Forest Practices Biomass Work-group
September 19, 2011
Meeting Notes

Attendees:
Bridget Moran, Darin Cramer, Marc Engel, Rachael Jamison, Chris Mendoza, Marty Acker, Kara Whittacker, Stephen Bernath, Doug Hooks, Jess Williams, Randall Greggs, Tom Terry, Dick Miller, Bill Herman, George Cave, Ed Tolan, Eveleen Coleman, David Whipple, Tim Harrington.

Topic:
Soil Health & Soil Productivity

Resources (attached):
- "Specific Forest Practices Rules Protecting Soil Health and Productivity" (presented by Marc Engel)
- "BMPs: Soil Health and Productivity" (presented by Kara Whittacker)

Notes:
DNR Forest Practice Rule Presentation
WAC 222-34-040 (reference WAC 222-30-090): Who determines when a site is "prepared" post-harvest?

- Original section of the rule was written in 1975.
- Application requires landowner to describe to DNR how they will reforest.
- (1) Most commonly used with fragile soils and soils vulnerable to compaction.

WAC 222-30-070 Moisture Conditions.

- Compliance is dependent on landowner making notification call to DNR. Violation is issued if the contact is not made. DNR applies a number of filters during the evaluation of each application.
- Question: Would it add too much work to add a biomass filter?
    - No, it wouldn't. There would just need to be another 2-day notification question added to the application related to biomass being harvested.

CC BMPs Presentation
Road Network Management

- Major obstacle is timber contract requirement to rebuild road, only for biomass to re-access and have to reabandon it again. How can DNR address this in contracts?
- DNR lands will be the most challenging to collect biomass from because of the contract constraints.

Regarding the 33% retention requirement from Minnesota/Michigan.

- What happens if post timber harvest, it is found that the 33% requirement isn't met? Does someone go back and rescatter material on the site?
- Marty's Measurement Suggestion: Calibrate intersect line transects to size classes… (Marty, please insert details, notes don't make a lot of sense)
- Does the 33% only account for woody materials? How is this measured/determined?

Soil Compaction

- Concerning the use of historic/pre-existing skid trails to minimize soil disturbance.
    - Equipment dependent
    - Tom T. indicated that research is showing some soil types do better with some compaction (helps with water retention). Soil disturbance area reduction is not always

hingent on traffic. Not all 'disturbance' is bad. BMP's should focus on detrimental disturbance.

Group Discussion

- For biomass harvest on sensitive soils, perhaps it would be best to say you can't go back out onto the site to collect, but must limit your collection to the landing.
- BMP's can be useful even if they are redundant to the rules. Rules and BMP's being presented on this topic appear to be harmonic.
- We should consider a presentation to the Contract Loggers at the end of this process to discuss our outcomes and impacts it might have on them.
- Future Field Trip Potential: Shovel and cable demonstration.
- How compliant is DNR FP rules?
    - Rules are dynamic.
    - Where is DNR seeing the most non-compliance?
    - DNR has 50+ FP foresters working on application approval/follow-up. High risk sites get more visits.
    - What are the non-compliance trends? There is currently a 70-80% compliance rating average.
- What is the difference between landowner responsibility for stewardship and FP rules?
- There is a difference between removing biomass from the roadside (conventional harvest – logging clean-up).
    - Perhaps the group should focus discussions on how and how much should be returned for from the timber harvest site just to collect biomass.
    - Biomass should be intricately linked to timber harvest.
    - Difference between landing collection and biomass harvest (going back out onto the site to collect biomass)
- If price for biomass increased, would more be harvested?
    - Want to be careful of the rules putting the brakes on the industry due to costs of implementation.
- Missing from rules: piece size limit (Example: In Finland, you can't get below 1")

Specific Forest Practices Rules

Protecting Soil Health and Productivity

The listed rules below summarize how the forest practices rules affect the harvest of biomass.

Chapter 222-16 WAC, Definitions

WAC 222-16-010 General definitions

Unless otherwise required by context, as used in these rules:

"Equipment limitation zone" means a 30-foot wide zone measured horizontally from the outer edge of the bankfull width of a Type Np or Ns Water. It applies to all perennial and seasonal nonfish bearing streams.

"Erodible soils" means those soils that, when exposed or displaced by a forest practices operation, would be readily moved by water.

"Low impact harvest" means use of any logging equipment, methods, or systems that minimize compaction or disturbance of soils and vegetation during the yarding process. The department shall determine such equipment, methods or systems in consultation with the department of ecology.

"Plantable area" is an area capable of supporting a commercial stand of timber excluding lands devoted to permanent roads, utility rights of way, that portion of riparian management zones where scarification is not permitted, and any other area devoted to a use incompatible with commercial timber growing.

"Riparian function" includes bank stability, the recruitment of woody debris, leaf litter fall, nutrients, sediment filtering, shade, and other riparian features that are important to both riparian forest and aquatic system conditions.

"Scarification" means loosening the topsoil and/or disrupting the forest floor in preparation for regeneration.

"Side casting" means the act of moving excavated material to the side and depositing such material within the limits of construction or dumping over the side and outside the limits of construction.

"Site preparation" means those activities associated with the removal of slash in preparing a site for planting and shall include scarification and/or slash burning.

"Skid trail" means a route used by tracked or wheeled skidders to move logs to a landing or road.

"Slash" means pieces of woody material containing more than 3 cubic feet resulting from forest practices activities.

Chapter 222-20 WAC, Application and Notification

WAC 222-20-040 Approval Conditions.

(1) Whenever an approved application authorizes a forest practice which, because of soil condition, proximity to a water course or other unusual factor, has a potential for causing material damage to a public resource, as determined by the department, the applicant shall, when requested on the approved application, notify the department two business days before the commencement of actual operations.

Chapter 222-24 WAC, Road Construction and Maintenance

WAC 222-24-030 Road construction.

(1) **Right of way timber** shall be removed or decked in suitable locations where the decks will not be covered by fill material or act as support for the fill or embankment.

(9) **Waste disposal.** When spoil, waste and/or other debris is generated during construction, this material shall be deposited or wasted in suitable areas or locations and be governed by the following:

(a) Spoil or other debris shall be deposited above the 100-year flood level of any typed waters or in other suitable locations to prevent damage to public resources. The material shall be stabilized using the recommended schedule and procedures found in the board manual, section 3.

(b) All spoils shall be located outside of Type A and Type B Wetlands and their wetland management zones. Spoils shall not be located within the boundaries of forested wetlands without written approval of the department and unless a less environmentally damaging location is unavailable. No spoil area greater than 0.5 acre in size shall be allowed within wetlands. (See WAC 222-24-015, Construction in wetlands.)

Chapter 222-30 WAC, Timber Harvesting

Per WAC 222-30-010, "This chapter covers all removal of timber for commercial operations, commercial thinning, salvage of timber, relogging merchantable material left after prior harvests, postharvest cleanup, clearing of merchantable timber from lands being converted to another use. It does not cover removal of incidental vegetation or removal of firewood for personal use."

WAC 222-30-020 Harvest unit planning and design.

- Logging systems should be appropriate for terrain, soils, and timber type so that yarding or skidding can be economically accomplished and achieve the ecological goals of WAC 222-30-010 (2), (3) and (4) in compliance with these rules.
- Landing location should be located to prevent damage to public resources. Avoid excessive excavation and filling.
- Forested wetlands:
    - Harvest methods shall be limited to low impact harvest or cable systems. Where feasible, at least one end of the log shall be suspended during yarding. (Note: "low impact harvest" is defined in WAC 222-16-010: "… means use of any logging equipment, methods, or systems that minimize compaction or disturbance of soils and vegetation during the

yarding process. The department shall determine such equipment, methods or systems in consultation with the department of ecology.")

- Wetland management zones (WMZs): dependent on whether wetland includes bogs, and size (acres) of wetland.
    - No tractor, wheeled skidders, other ground based harvesting systems in WMZ without DNR approval.
        - Channel migration zones. No harvest, construction or salvage within CMZ, except road crossings and creation and use of yarding corridors.
        - Bankfull width. No harvest, construction or salvage within the bankfull width of any Type S or F Water or any buffered length of Type Np Water, except for the construction and maintenance of road crossings in accordance with applicable rules and creation and use of yarding corridors.

WAC 222-30-021 Western Washington riparian management zones.

<u>Type S and F Waters</u>

RMZs

- Core zone: 50 foot no harvest.
    - Inner zone harvest must meet stand requirement to "…protect aquatic resources and related habitat to achieve restoration of riparian function, and the maintenance of these resources once they are restored"

<u>Type Np and Ns Waters</u>

- Equipment limitation zone: 30 feet wide to limit surface disturbances caused by equipment.
- On-site mitigation is required if any of the following activities exposes the soil on more than 10 percent of the surface area of the zone.
    - Ground based equipment'
    - Skid trails;
    - Stream crossings, other than existing roads; or
    - Cabled logs that are partially suspended.

- Mitigation must be designed to replace the equivalent of lost functions especially prevention of sediment delivery. Examples include water bars, grass seeding, mulching, etc. **DNR is authorized to prevent actual or potential material damage to public resources under WAC 222-46-030 or -040 (notice to comply and stop work order) to condition FPAs.**

- Sensitive site and RMZs protection.

    - 50 foot no-harvest buffer along each side of Type Np Water; at least 50 percent if stream length must be protected by buffers on both sides. Buffered segments must be at least 100 feet in length.

    - No harvest permitted:

        - within 50 of outer perimeter of a soil zone perennially saturated from a headwall seep or side-slope seep;

        - within 56 foot radius buffer patch centered intersection of 2 or more Type Np Waters, or centered on a headwater spring or point at the uppermost extent of a Type Np Water;

        - on an alluvial fan.

- None of the limitation on harvest in or around sensitive sites will preclude or limit construction or maintenance of roads for the purpose of crossing streams, or the creation and use of yarding corridors.

- To the extent reasonably practical, the operation will both avoid creating yarding corridors or road crossings through Type Np RMZs or sensitive sites and associated buffers, and avoid management activities which would result in soil compaction, the loss of protective vegetation or sedimentation in perennially moist areas.

- Where yarding corridors or road crossings through Type Np Water RMZs or sensitive sites and their buffers cannot reasonably be avoided, the buffer area must be expanded to protect the sensitive site by an area equivalent to the disturbed area or by providing comparable functions through other management initiated efforts.

WAC 222-30-022 Eastern Washington riparian management zones.

<u>Type S and F Waters</u>

- Core zone: 30 foot no harvest.

- Inner zone harvest must meet stand requirement to "…protect aquatic resources and related habitat to achieve restoration of riparian function, and the maintenance of these resources once they are restored"

Type Np Waters

- Equipment limitation zone: 30 feet wide. Mitigation required if harvest activities expose the soil on more than 10 percent of the equipment limitation zone length. **DNR authorized to prevent actual or potential material damage to public resources under WAC 222-46-030 or -040 or any related authority to condition FPAs.**

WAC 222-30-023 Riparian management zones for exempt 20-acre parcels.

WAC 222-30-030 Stream bank integrity.

Within riparian management zones of Type S, F, and Np Wasters, operators must:

- Avoid disturbing brush and similar understory vegetation;
- Avoid disturbing stumps and root systems and any logs embedded in the bank;
- Leave trees that display large root systems embedded in the bank.

WAC 222-30-045 Salvage logging within RMZ

- No salvage in any typed water.
- No salvage in core zone.

WAC 222-30-060 (4) Cable yarding in RMZs, sensitive sites, and WMZs

Reasonable care shall be taken to minimize damage to the vegetation providing shade to the stream or open water areas and to minimize disturbance to understory vegetation, stumps and root systems.

WAC 222-30-070 Ground-based logging systems

- **Type S or F Water**: no ground-based equipment allowed except with DNR approval and an HPA.
- **Type Np and Ns Waters**
    - ground based transport of logs is not allowed across flowing water.

- whenever skidding across Type Np or Ns Waters, the direction of the log movement between stream banks shall be designed to minimize potential for damage to public resources.

- to maintain wetland water movement and water quality, and to prevent soil compaction, ground-based logging systems shall not be used in Type A or B wetlands.

- **Wetlands**:

  - No equipment allowed in Type A or B wetlands.

  - Where harvest in wetlands is permitted, ground-based logging systems limited to low impact harvest systems; only allowed during periods of low soil moisture or frozen soil conditions.

- **RMZs**: any use of ground-based yarding equipment within zone must

  - be approved by DNR;

  - minimize routes through zone;

  - minimize damage to leave trees and vegetation in the zone to the extent practical and consistent with good safety practices.

- **WMZs:**

  - where feasible logs shall be skidded with at least one end suspended from the ground so as to minimize soil disturbance and damage to leave trees and vegetation in the WMZ;

  - ground-based harvesting systems shall not be used within the minimum WMZ unless DNR approved.

- **Deadfalls**: logs firmly embedded in the bed or bank of Type S or F Waters shall not be removed or disturbed without HPA.

- **Moisture conditions**:

  - Systems shall not be used on exposed erodible soils or saturated soils if sediment delivery is likely to disturb a wetland, stream, lake or pond;

  - When soil moisture is high and unrestricted operation of ground-based equipment would result in unreasonable soil compaction, operations shall be restricted to methods that minimize widespread soil compaction or, operations postponed until site conditions improve such that yarding may proceed without causing unreasonable soil compaction and the long-term impacts to soil productivity and moisture absorption capacity that can result.

    - **Protection of residual timber**:

- Reasonable care shall be taken to minimize damage from skidding to the stems and root systems of residual timber and to young reproduction.

- **Skid trail location and construction**:

  - Shall be kept to the minimum width.

  - Reasonable care shall be taken to minimize the amount of sidecast required and shall only be permitted above the 100-year flood level.

  - Shall be outsloped where practical, but be insloped where necessary to prevent logs from sliding or rolling downhill off the skid trail.

  - Skid trails running parallel or near parallel to streams shall be located outside the no-harvest zone of all typed waters and at least 30 feet from the outer edge of the bankfull width of the unbuffered portions of Type Np or Ns Water unless approved in writing by the department.

  - Skid trails shall cross the drainage point of swales at an angle to minimize the potential for delivering sediment to a typed water or where channelization is likely to occur.

- **Skid trail maintenance.**

  - Upon completion of use and termination of seasonal use, skid trails on slopes in exposed soils shall be water barred where necessary to prevent soil erosion.

  - Skid trails located within 200 feet horizontal distance of any typed water that directly delivers to the stream network shall use water bars, grade breaks, and/or slash to minimize sediment delivery to the stream. Water bars shall be placed at a frequency to minimize gullying and soil erosion. In addition to water barring, skid trails with exposed soil that is erodible and may be reasonably expected to cause damage to a public resource shall be seeded with a noninvasive plant species (preferably a species native to the state) and adapted for rapid revegetation of disturbed soil, or treated with other erosion control measures acceptable to the department.

- **Slope restrictions.** Ground-based systems shall not be used on slopes where in the opinion of the department this method of operation would cause actual or potential material damage to a public resource.

WAC 222-30-080 Landing cleanup.

Except as approved by the department, the following rules shall be met within 60 days after completion of hauling logs from any landing, or as soon thereafter as practical.

*(1) **Drainage.**

(a) Clean any ditches and culverts obstructed by dirt or debris during operation(s).

(b) Establish a slope that will prevent water from accumulating on the landing or running from the

landing down any erodible fill.

*(2) **Other erosion control measures.**

(a) Cut slopes shall be cut back to an angle expected to remain stable.

(b) Where exposed soil is unstable or erodible and may be reasonably expected to cause damage to a public resource, it shall be seeded with grass, clover or ground cover or compacted, riprapped, water barred, benched or mulched, or be treated by other means approved by the department.

(3) **Cleanup.**

(a) Slash accumulations which would prevent reforestation of otherwise plantable fills, sidecast or cut slopes of landings shall be disposed of or be piled on the landing floor for future disposal.

(b) Slash shall not be buried in any filled portion of the landing in connection with landing cleanup operations.

(c) All cables, machine parts and other inorganic debris resulting from harvest operation(s) shall be removed at the time of landing cleanup.

WAC 222-30-090 Postharvest site preparation

The following sit preparation is required to establish a condition suitable for reforestation:

- Cutting, slashing, or other treatment of all noncommercial tree species, other competing vegetation, and nonmerchantable size trees commonly known as "whips" which will not reasonably utilize the growing capacity of the soil except in wetland management zones, riparian management zones; or
- Pile or windrow slash; or
- Mechanically scatter slash; or
- Leave the cutover area in a condition for controlled broadcast burning, and subsequently burn.

Chapter 222-34 WAC, Reforestation

WAC 222-34-030 Reforestation plans—Reports--Inspections

(1) Reforestation plans. Reforestation plans must be submitted with the application or notification except where no reforestation is required. The department shall designate difficult regeneration areas utilizing silvicultural information. When a forest practice is proposed for such an area, the department may require additional information regarding harvest systems and post harvest site

preparation, as well as regeneration. The department shall approve the reforestation plan for difficult regeneration areas if it determines that such a plan will achieve acceptable stocking according to WAC 222-34-010 and 222-34-020.

WAC 222-34-040 Site preparation and rehabilitation.

(1) **Heavy equipment**. Heavy equipment shall not be used in connection with site preparation or rehabilitation work:

(a) When, because of soil moisture conditions or the type of soils, undue compaction or unnecessary damage to soil productivity would occur or erosion would result in damage to water quality; or

(b) Within riparian management zones, Type A and B Wetlands, wetland management zones, or within equipment limitation zones of Type Np and Ns Waters on slopes of 30 percent or less. On slopes greater than 30 percent heavy equipment shall not operate within 50 feet of Type S through Ns Waters unless a site specific plan has been approved by the department.

(2) Surface water drainage. Where site preparation or rehabilitation involves contouring or terracing of slopes, drainage ditches, or similar work:

(a) The gradient of ditches or other artificial water courses in erodible soils shall not cause significant stream, lake, pond, or wetland siltation.

(b) Ditches and other artificial water courses shall not discharge onto any road, landing or fill.

(c) Ditches and other artificial water courses shall not be constructed to discharge onto the property of other parties without their consent.

BMPs: Soil Health and Productivity

Conservation Caucus perspective

Sept. 19, 2011

- Elliot 2009: Table 1, typical BMPs to follow to minimize impacts of biomass use
  - **Onsite practices**
    - Minimize mineral soil exposure
      - Minimize turnarounds with equipment
      - Use designated skid trails
      - Use harvesters with longer booms
    - Maintain undisturbed buffers along streams
    - Avoid working when soils are wet
      - Winter logging may work
    - Avoid dragging logs
      - Lift ends with skidders
      - Use grapple skidders or forwarders
    - Minimize the amount of traffic
    - Mitigate skid trails
      - Install frequent water bars
      - Cover trails with slash
    - Use low ground pressure equipment
      - Bigger tires or tracks
      - Note: Smaller vehicles make more trips
  - **Road network management**
    - Remove unwanted road segments, especially culverts and stream crossings
    - Outslope whenever safe with frequent dips
    - Keep insloped ditches stable with coarse gravel or vegetation
    - Install cross drains or ditch relief culverts where there is adequate vegetated buffer available between the road and the stream
      - Consider the fate of all road drainage
    - Install ditch relief culverts about 50 ft before stream crossings
    - Use gravel (or asphalt) within 50 ft of live water crossings
    - Avoid ruts
      - Close roads when wet
      - Use gravel
      - Blade regularly
    - Monitor culverts to prevent blockage and diversion
    - Locate roads to minimize sediment delivery to streams

- Stewart et al. 2010 (Table 27): soil productivity protection measures from states with existing biomass harvesting guidelines
  - **Forest floor, litter, stumps, roots**
    - Retain the litter layer, stumps and roots as intact as possible (Maine)
    - Do not remove the forest floor, litter layer, and/or root system (Minnesota)
    - Retain the forest litter layer, forest floor, stumps, and/or root systems (Wisconsin)
  - **Sensitive soil types**
    - Retain as many tops and branches as possible on low fertility sites, sallow soils, coarse sandy soils, poorly drained soils, steep slopes, and other erosion-prone sites (Maine)

        - Avoid additional biomass harvests from erosion-prone sites; install erosion control devices (Minnesota)
        - Avoid biomass harvesting on ombrotrophic, organic soils deeper than 24 inches; aspen/hardwood cover types on shallow soils (8 inches or less to bedrock) (Minnesota)
        - Do not harvest FWD on shallow soils (bedrock within 20 inches of surface; Wisconsin)
        - Do not harvest FWD on dry, nutrient-poor, sandy soils (Wisconsin)
        - Do not harvest FWD on soils classified as dysic Histosols (wetland soils with 16 inches organic material, nutrient-poor and low pH; Wisconsin).
        - For shallow soils and droughty sands, consider retaining 33% or more of the FWD post-harvest (Minnesota)
        - On shallow, nutrient poor soils, consider leaving additional residue (more than 33%; Michigan)
    - **Overall retention**
        - Retain a minimum of 33% of the harvest residue (Missouri)
    - **Planning operations**
        - Avoid skidding on shallow soils and steep slopes (Missouri)
        - Roads, skid trails, and landings should occupy no more than 1- 3% of the site (Minnesota)
        - Minimize soil compaction and rutting by matching operating techniques and season of operation to soil types and moisture levels (Pennsylvania)
        - Minimize the soil disturbance though careful design and placement of landings, roads, and skid trails (Pennsylvania)
    - **Silvicultural strategies**
        - Lengthening rotations and/or using uneven-aged management to encourage soil fertility (Missouri)

- **Nutrients/productivity**
    - Removal of more of non-merchantable woody residue as is done in whole tree harvesting increases the amount of nutrients taken, but *the impact depends on what fraction of total nutrients were in the removed vegetation* (Stewart et al. 2010).
    - From a nutrient availability perspective, it is *the soil amount is important, not just concentration*. A deeper, more massive soil contains more nutrients than a shallow soil with the same nutrient availability per unit mass (Stewart et al. 2010).
    - Retain logging slash on site, especially on sites with nutrient-limited and coarse-textured soils (Page-Dumroese et al. 2010).
    - Maine's, Minnesota's, Missouri's, Michigan's, and Wisconsin's guidelines include recommendations based upon the soil types, with *poor, shallow, sandy soils being classified as less suitable for biomass harvest* (Evans et al. 2010).
    - The forest floor, including roots, stumps and below-ground biomass, should always be off-limits to biomass harvesting. This material provides too many irreplaceable functions to sustaining a healthy forest, including nutrients essential for tree growth and maintaining biodiversity (PA DCNR).
    - Leaving residues on-site has an overall positive effect on soil carbon stocks in conifer-dominated ecosystems via direct incorporation of C into the soil and the maintenance of soil microclimate conducive to reduced decomposition (Gershenson et al. 2010).
    - Soil carbon losses can be minimized where retention of post-logging debris on site is maximized (Gershenson et al. 2010).
    - Limit high disturbance site preparation activities to 10% of the total project area to minimize loss of soil C (Gershenson et al. 2010).

- Since initial losses from harvest activities can be as high as 20% of ecosystem carbon, an *interharvest period of adequate length* (at least 50 years) is critical for ensuring that such losses are replenished (Gershenson et al. 2010).
- Angima & Terry 2011: Chapter 6, Maintaining Adequate Nutrient Supply
  - Take extra precaution during harvest activities in or around ecologically sensitive areas, riparian zones, and areas characterized by organic or shallow soils with low nutrient pools.
  - Conservation of large woody debris is important from a wildlife and biotic diversity perspective and also must be considered when retention guidelines are specified during harvest (Bull 2002).
  - Removing only logs (bole-only harvest) presents a relatively low risk of loss in productivity, whereas whole-tree yarding may create a greater risk depending on how much of the nutrient pool is removed relative to the total pool before harvest.
  - Retain at least 30% of the fine woody debris on slopes conducive to ground-based harvesting and 50% or more on steeper slopes.
  - When removing logging residuals for biomass harvest or fuel reduction, or when piling slash to create planting spaces, it is best to wait until the residuals dry so that needles and fine branches can fall off and remain distributed as uniformly as possible across the site.
  - Retain at least 30% of the fine woody debris on slopes conducive to ground-based harvesting and 50% or more on steeper slopes.
  - When removing logging residuals for biomass harvest or fuel reduction, or when piling slash to create planting spaces, it is best to wait until the residuals dry so that needles and fine branches can fall off and remain distributed as uniformly as possible across the site.

- **Soil compaction**
  - Position limbs and tree tops on equipment travel corridors as a protective mat to reduce exposure and compaction of soil (Hartsough et al. 1994; Page-Dumroese 1993).
  - Use well-planned systems of designated equipment corridors to limit the total area disturbed during harvest (Moghaddas and Stephens 2008; Page-Dumroese et al. 2010).
  - Avoid biomass collection when soil moisture is high (Han et al. 2009).
  - Utilize historic/preexisting skid trails to help minimize cumulative soil disturbance from multiple harvest entries (Page-Dumroese 2010, Stewart et al. 2010).
  - Limit the areal coverage of equipment corridors (Stewart et al. 2010).
  - Angima & Terry 2011: Chapter 5, Managing Soil Disturbance
    - Avoid situations in which the risk is high because of site conditions and time of year. Schedule higher-risk soils during the driest time of the year. Take extra precautions when operating during higher-risk conditions.
    - Suggested BMPs for consideration (*topics only, see text for full list*)
      - good communication between the landowner, harvest manager, and equipment operators
      - during the harvest-planning phase
      - for felling and cutting
      - for yarding
      - prepare dirt spurs (temporary access roads) prior to logging and use them under the following conditions
      - for entering the unit with harvesting equipment
      - to maintain a systematic logging pattern to minimize the number of trails

- Angima & Terry 2011: Ch. 1, Understanding and Managing Risk
  - **The objective is to manage risk (hazards + consequences) at a low-to-moderate level**

- BMP prescriptions should be site specific (considering site conditions and potential hazards and consequences), be cost effective, have a low probability of causing a decrease in soil productive capacity or other detrimental impacts, and have a high likelihood of meeting specified management objectives.

Summary: factors to be considered to determine extent of woody biomass removal

- Create site categories based on level of risk and a set of BMPs for each category
- Site-specific Risk analysis
  - Site Class
  - Soil erosion hazard
  - Mass wasting hazard
  - Soil operability risk rating
  - Fire/pest hazard
  - Amount of preexisting woody biomass
  - Disturbance history
  - Non-soil resources (wildlife, water quality, etc.)
  - Degree of adverse impacts (consequences)
- BMPs that apply to all sites
  - Onsite practices (see above)
    - Soil disturbance class limits
    - Soil disturbance area (%)
    - WRT, GRT, and log retention
    - Forest floor and legacy wood retention
  - Road network management
  - Non-soil resources (wildlife, water quality, etc.)