few machines having the processors to trim slash. Feller-bunchers seldom operate on a "slash mat." Tractor or rubber-tired skidder (RTS) skidding uses 100 ft. spacing of skid trails with minimal activity allowed off trails. Timber is accessed by directional fell methods. Underburning is often used for site preparation. Whole tree yarding is common. Primary prescriptions are partial cuts or improvement cuts.

Monitoring Methods: "Intensive" monitoring uses systematic <u>*"pace transects" (two to three per unit)*</u> along contours. Monitored disturbance modes are compaction, displacement, erosion, burning, and puddling. Coring for bulk density was used for calibration of field methods, and infiltration tests are completed on most units. About 80 percent of monitoring is in previously-cut units. Soil monitoring results are in documents used for planning and monitoring. The soil scientist has been formally monitoring sales since 1991.

Monitoring Frequency: Including pre-project monitoring, and an average of three sales a year for the past three years, 30 cutting units have been monitored each year. All proposed units are monitored for pre-project activities. For post-project activities, monitoring is primarily initiated by District resource specialists or managers.

Recent Results: For pre- and post- activities, over 50 percent substantially exceed standards. Compaction is the primary disturbance mode for pre-project monitoring. Displacement is a problem for post-project units on slopes greater than 30 percent. Sales using feller-bunchers without processers (on no slash mat) sometimes exceed soil protection standards. Other sales fall within standards.

Trends: Trends are towards lower levels of soil disturbance. The Forest has recently made large changes in planning and implementation of projects to attempt to remedy the situation.

Emerging Issues: Retention of organic materials (fine organic material and large woody debris) is becoming an important issue. Watershed-level cumulative effects from previous logging activities are now being considered in forest planning. Monitoring indicates winter logging on this forest does not always protect soils, and future monitoring will emphasize this method.

Forest: GALLATIN NATIONAL FOREST

Ecological Characteristics: Production of wood is 20 to 65 cft. per year. Last year sales were less than 2 million board feet. Soils are developed a variety of substrates with no volcanic ash. All soils are compactible with the exception of extremely gravelly soils developed in glacial till derived from coarse-crystalline rocks.

Timber Activities (including Harvest, Fuel Abatement, and Site Preparation): About 30 percent of available lands are tractor ground. The upper slope limit on tractor skidding is 35 percent. Sawyers are still used for harvest, but the trend is towards feller-bunchers. Tractor or rubber-tired skidder (RTS) skidding use 75 ft. spaced skid trails with NO activity allowed off trails. Timber is accessed by directional fell and cable pull methods. Site preparation is by tractor. Primary prescriptions are clear-cuts.

Monitoring Methods: "Intensive" monitoring uses *100 ft., randomly placed transects (12 to 16)* to represent the cutting unit, evaluating all disturbance modes (compaction, displacement, erosion, burning, and puddling.) Sand-cone bulk density methods are used to calibrate field methods. Soil monitoring results are placed in documents used for planning and monitoring. *"Walk through"* monitoring is a random walk through the cutting unit, measuring soil disturbance to determine if further sampling is warranted. The soil scientist has been formally monitoring sales since 1994.

Monitoring Frequency: There were two sales last year, and each was monitored with a total of four cutting units. A total of seven sales have been monitored, with a total of 18 cutting units.

Recent Results: In 1994 and 1995 soil disturbance monitoring showed excessive disturbance, well over soil protection guidelines. The Forest made changes in tractor harvest methods to meet guidelines. There was not enough sale activity to warrant monitoring until 1999 when two sales were monitored. The first sale monitored in 1999 met standards. It was winter-logged and soil guidelines were followed. The latter sale did follow soil protection guidelines. Slope and skid trail guidelines were not followed in the sale planning process. The Timber Sale Administrator initiated mitigative measures.

Trends: The Forest has made changes in the planning process to reduce soil disturbance. However, not enough sales have occurred to evaluate effectiveness of these methods.

Emerging Issues: Future sales should be planned and executed to meet soil protection guidelines. Retention of organic materials will become an important issue. Cumulative effects will eventually become important as harvest begins to occur on previously cut sites, particularly in shelterwood prescriptions.

GENERAL COMMENTS

Forests with lower volumes and less productive soils continue to show high levels of soil damage, though those Forests have recently made steps in improvement.

Protection of the soil appears to be dependent on two factors. The first is physical protection by operating only on 4 to 8 inch slash mats, made up of branches, tops, and small logs, or over snow (with some exceptions.) Even high-impact equipment may do little soil damage.

The second factor is the equipment type and its use. The use of forwarders and harvesters (having slash production capabilities), excavators for site preparation, and cable skidding result in improvement in productivity protection. Methods using tractors often increase soil damage. Dozer piling methods contribute to this damage. Dispersed skidding methods generally cause unacceptable soil damage. Designating skid trails with no or minimal activity allowed off trail reduces impacts. The trend towards less intensive site preparation also contributes to this.

Control of operations is an important part of all harvest activities, and is a secondary objective in all soil monitoring projects.

APPENDIX B

SOIL CONDITION RATING GUIDE

		Condition Category	
Soil Parameter	Indicator	Satisfactory	Detrimental
Compaction	Surface Structure	Unchanged from natural	Platy or Massive
	Rupture Resistance	Loose, friable, slightly hard	Very hard, very rigid, extremely Firm

	Bulk Density	No increase over Natural	Greater than 15% increase
	Infiltration	No decrease	Greater than 50% Decrease
Rutting	Wheel Ruts (2” deep or more)	None	Observed
Displacement	Surface Soil Removal	None to small areas	Greater than 100 square feet
Burned Soil	Oxidation	Charred duff	reddish soil (oxidized)
	Hydrophobicity	none to slight	common or continuous
Erosion	Rills, Gullies	Absent	Well defined, Active, and continuous
	Pedestals	None	Pedestals are Common and Shallow roots Are exposed
	Deposition	None	Deposits are common
Mass Movement	Slumps or Debris flows	None	Observed

End of Soil Monitoring Report – Kuennon