Section 11. Soil Measurements and Sampling

11.0 INTRODUCTION

The objective of the Phase 3 (P3) Soils Indicator is to assess forest ecosystem health in terms of the physical and chemical properties of the soils. The soil resource is a primary component of all terrestrial ecosystems, and any environmental stressor that alters the natural function of the soil has the potential to influence the vitality, species composition, and hydrology of forest ecosystems.

Specifically, soils data are collected on P3 plots to assess (Santiago Declaration 1995):

- the potential for erosion of nutrient-rich top soils and forest floors.
- factors relating to the storage and cycling of nutrients and water.
- the availability of nutrients and water to plants (dependent upon soil structure and texture).
- carbon sequestration (the amount of carbon tied up in soil organic matter).
- deposition of toxic metals from pollution.
- acidification of the soil from deposition of pollutants.

Chemical properties of the soil are analyzed in order to develop indices for plant nutrient status, soil organic matter, and acidification. Together, these three factors largely determine the fertility and potential productivity of forest stands. Soil nutrient status refers to the concentration of plant nutrients (e.g., potassium, calcium, magnesium, and sodium) and is a key indicator of site fertility and species composition. The amount of organic matter in the soil largely determines water retention, carbon storage, and the composition of soil biota. Loss of soil organic matter as a result of management practices can alter the vitality of forest ecosystems through diminished regeneration capacity of trees, lower growth rates, and changes in species composition. Finally, increased soil acidity resulting from deposition of atmospheric pollutants has the capacity to reduce nutrient availability, decrease rates of decomposition, promote the release of toxic elements into the soil solution (e.g., aluminum), and alter patterns and rates of microbial transformations.

Nutrient and water availability to forest vegetation is also dependent on the physical capacity of roots to grow and access nutrients, water, and oxygen from the soil. In addition to playing an important role in plant nutrition, the physical properties of the soil largely determine forest hydrology, particularly with regards to surface and ground water flow. Human activities that result in the destruction of soil aggregates, loss of pore space (compaction), and erosion may increase rates of surface runoff and alter historic patterns of stream flow. In some areas, these changes may result in flooding and/or dewatered streams and can reflect on both the health of aquatic ecosystems and the management and conservation of associated forest and agricultural areas.

11.1 SUMMARY OF METHOD

The soil measurement and sampling procedures are divided into three parts: soil erosion, soil compaction, and soil chemistry. Data collection for soil erosion assessment consists of estimating the percent of bare soil in each subplot. These measurements are combined with data from other sources and used to parameterize established models for erosion potential (RUSLE, WEPP). Soil compaction measurements consist of an estimate of the percentage of soil compaction on each subplot along with a description of the type of compaction. Data are recorded using a handheld computer (PDR) with a preloaded data input program.

The chemical and physical properties of the soil are assessed through the collection of soil samples, which are then submitted to a regional laboratory for analysis. Soil samples are collected from the forest floor (subplots 2, 3, and 4) and underlying mineral soil layers (subplot 2). The entire forest floor layer is sampled from a known area after measuring the thickness of the duff (humus) and litter layers at four locations in a sampling frame of known area. Once the forest floor has been removed, mineral and organic soils are sampled volumetrically by collecting cores from two depths: 0 to 10 cm (0-4 inches) and 10 to 20 cm (4-8 inches). The texture of each layer is estimated in the field and characterized as organic, loamy, clayey, sandy, or coarse sandy. Following soil sampling, the depth to any restrictive horizon within the top 50 cm (20 in) is estimated using a soil probe. In the case of organic soils (e.g., wetland soils), samples are collected from the litter layer and the 0 -10 cm and 10-20 cm organic layers.

Physical and chemical properties of the soil are determined in the laboratory. Analyses of forest floor samples include bulk density, water content, total carbon, and total nitrogen. Analyses of mineral soil samples include bulk density, water content, coarse fragment content, total organic and inorganic carbon, total nitrogen, plant available (extractable) phosphorus and sulfur, exchangeable cations (calcium, magnesium, sodium, potassium, and aluminum), pH, and trace metals such as manganese. These data are used to provide indexes of nutrient status, acidification, and carbon sequestration.

11.2 SOIL EROSION

Erosion is defined as the wearing away of the land surface by running water, wind, or ice. Erosion is a natural process that occurs on all non-flat areas of the landscape. However, human activity (such as timber removal or road-building) can result in accelerated rates of erosion that degrade the soil and reduce the productivity of land. Extensive areas of soil erosion can have a major effect on the aquatic ecosystems associated with forests, recreational opportunities, potable water supplies and the life span of river infrastructure (e.g., dams, levees).

On average, the U. S. loses about 5 billion tons of soil annually to water and wind erosion. As this soil is removed from the landscape, it carries with it all of the nutrients and organic matter that took decades to centuries (or longer) to build-up. On human time scales, fertile topsoil is not a renewable resource.

11.2.1 Definitions

Cryptobiotic crusts	A layer of symbiotic lichens and algae on the soil surface (common in arid regions)
Duff (Humus)	A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) can no longer be identified.
Forest floor	The entire thickness of organic material overlying the mineral soil, consisting of the litter and the duff (humus).
Litter	Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.)
Soil erosion	The wearing away of the land surface by running water, wind, ice or other geological agents.

11.2.2 Overview of Method

On FIA plots, soil erosion potential is estimated using published models, such as the Revised Universal Soil Loss Equation (RUSLE) and the Water Erosion Prediction Project (WEPP). These models are based on factors that represent how climate, soil, topography, and land use affect soil erosion and surface runoff. Generally, these models require the following factors for analysis: percent slope, slope length, precipitation factor, vegetation cover, and litter cover. Some of these factors are collected as part of the P2 mensuration data and other P3 indicators (percent slope and vegetation cover), one factor is obtained from outside sources (precipitation factor), and the remaining factors (% cover, which is given by 100 - % bare soil, and soil texture) are measured on each subplot as part of the soil indicator.

Estimates of bare soil are made on all four subplots. Soil texture is measured at the soil sampling site adjacent to subplot 2 during the collection of mineral and organic soil samples.

11.2.4 Data Reference Information

The following data screen is used to collect erosion data on each forested Phase 3 subplot: (Figure 11-1)

```
POINT  1 Erosion Data
%Soil  .. %Compc ..
```

Figure 11-1. PDR screen for soil erosion and compaction measurements.

11.2.4.1 PERCENT COVER OF BARE SOIL (**%Soil**)

Record a two-digit code indicating the percentage of the subplot that is covered by bare soil (mineral or organic). Fine gravel (2-5 mm) should be considered part of the bare soil. However, do not include large rocks protruding through the soil (e.g., bedrock outcrops) in this category since these are not erodible surfaces. For the purposes of the soil indicator, cryptobiotic crusts are not considered bare soil.

If the subplot includes non-forested areas, multiply the % Soil in the forested part of the subplot by the % of the subplot that is in forested area. For example, if 50% of the subplot is forested and the ground vegetation cover of the forested part is 30%, then the % Soil for the entire subplot is 15 %.

When Collected: All forested subplots
Field Width: 2-digits
Tolerance: Within 10%
MQO: 75% of the time
Values:

00	Absent	35	31-35%	75	71-75%
01	Trace	40	36-40%	80	76-80%
05	1 to 5%	45	41-45%	85	81-85%
10	6-10%	50	46-50%	90	86-90%
15	11-15%	55	51-55%	95	91-95%
20	16-20%	60	56-60%	99	96-100%
25	21-25%	65	61-65%		
30	26-30%	70	66-70%		

Reporting Unit:

11.3 SOIL COMPACTION

Compaction refers to a reduction in soil pore space and can be caused by heavy equipment or by repeated passes of light equipment that compress the soil and break down soil aggregates. This compression increases the bulk density and reduces the ability of air and water to move through the soil. These conditions also make it more difficult for plant roots to penetrate the soil and obtain necessary nutrients, oxygen, and water.

In general, compaction tends to be a greater problem on moist soils and on fine-textured soils (clays). These effects can persist for long periods of time and may result in stunted tree growth.

11.3.1 Overview

Information about compaction is collected on all subplots that are in a forested condition. Compaction data collected as part of the soil indicator include an estimate of the percent of each subplot affected by compaction and the type(s) of compaction present.

11.3.3 Data Reference Information

Information about compaction on the subplot is recorded on the erosion screen of the PDR. When a non-zero value is entered for the amount of compaction on the subplot, a pop-up screen appears requesting additional information regarding the type of compaction (Figure 11-2).

```
POINT  1 Erosion Data
%Soil  .... %Compc 01. TyRutTr . TyComTr . TyComAr .
TyOther .
```

Figure 11-2. PDR screen for soil erosion and compaction measurements when a non-zero value is entered for %Compc (percentage of subplot compacted).

11.3.3.1 % COMPACTED AREA ON THE SUBPLOT **(%Compc)**

Record a two-digit code indicating the percentage of the subplot that exhibits evidence of compaction. Soil compaction is assessed relative to the conditions of adjacent undisturbed soil. Do not include improved roads in your evaluation.

When Collected: All forested subplots
Field Width: 2-digits
Tolerance: Within 15%
MQO: 75% of the time
Values:

00	Absent	35	31-35%	75	71-75%
01	Trace	40	36-40%	80	76-80%
05	1 to 5%	45	41-45%	85	81-85%
10	6-10%	50	46-50%	90	86-90%
15	11-15%	55	51-55%	95	91-95%
20	16-20%	60	56-60%	99	96-100%
25	21-25%	65	61-65%		
30	26-30%	70	66-70%		

Reporting Unit:

11.3.3.2 TYPES OF COMPACTION (TyRutTr, TyComTr, TyComAr, TyOther)

Record the types of compaction encountered on the subplot. For each of the following compaction types, record a “1” if the type is present, record a “0” if it is not.

TyRutTr: Type of compaction is a rutted trail. Ruts must be at least 2 inches (5 cm) deep into mineral soil or 6 inches (15 cm) deep from the undisturbed forest litter surface.

TyComTr: Type of compaction is a compacted trail (usually the result of many passes of heavy machinery or vehicles).

TyComAr: Type of compaction is a compacted area. Examples include the junction areas of skid trails, landing areas, work areas, etc.

TyOther: Type of compaction is some other form. (An explanation must be entered in the plot notes).

When Collected: All forested subplots
Field Width: 1-digit
Tolerance: 75% correct
MQO:
Values: 1 (present) or 0 (not present)

11.4 SOIL SAMPLE COLLECTION

The chemical and physical properties of the soil are assessed through the collection of soil samples, which are then submitted to a regional laboratory for analysis. Soil samples are collected from the forest floor (subplots 2, 3, and 4) and underlying mineral soil layers (subplot 2). The entire forest floor layer is sampled from a known area after measuring the thickness at the north, south, east, and west edges of a sampling frame of known area. Once the forest floor has been removed, mineral and organic soils are sampled volumetrically by collecting cores from two depths: 0 to 10 cm and 10 to 20 cm. The texture of each layer is estimated in the field and characterized as organic, loamy, clayey, sandy, or coarse sandy. Following soil sampling, the depth to any restrictive horizon within the top 20 in is estimated using a soil probe. In the case of organic soils, samples are collected from the litter layer and the 0 to 10 cm and 10 to 20 cm organic layers.

11.4.1 Definitions

Duff (Humus): A soil layer dominated by organic material derived from the decomposition of plant and animal litter and deposited on either an organic or a mineral surface. This layer is distinguished from the litter layer in that the original organic material has undergone sufficient decomposition that the source of this material (e.g., individual plant parts) can no longer be identified.

Forest floor: The uppermost layer of the soil, consisting of both the litter and duff (humus).

Litter	Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.)
Loam	The textural class name for a soil having a moderate amount of sand, silt, and clay.
Mineral soil	A soil consisting predominantly of products derived from the weathering of rocks (e.g., sands, silts, and clays).
Organic soil	For the purposes of FIA, an organic soil is defined as any soil in which the organic horizon is greater than 8 inches (20 cm) in thickness. These soils are prevalent in wetland areas such as bogs and marshes and may be frequently encountered in certain regions of the country (e.g., Maine, northern Minnesota, coastal regions)
Restrictive layer	Any soil condition which increases soil density to the extent that it may limit root growth. This limitation may be physical (hard rock) or chemical (acid layer) or both.
Sampling frame	A frame used to collect forest floor samples from a known area. A bicycle tire 12 inches in diameter has been selected as the national standard.
Texture	The relative proportion of sand, silt, and clay in a soil.

11.4.2 Location of Soil Sampling Sites

Soil samples are collected within the annular plot along soil sampling lines adjacent to subplots 2, 3, and 4 (Fig. 11-3). During the first visit to a plot for soil sampling, soil samples will be collected at the point denoted as Soil Visit #1. On subsequent visits to a plot, soil sampling sites visit #2 or larger will be sampled. The soil sampling sites are spaced at 10 ft intervals alternating on opposite sides of soil sampling site number 1.

The initial sampling points (Soil Visit #1) are located:

- Subplot 2 soil measurement site: 30 ft due south (180^o) from the center of subplot 2.
- Subplot 3 soil measurement site: 30 ft northwest (300^o) from the center of subplot 3.
- Subplot 4 soil measurement site: 30 ft northeast (60^o) from the center of subplot 4.

If the soil cannot be sampled at the designated sampling point due to trampling or an obstruction (e.g., boulder, tree, standing water), the sampling point may be relocated to any location within a radius of 5 ft.

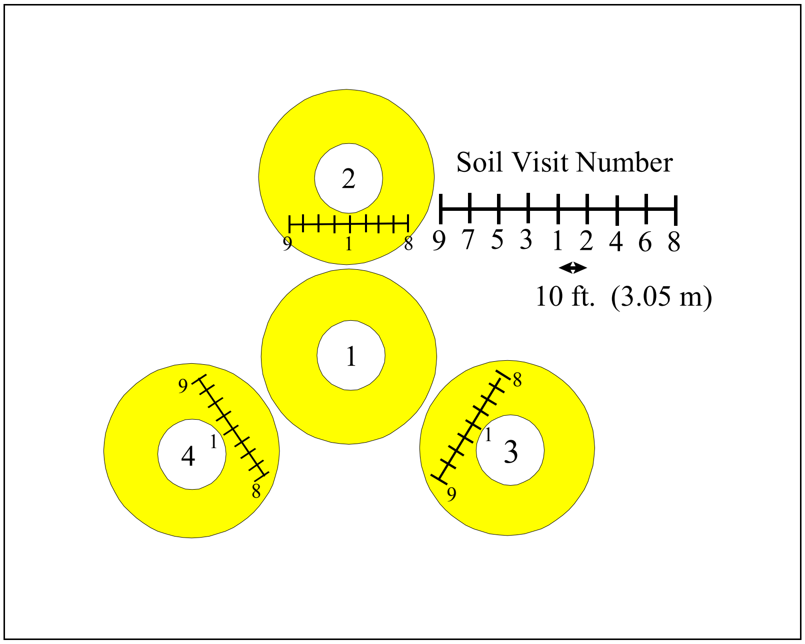

Figure 11-3. Location of soil sampling sites

11.4.3 Procedure

Forest Floor

Forest floor samples are collected from soil sampling sites adjacent to subplots 2, 3, and 4. Samples are collected if, and only if, the soil sampling sites are forested. The forest floor is sampled as a complete unit using a sampling frame.

1. Place the sampling frame over the sampling point taking care not to compact the litter layer. Locate the points due north, due east, due south and due west on the inside of the soil sampling frame and mark these with small vinyl stake flags. Carefully remove the sampling frame.

2. Measure the thickness of the entire forest floor to the nearest centimeter at the four flagged locations. At each sampling point, also measure the thickness of the litter layer.

3. Replace the soil sampling frame. Using a pair of clippers, carefully remove all live vegetation from the sample area. Living mosses should be clipped at the base of the green, photosynthetic material.

4. Using a sharp knife or a pair of clippers, carefully cut through the forest floor along the inner surface of the frame to separate it from the surrounding soil.

5. Using inward scooping motions, carefully remove the entire volume of the forest floor from within the confines of the sampling frame. Discard all woody debris (including pine cones, large pieces of bark, and decomposed wood) above ¼" in diameter (approximately the diameter of a pencil). Discard any rocks or pebbles collected with the forest floor material.

6. Working over the tarp, place the entire forest floor layer sample into a pre-labeled gallon

sample bag. In some areas more than one bag might be required to hold the sample. If so, label the bags with identical information, then add "1 of 2" and "2 of 2" respectively.

Mineral Soil

Two mineral soil samples 0 - 10 cm and 10-20 cm (0-4 in and 4-8 in) are collected from the soil sampling site adjacent to **subplot 2 only**, and are collected if, and only if, the soil sampling site is forested.

1. Mineral soil samples are collected from within the area of the sampling frame after the forest floor has been removed.

2. Place the core sampler in a vertical position and drive the sampler into the soil until the top of the coring head is about 1 in above the mineral soil surface. At this point, the soil should be even with the top of the liner.

3. With the handle of the slide hammer down, rotate the sampler in a circular motion. This motion breaks the soil loose at the bottom of the sampler and makes it easier to remove the core. Do not extend the sliding part of the slide hammer upwards to gain additional leverage as this may bend the attachment. Remove the core sampler from the ground by pulling the slide hammer upwards in a smooth vertical motion.

4. If a complete and intact core has been collected, unscrew the coring head from the top cap and carefully slide the core liners onto the tarp (see section 11.4. for techniques used in handling problem soils). If necessary, use the crescent and slip wrenches to separate the parts. Trim the top and bottom of the core even with the liner rims. Take care to avoid any loss of soil from the cores; if any material spills, you must resample.

5. Using a knife, slice through the soil core at the interface between the two liners (the 10-cm depth). Remove the soil from the 0-10 cm stainless steel liner and place it into a pre-labeled soil sample bag. Repeat for the 10-20 cm core. Be sure to place all of the material in the liner (including coarse fragments, roots, soil, etc.) into the sample bags.

6. For each plot, you should have a maximum of five samples:

   - Three labeled gallon bags containing the forest floor samples from the sampling sites adjacent to subplots 2, 3, and 4.
   - One labeled quart bag containing the 0 - 10 cm mineral soil sample from the soil sampling site adjacent to subplot 2.
   - One labeled quart bag containing the 10 - 20 cm mineral soil sample from the soil sampling site adjacent to subplot 2.

7. Clean all soil sampling equipment thoroughly before sampling soil at the next plot.

Organic soils

For the purposes of this program, an organic soil is defined as any soil in which the organic horizon is greater than 20 cm (8 inches) in thickness. These soils are prevalent in certain regions of the country (e.g., Maine, northern Minnesota, coastal regions) and proper sampling requires modification of the above procedures.

- Due to the large thickness of the underlying organic soil, sampling is restricted to the litter layer. Measure the entire thickness of the of the forest floor to a maximum depth of 50 cm. However, only collect a sample of the litter layer (as described above).

- Attempt to collect a soil sample using the impact driven corer. In many cases, this will not be possible without severe compaction of the sample. If compaction occurs, or if you have difficulty in obtaining a complete core, samples may be collected at the 0 - 10 cm and 10 - 20 cm depth increments using a Dutch auger or shovel (see section 11.4.8).

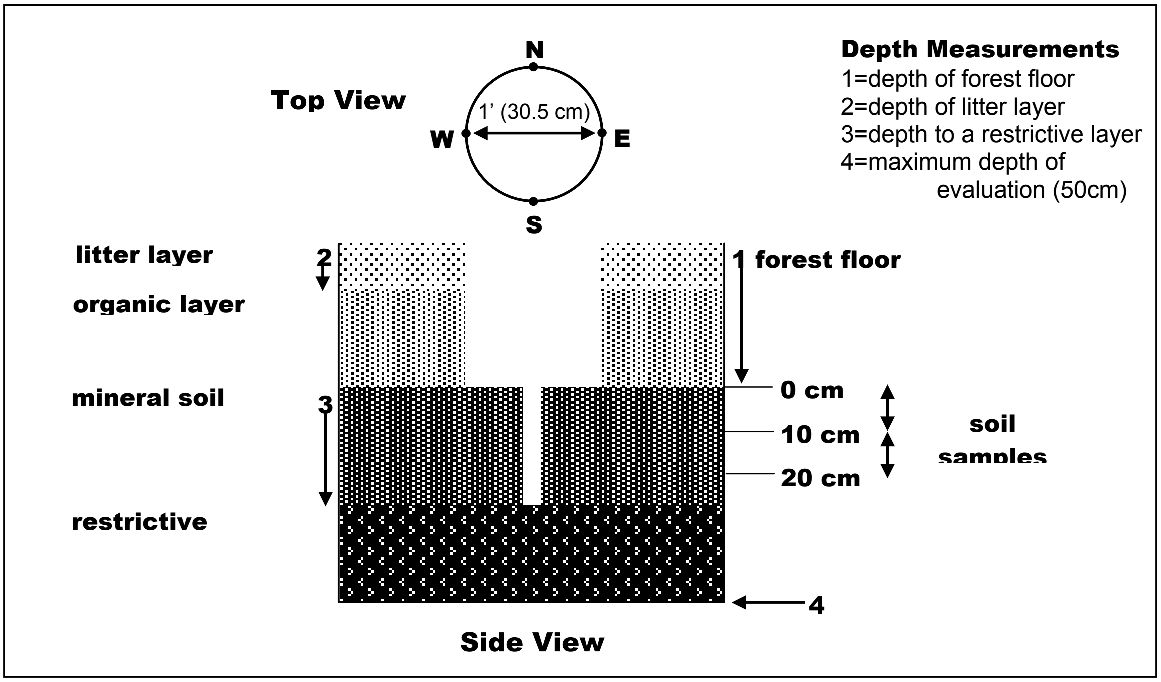

Figure 11-4: Cross-sectional views of sampling sites (top view and side view).

11.4.4 Data Reference Information

```
LINE  1 Soils
Sampled? 1 SampLoc 1 CndCls  .
Visit#  1 FflThkN .. LitTnkN ..
FflThkE .. LitTnkE .. FflThkS ..
LitTnkS .. FflThkW .. LitTnkW ..
DepSub .. Texture1 . Texture2 .
```

Figure 11-5 PDR screen for soil sampling site.

11.4.4.1 WAS SAMPLE COLLECTED (**Sampled?**)

Record whether or not a forest floor or mineral soil sample was collected at the soil sampling location. For both forest floor and mineral samples, it is the condition of the soil sampling sites in the annular plot that determines whether soil samples are collected. Samples are collected if, and only if, the soil sampling site in the annular plot is in a forested condition (regardless of the condition class of the subplot).

For example, in cases where the subplot is forested and the soil sampling site is not, soil samples **are not** collected. Similarly, in cases where the soil sampling site is forested and the subplot is not, soil samples **are** collected.

When Collected: Subplots 2, 3, and 4
Field Width: 1-digit
Tolerance: No errors
MQO: At least 99% of the time
Values:

1 Sampled
2 Not sampled: non-forest

The following are for forest conditions:

3 Not sampled: too rocky to sample
4 Not sampled: water or boggy
5 Not sampled: access denied
6 Not sampled: too dangerous to sample
7 Not sampled: obstruction in sampling area
8 Not sampled: broken or lost equipment
9 Not sampled: other - enter reason in plot notes

Reporting Unit:

11.4.4.2 SAMPLE LOCATION (**SampLoc**)

Record the number of the subplot adjacent to the soil sampling site.

When Collected: Subplots 2, 3, and 4 (where the soil sampling site is in a forested condition)
Field Width: 1-digit
Tolerance: No errors
MQO: At least 99% of the time
Values: 2, 3, or 4

11.4.4.3 CONDITION CLASS (**CndCls**)

Record the condition class for the soil sampling site on the PDR. If the condition class for the soil sample is different from any recorded on the 4 subplots, enter "0".

When Collected: All forested subplots
Field Width: 1-digit
Tolerance: No errors
MQO: At least 95% of the time
Values:

11.4.4.4 VISIT # (**Visit #**)

Record the number of the soil sampling location (Figure 11-3) at which the soil sample was collected.

When Collected: Subplots 2, 3, and 4 (where the soil sampling site is in a forested condition)

Field Width: 1 or 2 digits
Tolerance: No errors
MQO: At least 99% of the time
Values: 1 to 10

11.4.4.5 FOREST FLOOR THICKNESS (FflThkN, FflThkE, FflThkW, FflThkS)

Record the thickness (to the nearest centimeter) of the forest floor measured from the top of the litter layer to the boundary between the forest floor and mineral soil. If the depth is exactly half way between cm readings, round the reading down if it is an even number and round up if it is an odd number. For example, a depth of 2.5 cm should be entered as 2 cm and a depth of 3.5 cm should be entered as 4 cm.

Measure to a maximum depth of 50 cm. If the thickness of the forest floor is greater than 50 cm, then code "50." For locations where bare soil or bedrock material is exposed, enter "0" cm depth. On organic soils, measure the entire thickness of the forest floor (to 50 cm) even though you will only sample the litter layer.

When Collected: Soil sampling sites adjacent to subplots 2, 3, and 4 that are in a forested condition.
Field Width: 2-digits
Tolerance: Within 5 cm
MQO: 90% of the time
Values: 00 to 99
Reporting Unit: 1 cm

11.4.4.6 THICKNESS OF THE LITTER LAYER (**LitThkN, LitThkE, LitThkW, LitThkS**)

Record the thickness of the litter layer (to the nearest cm) at each of the four locations within the sampling frame. The bottom of the litter layer can be distinguished as the boundary where plant parts (such as leaves or needles) are no longer recognizable as such because of decomposition. Another criterion is that the organic layer may contain plant roots, but the litter layer will probably not. At some locations, the depth of the forest floor and the litter layer may be the same. For locations where bare soil or bedrock material is exposed, enter "0" cm depth.

When Collected: Soil sampling sites adjacent to subplots 2, 3, and 4 that are in a forested condition.
Field Width: 2-digits
Tolerance: Within 5 cm
MQO: 90% of the time
Values: 00 to 99
Reporting Unit: 1 cm

11.4.4.7 DEPTH TO RESTRICTIVE HORIZON (**DepSub**)

Insert the tile probe into five locations within the soil sampling area (center, north, east, south and west edges) and push it into the soil to identify if a restrictive horizon exists. Record the median depth to a restrictive layer. The maximum depth for testing for a restrictive horizon is 50 cm (20 in). If a restrictive layer is encountered within the 50 cm, record the median depth (cm) to the restrictive horizon of the five locations probed. If a restrictive horizon is not encountered, record "50" on the PDR.

Code "00" if superficial bedrock is present.
Enter "99" if too many rock fragments or cobbles prevent inserting soil probe.

When Collected: All forested subplots
Field Width: 2-digits
Tolerance: Within 15 cm
MQO: 90% of the time
Values:
Measurement Unit: 1 cm

11.4.4.8 SOIL TEXTURE IN THE 0-10 CM LAYER (**Texture 1**)

Record the code for the soil texture of the 0-10 cm layer. To estimate texture in the field, collect a sample of the soil from the appropriate horizon and moisten it with water to the consistency of modeling clay/wet newspaper; the sample should be wet enough that all of the particles are saturated but excess water does not freely flow from the sample when squeezed. Attempt to roll the sample into a ball. If the soil will not stay in a ball and has a grainy texture, the texture is either sandy or coarse sandy. If the soil does form a ball, squeeze the sample between your fingers and attempt to form a self-supporting ribbon. Samples which form both a ball and a ribbon should be coded as clayey; samples which form a ball but not a ribbon should be coded as loamy.

When Collected: Soil sampling sites adjacent to subplot 2 that are in a forested condition
Field Width: 1-digit
Tolerance: Within 1 class
MQO: 80% of the time
Values:

0	Organic
1	Loamy
2	Clayey
3	Sandy
4	Coarse Sand

Reporting Unit: 4 classes

11.4.4.9 SOIL TEXTURE IN THE 10-20 CM LAYER (**Texture 2**)

Record the code for the soil texture of the 10-20 cm layer (see the directions for Texture 1).

When Collected: Soil sampling sites adjacent to subplot 2 that are in a forested condition
Field Width: 1-digit
Tolerance: Within 1 class
MQO: 80% of the time
Values:

0	Organic
1	Loamy
2	Clayey
3	Sandy
4	Coarse Sand

Reporting Unit: 4 classes

11.4.5 Tips for Telling the Difference between Mineral and Organic Soil Horizons

In some soils, telling the difference between the bottom of the O-Horizon and the top of an A-horizon (organic-rich mineral horizon) can be difficult. If uncertain:

- Look for evidence of plant parts (e.g., leaves, needles). If you can see them decomposing in place, you're still in organic.
- Rub the soil between your finger. Does it crumble (organic) or feel more like modeling clay (try pinching into a ribbon).
- Look for shiny flecks of mica or quartz (won't help in all soils).
- Look for a subtle change in color. Organic horizons tend to be black; an A-horizon may be more brownish.
- Wet a sample of the material and press it between your fingers. Note the color of the liquid that runs out. The blacker the color, the higher the organic content.
- Check for a change in density (mineral soils are denser).

11.4.6 Assembly and Operation of Impact Driven Soil Corer (Bulk Density Sampler)

The impact driven core sampler is used to collect a known volume of soil with a minimum of compaction and disturbance. The weight of this core is then used to determine bulk density (the mass of soil per unit volume), an important physical property of the soil. Although we usually think about the soil in terms of the mineral fraction, soils are actually a matrix of solids (mineral and organic), water, and air. The ratio between these fractions (pore space) determines the capacity of the soil to provide nutrients, air, and water to plant roots. In addition, bulk density is used to convert the chemical concentrations obtained in the lab to a volumetric basis, which is more meaningful in terms of plant nutrition.

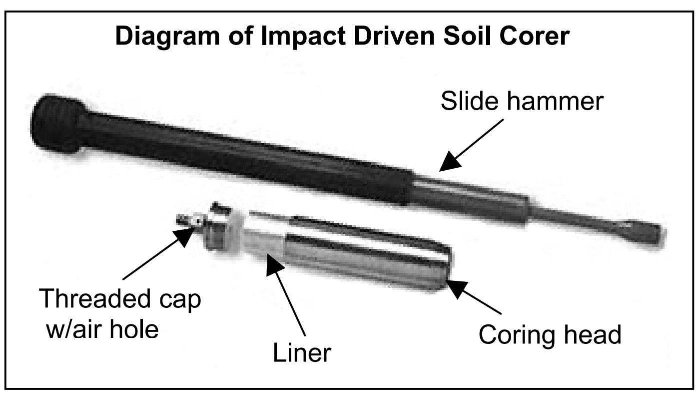

Figure 11.6: Diagram of Impact Driven Soil Corer

Assembly

- Thread the top cap of the soil coring head onto the slide hammer attachment and tighten. This connection must be tight; if not, this connection may be sheared off during use.

- Insert two 2-in diameter x 4-in long stainless steel soil core liners into the soil coring head. It may be helpful to number the core liners with an indelible marker in order to tell them apart after the sample has been collected.

- Thread the soil coring head onto the top cap and slide hammer attachment until the top rim of the coring head just contacts the top cap. Make sure that the vent hole in the top cap is kept open, so that air displaced while the coring head is driven into the soil can escape from inside the coring head.

Maintenance

- Take care to clean and dry the inside and outside of the soil coring head after each sample. Moisture can cause rust build-up on the inside of the core head and make it difficult to insert and remove the liners.

- Use a brush and rag to clean both the inside and outside of the core liners as well. Grit on the outside of the liner can cause damage to the inside of the coring head and make it difficult to collect samples.

- Never twist, pull, or put pressure on the core sampler while the hammer attachment is extended. This can cause the attachment to break or bend.

11.4.7 Regulations Governing Sample Collection (National Historic Preservation Act)

The National Historic Preservation Act of 1966 (as amended) provides for the protection of historical and cultural artifacts. Due to the random placement of the Phase 3 monitoring design, a possibility exists that a Phase 3 plot may be located on a site of prehistoric or historical significance.

- If cultural artifacts are encountered on a Phase 3 plot, do **not** take soil samples. Code the site as not sampled on the PDR and record a plot note explaining why soil samples were not taken.

In order to obtain permits to sample on National Forests, National Parks, and other federal lands, FIA field crews must follow the procedures outlined in this manual. If needed, archeologists or cultural resource specialists in these land management agencies will assist in obtaining permission to sample. Assistance is also available from State Historic Preservation Programs for state and private lands.

11.4.8 Alternate Sampling Methods for “Problem” Soils

In some cases, the soil coring procedure outlined above will not work. For example, in saturated organic soils, use of the core sampler may cause significant compaction of the sample. Very sandy soils or dry soils may tend to fall out of the liners, while in soils with a high rock content or a shallow depth to bedrock, it may not be possible to drive the core sampler into the ground. Approaches to handling these specific problems are addressed in section 11.4.9.

In general, make at least three attempts to collect a sample using the core sampler. If these attempts are unsuccessful, then use one of the following techniques to collect a sample.

1. Excavation method (hand shovel) — Dig a shallow hole whose width is at least 1.5 times the length of your knife. Starting at the top of the mineral soil, measure down 20 cm. Make a mark on the side of the hole at 10 and 20 cm. Use your hand shovel to

collect material from the 0-10 and 10-20 cm depth increments. Collect a sufficient volume of soil from the sides of the hole at each depth increment to approximately equal the volume of a soil core liner and place each depth increment sample in separate soil sample bags. Be sure to collect material from throughout the entire depth increment to avoid biasing the sample.

2. Tube probe — Remove the forest floor from an area and use the tube probe to collect samples from the 0-10 cm depth at a number of locations. Composite these samples until you have a sample volume approximately equal to that of the soil core liner. Repeat the sub-sampling and compositing for the 10-20 cm layer by returning to the points sampled previously and pushing the tube probe into the soil an additional 10 cm.

3. Dutch auger — Dutch augers can be very useful in wetland or saturated soils. In an area where the forest floor has been removed, drill into the soil with the auger and use a tape measure to help you collect material from the 0-10 and 10-20 cm depth increments.

For all of these methods, make sure to collect approximately the same amount of soil material (< 2 mm) that would have been needed to fill the core liner. Completion of the laboratory analyses requires at least 150 g of mineral soil.

In soils with a large number of small rocks and pebbles, this means that you will need to collect a larger amount of sample so that the lab will have enough material to analyze once the rocks have been removed. In these soils, collect enough material to fill two core liners.

Be certain to circle “Other” on the label under sampler type.

11.4.9 Commonly Encountered Problems

Because of the many different types of soil found in the field, it may not always be possible to obtain soil core samples using the soil core sampler. Personal judgment may be required in determining the most appropriate way to collect samples. The following section provides some suggestions on how to overcome these problems.

1. *Rocky soils*

   In soils containing a high percentage of rocks, it may not be possible to drive the core sampler in to the required 20 cm. If this occurs, remove any soil within the sampler, test for the presence of a obstruction using a plot stake pin or the tile probe, and make a second attempt either within the area where the forest floor has been removed or within the available soil sampling area (within a 5 ft radius of the original soil sampling location). Make a maximum of five attempts. If a complete sample from the 0-10 cm depth can be obtained, collect that sample. Otherwise, use the excavation or soil tube probe approaches outlined above (Section 11.4.8).

2. *Very sandy soils (or very dry soils) – sample falls out of the core*

If the soil will not stay in the core liner, use the shovel to dig around the soil coring head while it is still in place. Tilt the soil corer to one side and insert the blade of the shovel underneath the base of the core. Use the base of the shovel to hold the sample in place as you remove the corer from the soil. Depending on the soil type, this technique may require some practice and/or the use of a partner.

3. *Saturated or wetland soils.*

   Attempt to collect a sample using the soil corer. If this is not possible, or if compaction occurs, use one of the three alternate methods outlined in Section 11.4.8.

4. *Other situations in which a complete 20 cm core cannot be collected*

   If a complete core cannot be obtained in one sample, but is cohesive enough to collect a second sample from the same hole, try the following. Collect a partial sample and measure the length of the collected core. Reinsert the sampler and drive it into the soil to an additional depth close to the length of the collected core. Remove the new core from the sampler. When placed together, the two cores should exceed 20 cm in length. With a knife, cut the cores at the 10 cm and 20 cm lengths. Replace the additional soil into the soil hole.

11.5 SAMPLE LABELS

Pre-printed labels will be provided to each field crew. Completion of all items on the soil label is essential for proper processing of the sample by the laboratories. In past years, numerous samples have had to be discarded due to mistakes or inconsistencies on the labels. If you encounter a situation where you need to make additional notes on the sample (e.g., a sample which was particularly unusual or required significant deviation from the standard methods), place a star on the upper right corner of the label and make a note on the sample shipping form.

An example label is presented in Figure 11-7.

Soil Sample Collected by Regular Field Crew

State: FIA Plot: P3 Hex:

Plot #: 1 Soil Visit #: 1 Crew **#** ________________

Date: ____/____/ 2001 Subplot#: 2 3 4

Mineral soil:	Forest Floor	Mineral 1 0–10 cm	Mineral 2 10–20 cm
Organic Soil:	Litter	Organic 1 0–10 cm	Organic 2 10–20 cm

Sampler: Frame Bulk density Other

Figure 11.7 Example soil label

STATE

The 2-digit FIPS code for the State (see Appendix 1 in the P2 field guide). This will be used by the soil analysis laboratory for batching of samples (should be pre-printed on labels).

FIA PLOT NUMBER
The FIA plot number (should be pre-printed on label)

P3 HEX NUMBER
The seven digit P3 hexagon number for the plot. This must be the same as that entered on the PDR (should be pre-printed on label).

PLOT #:
This number will usually be "1." However, if more than one Phase 3 plot is located within a hexagon, then enter the number of the plot. Since most labels are preprinted, the number "1" may already be printed on the label. If incorrect, cross through this value and write the correct plot number above. If uncertain, check with your field supervisor.

SOIL VISIT #:
Record the soil visit number as described in Figure 11-3. For the first soil sample collected along a soil sampling line, this number will be "1". All subsequent visits to a plot will have higher numbers.

DATE SAMPLED:
Enter the date that soils were sampled on this plot.

CREW NUMBER
Enter your field crew identification number. If you have not been assigned a number, enter your last name.

LAYER TYPE:
Circle the type of sample collected and the depth increment of the sample.

For mineral soils, the choices are:

Forest Floor	litter + humus/duff
Mineral 1	0 -10 cm layer of mineral soil
Mineral 2	10 - 20 cm layer of mineral soil

For organic soils (e.g., a peatland or wetland soil with more than 20 cm of organic matter at the surface), the choices are:

Litter	forest floor (only the litter portion is collected)
Organic 1	0 - 10 cm layer of organic soil
Organic 2	10 - 20 cm layer of organic soil

SUBPLOT #:
Circle the subplot adjacent to the soil sampling site.

Subplot 2	Soil sample is from a soil sampling site adjacent to subplot 2
Subplot 3	Soil sample is from a soil sampling site adjacent to subplot 3
Subplot 4	Soil sample is from a soil sampling site adjacent to subplot 4

SAMPLER:

For mineral or organic soils, circle the method used to collect the sample

Sampling frame	12-in diameter bicycle tire
Bulk density	Impact-driven soil core sampler
Other	Soil tube probe, excavation method, mud auger, or Dutch auger

11.6 SAMPLE SHIPPING

After samples have been collected, changes in the oxygen and moisture content within the bag can cause significant alteration of sample chemistry. To prevent this from occurring, samples are to be shipped on a **weekly** basis to the regional soil lab designated for your state. Do not keep soil samples longer than a week unless they can be stored in a refrigerated area. Ship samples using the most economical rate. There is no need to ship soil samples using expensive overnight delivery rates.

11.6.1 Shipping Forms

All crews will be provided with shipping forms for forwarding soil samples to a regional laboratory that has been approved to receive soil samples from regulated areas. The addresses for the regional labs are listed at the bottom of the shipping form. An example shipping form is provided in Figure 11.8.

The shipping forms consist of a triplicate copy. Prior to shipping samples, crews should completely fill out the shipping form and:

- Send the original with the soil samples to the laboratory.
- Mail one copy immediately to the laboratory in a separate envelope along with a copy of the shipping (tracking) information from the shipping service. The separate mailing of shipping forms will serve to notify the laboratory if a shipment of samples has been misplaced during transport.
- Send the third copy to the regional field supervisor for their records.

A separate line must be completed for each sample collected. Information on the sample shipping form is used by the laboratory to create an inventory of samples, to assign lab numbers, and to help resolve inconsistencies on the sample label. A complete and accurate inventory of samples is critical to efficient and cost-effective processing of samples.

FIA Phase 3 Soil Samples Shipping Form

Name: ________________________ Shipped Via: ________________________
Signature: ______________________ Tracking Number: _____________________
State Code: ____ Date: ______________________________
Crew # (if assigned): _____________ QA Status: ☐ Standard ☐ Audit

Hexagon Number	**Date Sampled**	**Layer Type** Forest Floor, Litter, Mineral 1 (0-10 cm), Mineral 2 (10-20 cm),Organic 1 (0-10 cm), or Organic 2 (10-20 cm)	**Subplot Number** 2, 3, or 4	**Bags/Sample** (note if more than 1 such as for large forest floor samples)

Total Number of Bags Sent ___________

Please provide all information and ship samples WEEKLY to the appropriate lab for the region in which the samples were collected.

Southern states:

Russ Dresbach
MU Soil Characterization Laboratory
41 Mumford Hall
University of Missouri, Columbia
Columbia, MO 65211
Phone: (573) 882-3704

Northeast and North Central states:
Don Nagel
Forestry Sciences Lab
1831 Highway 169 East
Grand Rapids, MN 55744
Phone: 218-326-7101

Western states:

Soil & Water Analysis
Forestry Sciences Lab
860 N. 1200 E.
Logan, UT 84321
Phone: 435-755-3560

Instructions:
1) Fill out form completely. Make certain all soil sample bag labels are correct and complete.
2) Send white copy with soil samples.
3) Mail yellow copy in separate envelope to lab.
4) Keep pink copy.
5) Regular field crews: Please check “Standard” box at top of form.
6) QA crews: Please use a separate form for QA audit samples and check “Audit” box

NAME:

Enter your name here.

SHIPPED VIA:
Enter the method used to ship the sample (e.g., UPS, Priority mail, regular mail).

SIGNATURE:
Sign your name here.

TRACKING NUMBER:
Enter the tracking number assigned to the shipment. This information is used by regional supervisors and the laboratories to locate lost or missing shipments.

STATE CODE:
Enter the two-digit FIPS code for the state in which the samples were collected.

DATE:
Enter the date on which samples were shipped.

CREW NUMBER:
If you have been assigned a crew number, enter it here.

QA STATUS:
Indicate whether this sample was collected as part of a standard plot or as part of an audit/QA plot. Unless you are conducting a hot, cold, or blind check, the option for "standard" should be checked.

HEXAGON NUMBER:
Enter the seven digit P3 hexagon number for the plot. This must be the same as that entered on the PDR (should be pre-printed on sample label).

DATE SAMPLED:
Enter the date that the soil sample was collected.

LAYER TYPE:
Indicate the soil layer from which this sample was collected. Choices for mineral soils are: forest floor, mineral 1 (0-10 cm), and mineral 2 (10-20 cm). Choices for organic soils (> 20 cm of organic matter at the soil surface) are: litter, organic 1 (0-10 cm), and organic 2 (10-20 cm).

SUBPLOT NUMBER:
Enter the subplot adjacent to the soil sampling line from which this sample was collected.

BAGS/SAMPLE
Enter the number of bags associated with a sample. For some forest floor samples, more than 1 bag may be needed to collect all of the material. The lab uses this information to make certain that samples consisting of multiple bags are processed together.

TOTAL NUMBER OF BAGS SENT:
Enter the total number of bags contained in the shipment. The laboratory staff will compare the number on this shipping form to the number of bags that they receive in order to make sure that no samples are missing.

11.6.2 Government Regulations For Pest-Regulated States (Southern Region, NY, AZ, NM, CA, and HI)

In order to limit the movement of agricultural pests (e.g., fire ant, corn cyst nematode, golden nematode, witchweed, and Mexican fruit fly), the shipment of soil samples across state boundaries is strictly regulated by the USDA. States with these pests are primarily located in the southern United States and include AL, AR, FL, GA, LA, MD, MS, NC, OK, SC, TN, and TX); soil shipments are also regulated in AZ, NM, CA, HI, and NY. In order to receive a permit to accept soil samples from these areas, the soil labs have had to sign a compliance agreement with the Plant Protection and Quarantine program of the USDA Animal and Plant Health Inspection Service (APHIS) and pass an inspection.

The burden for meeting APHIS shipping regulations falls on the field crews. Crews must:

- Double bag or enclose all samples from a shipment within a larger plastic bag (i.e. trash bag).
- Attach a shipping label to the outside of the box .
- Attach a regulated soils label showing the regional lab's APHIS permit number to the box.

After analysis, all soil samples must be stored or disposed of in the prescribed manner.

11.7 TASKS THAT CAN BE PERFORMED BY OTHER CREW MEMBERS

In order to maximize efficiency on the plot, crew members not trained in the soil indicator may be asked to assist with certain tasks related to sample collection. These tasks include:

- Locating the sampling site (with instruction from trained crew member).
- Assembling the impact driven corer.
- Filling in bag labels and sample shipping forms (Note: these should be checked by trained crew member prior to leaving the plot to ensure completeness and accuracy).
- Cleaning the core liners and the coring head.
- Disassembling the impact driven corer.

11.8 QUALITY ASSURANCE (QA)

The QA program for the soils indicator addresses both field and laboratory measurements. For field measurements, QA protocols are the same as those used for all other Phase 3 indicators. Measurement quality objectives (MQO's) have been established for each of the measurements. The MQOs are used during training, certification and auditing to assist with the control of data quality. Periodic re-measurements are undertaken to establish data quality attributes such as precision, bias and comparability.

This manual only addresses aspects of QA related to the field portion of the program. Soil laboratories have another set of guidelines for ensuring data quality and are required to enroll in a national proficiency testing program. Details of the lab QA protocol may be obtained by contacting the regional lab directors.

11.8.1 Training And Certification

Field crews are trained to make field measurements as well as take soil samples. After training, all field crew members are tested and certified for soil indicator measurements. Each trained crew member must demonstrate the ability to conduct soil measurements within established MQOs.

11.8.2 Hot Checks, Cold Checks, and Blind Checks

QA/QC for the field portion of the soil indicator consists of three parts

Hot checks (audits)	During a hot check, auditors will observe field crew members during data collection on a field plot, review the methods, identify problems, and suggest any needed corrective actions. Auditors may also conduct independent soil measurements.
Cold Checks	Cold checks differ from hot checks in that the field crews are not present for the audit. Auditors conduct spot checks on field measurements and compare these to data collected by the crews. Auditors may correct any error that they find in the data.
Blind Checks	These represent the complete remeasurement of a plot by the auditors. However, the auditors do not have access to the data from the field crew. These are used to provide an unbiased estimate of data variance.

11.8.3 Reference Plots

Remeasurements of field observations by regional trainer crews occur on routine plots recently visited by a standard field crew (cold checks or hot checks) or on reference plots. All erosion and soil compaction remeasurements can be taken on the subplots as described in the soil measurement methods. Reference plots should be selected with areas of bare and compacted soil to allow for an evaluation of a crew's ability to make these measurements.

11.8.4 Debriefing

Feedback from the field crews is critical to identifying problems with the soil indicator measurements and improving the program for subsequent field seasons. Crew members conducting soil measurements should fill out a debriefing form and submit it to the regional field coordinator prior to the end of the field season. Crew members should consider it part of their responsibility to report any problems, inconsistencies, or errors in the manual or the method. These problems cannot be fixed unless FIA is made aware of them.

11.9 EQUIPMENT AND SUPPLIES

Minimum required equipment is listed below. Field personnel may add equipment as needed to improve efficiency in some areas.

11.9.1 Field Gear Unique to the Soil Indicator

- Retractable measuring tape (cm intervals) for measuring soil layer depths.
- Frame for sampling known area of surface litter material. A small bicycle tire (16 x 2.125 in tire size with an internal diameter of 12 in) has been chosen as the standard size.
- Impact-driven soil core (2-in diameter x 8-in depth) sampler with two 2-in diameter by 4-in long stainless steel core liners for obtaining mineral soil samples.
- Additional bulk density sampling equipment: crescent wrench and universal slip wrench for disassembling bulk density sampler if stuck.
- Tile probe (42 in) for measuring depth to a restrictive layer.
- Garden trowel or hand shovel for sampling forest floor and excavating soil sample hole where soil core sampler cannot be used.
- Small knife with sharp blade for sampling the forest floor layers.
- Pruning shears (very useful in cutting through roots and litter).
- Plastic water bottle for use in hand-texturing soil.

- Small plastic tarp (1 yd x 1 yd) to use as a working surface.
- Indelible ink markers (black thin-line) for marking sample bags.
- Cleaning cloths or tissues.
- Soil sample bags (9 x 12 in or quart size) for mineral soil samples.
- Soil sample bags (10 x 18 in or gallon size) for forest floor samples.
- Soil sample labels.

11.9.2 Optional Soils Equipment

- Supplemental soil sampling equipment for organic soils: Dutch auger.
- Supplemental soil sampling equipment for saturated or wetland soils: mud auger or piston-type core sampler.
- Garden gloves.
- 1-in diameter soil tube probe to take soil samples for hand-texturing or where soil core sampler cannot be used.

11.9.3 Required Equipment not Unique to the Soil Indicator:

- Compass for locating sampling points.
- Measuring tape -100 ft loggers tape for measuring distance to sampling locations.
- Flagging for marking soil sample points.
- Back pack for carrying sampling equipment to the field.
- Clear plastic shipping tape to cover labels after they have been filled out.

11.10 LABORATORY ANALYSES

Phase 3 forest floor samples are analyzed in the laboratory for bulk density, water content, total carbon, and total nitrogen. Phase 3 mineral soil samples are analyzed for:

- Bulk density, water content, and coarse fragment (>2-mm) content.
- pH in water and in 0.01 M $CaCl_2$.
- Total carbon.
- Total organic carbon.
- Total inorganic carbon (carbonates) (pH>7.5 soils only).
- Total nitrogen.
- Exchangeable cations (Na, K, Mg, Ca, Al, Mn).
- Extractable sulfur and trace metals.
- Extractable phosphorus (Bray 1 method for pH < 6 soils, Olsen method for pH > 6 soils).

Methods for preparing and analyzing the collected soil samples are available in a separate document.

11.11 REFERENCES

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11.12 ACKNOWLEDGEMENTS

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11.11 EXAMPLE DATA SHEETS

Soil Data Sheet 1

State: ___ ___ Hexagon #: ___ ___ ___ ___ ___ ___ ___
Plot #: ___ Soil Visit #: ___
Date: ___/___/_____ Crew Member(s): ____

Soil Sampling Site Information

Soil Sampling Site Adjacent To:	Condition Class	Sampling Code	Sampler Min 1	Sampler Min 2
Subplot 2:	_______	_______	_____	_____
Subplot 3:	_______	_______	_____	_____
Subplot 4:	_______	_______	_____	_____

Sampling Codes
1 = Sampled
2 = Not sampled: non-forest
3 = Not sampled: too rocky
4 = Not sampled: water
5 = Not sampled: access denied
6 = Not sampled: too dangerous
7 = Not sampled: obstruction in sample area
8 = Not sampled: broken or lost equipment
9 = Not sampled: other (enter reason in plot notes)

Sampler
1 = Bulk density
2 = Other

Forest Floor Thickness (cm)

	N	E	S	W
Subplot 2 Soil Sampling Site:	_____	_____	_____	_____
Subplot 3 Soil Sampling Site:	_____	_____	_____	_____
Subplot 4 Soil Sampling Site:	_____	_____	_____	_____

Litter Layer Thickness (cm)

	N	E	S	W
Subplot 2 Soil Sampling Site:	_____	_____	_____	_____
Subplot 3 Soil Sampling Site:	_____	_____	_____	_____
Subplot 4 Soil Sampling Site:	_____	_____	_____	_____

Depth to Subsoil Restrictive Layer (cm)

Subplot 2 Soil Sampling Site: _____
Subplot 3 Soil Sampling Site: _____
Subplot 4 Soil Sampling Site: _____

Field Texture Determination

			Soil Texture Codes
Subplot 2 Soil Sampling Site:	Mineral 1 (0-10 cm)	_____	0 = Organic
	Mineral 2 (10-20 cm)	_____	1 = Loamy
Subplot 3 Soil Sampling Site:	Mineral 1 (0-10 cm)	_____	2 = Clayey
	Mineral 2 (10-20 cm)	_____	3 = Sandy
Subplot 4 Soil Sampling Site:	Mineral 1 (0-10 cm)	_____	4 = Coarse sandy
	Mineral 2 (10-20 cm)	_____	

Note to regular field crews: Collect mineral 1 and mineral 2 samples from forested sampling sites adjacent to subplot 2 only

Soil Data Sheet 2
FIA Phase 3 Soil Erosion and Compaction Measurements

State: ___ ___ Hexagon #: ___ ___ ___ ___ ___ ___ ___

Plot #: ___ Soil Visit #: ___

Date: ___/___/_____ Crew Member(s): ____

Soil Erosion Measurements:

Subplot	Bare Soil[a] (%)
1	
2	
3	
4	

[a] Percent area cover estimates for entire subplot

Soil Compaction Measurements:

Measurement	Subplot 1	Subplot 2	Subplot 3	Subplot 4
% Area Compacted				
Type - Rutted Trail				
Type - Compacted Trail				
Type - Compacted Area				
Type - Other (Explain)*				

*Explanations: ____