The Colorado Wood Utilization and Marketing Program **presents:**

A Literature Review on Skidding and Yarding on Steep Slopes

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I. Introduction:

Many methods of skidding are available to timber harvesters today. Methods available for skidding include: rubber-tired skidding, tracked-skidding, cable yarding systems, and helicopter yarding. Each method has its own positive and negatives. Some methods and equipment are better for steep slopes than others. Tracked-skidders create less soil disruption than rubber wheeled skidders; however cable yarding systems create far less soil damage. Tracked-skidding, rubber-tired skidding, and cable yarding are ground-based so these systems still require building more roads which leads to more soil disruption. Helicopter yarding greatly reduces the amount of roads needed for skidding but is generally very expensive or even prohibitively so.

A. Logging and erosion:

i. Rice, J.S. Rothacher, and W.F. Megahan. "Erosional Consequences of Timber Harvesting: An Appraisal" R.M. National Symposium on Watersheds in Transition. Date Unknown.
The building of roads for logging is by far the greatest cause of soil erosion. The amount of disturbance caused by logging roads depends on the design standard of the road, steepness of slope, and total mileage on the road (322-323). The actual removal of the logs disturbs a greater area of land than road construction, but the overall damage due to log removal is far less (323). Cable-logging systems greatly reduce the amount of soil damage when compared to other conventional ground-based systems (323). The greatest amount of soil erosion occurs immediately after logging roads are constructed. The amount quickly decreases over time (324-325). Roads change the natural drainage patterns of hillsides and expose buried material to weathering (326). Roads also place more weight on the underlying soil which can cause landslides.

B. Skid Trail design:

i. J..J. Garland. "Designated skid trails minimize soil compaction." The Woodland Workbook. Sep. 1997.
Forest managers who plan skid trails can reduce the impact that logging operations will have on the soil. A manager should try to reduce the area

covered by skidders during the logging process by carefully flagging their designated skid trails. For steeper slopes, Garland recommends using "parallel" designed skid trails where the skid trails follow the contour lines of the slope. He also recommended that landings be placed to accommodate trucks and log decks. The slope of the landing should be about 8% or less, and landings should be located so the longest skid distance is less than 1,200 to 1,500 feet for most systems. For all ground-based skidding operations, downhill skidding is preferred. On slopes above 20%, skid trails should be excavated. Garland also recommends keeping skid trails narrow and adequately treated to help reduce soil erosion. Loggers should fell the trees "to lead" so that the tree butts will be facing the skid trails for easy access by the skidder. This will reduce the amount of damage to the residual trees. Skid trails should be as straight as possible so skid operators spend less time trying to figure out where to place their skidder. He also recommends removing all trees in skid trails and cutting stumps at ground level. Skid trail intersections should be at 45-degree angles or less with respect to travel toward the landing. Branching from the main trail directly opposite another trail branch and sharp curves at the bottom of steep downhill trail segments should be avoided. If old skid trails can be identified, they should be used. Slash collection on skid trails to reduce compaction by track skidders is also recommended; however one must be cautious of slash build up on trail for rubber wheeled operations because the slash will cause the rubber wheeled skidder to slip. Skid trails can be left or tilled for partial restoration after logging operations have finished.

C. Other Guidelines:

i. Section entitled: "How can erosion be prevented on landings, logging roads and skid trails on steep slopes." New York State Department of Environmental Conservation. Date unknown
http://www.dec.state.ny.us/website/dlf/privland/privassist/bmp.html
To protect slopes exceeding 30%, one must set roads and trails 150 feet away from ponds, streams, and marshes. Also winching logs off steep slopes will help limit the number of skid trails and decrease skid traffic to help reduce skidding erosion. Logging should be done in dry weather, or when the ground is frozen and/or covered with snow. After logging, loggers should regrade the roads and skid trails to help reduce the erosion. Water diversion devices can be installed to divert water away from roads and primary skid trails. Ditch water should not run into a stream; rather try to filter it into the woods. Keeping landings out of low spots and poorly drained area to help prevent landing induced erosion. Also place landings on gentle slopes at least 200 feet away from lakes, ponds, wetlands, and streams to help reduce the environmental cost of logging on steep slopes.

II. Skidding Equipment

A. Rubber-tired skidders (fixed boom grapples and swinging grapples)

i. Section entitled: "How can erosion be prevented on landings, logging roads "Development of rubber tired log skidders" http://www.vannattabros.com/skidder1.html, Updated 2/5/01

a. Evolution of heavy equipment for logging in the last 50 years has made ground skidding more feasible then the cable systems. Except in extreme conditions rubber tired skidders are preferred over tracked skidders. Rubber-tired skidders do not have as good of traction on steep slopes as tracked skidders.

b. According to Colorado Machinery, Ft. Collins, Colorado, rubber-tired skidders on average cost $20,000-$30,000, while tracked skidders run about $50,000-$60,000.

c. Rubber tired skidders are less complicated to operate than cable systems. Cable systems require hooking and un-hooking processes and resetting the system and direction changes that makes them very labor-intensive. Rubber-tired skidders generally just drive to the logs, grapple the load, and carry them off making the task less laborious. Swing grapples are very maneuverable to allow grappling of individual logs in thinning operations without damaging the residual stand. However, these machines are not very stable and can tip over easily. Also, these machines are expensive to maintain and expensive to purchase. The fixed boom grapple is not as versatile but has fewer moving parts so there is less of a chance of breaking the machine. Fixed boomed grapples are also much more stable than swing type grapples.

ii. "A comparison of flexible track and rubber wheeled skidders on soil compaction". By G. J. Sheridan, Australian Journal of soil research, 2003. There was very little difference seen between the amount of soil penetration resistance that was created by the rubber wheeled skidder and the track skidder. Rubber tired skidders generally put 3.8 times more pressure on the ground than track skidders however, the significance of the impact was negligible (p. 8-9). Generally the maximum amount of soil compaction that a soil will withstand is created in the first 9-10 passes on the skid trail made by a skidder (p. 10). Rubber wheeled skidders can't generally carry as much weight as track skidder so they have to make more passes on the skid trails to move the logs (p. 11).

iii. Types of rubber-tired skidders. Journals of Logging and Saw Mills, Timber West, May 2004. Product review. http://www.forestnet.com/timberwest/archives/May_June_04/skidder_review.htm

a. Caterpillar Brand http://www.cat.com/cda/layout?x=7
Basic modes are very similar in design and function. They have three models of rubber wheeled skidders; the first is 525B, 535B, and the

545. They range from 160-200 horse power engines. They have singe and duel function arches for sorting, bunching, and thinning. Also, the skidders have a single lever grapple. See the Caterpillar website for detailed specifications on the models.

b. John Deere: www.johndeere.com
   1. 540G III: The 540G is equipped with direct drive or torque converter transmission. It has full-diff lock wheel system for maximizing traction. The 540G is designed to make tight turns, and is very stable. It has a 117 net horse power engine.
   2. 548 III: Has a lot of the same features as the 540GIII, except it has a specially designed cab to make it more comfortable for the operator. It also has a 117 horse power engine.
   3. 640 III: This skidder has 160 horse power and direct drive transmission.
   4. Many more models of John Deere rubber wheeled skidders are listed at the John Deere website above, all model displayed have a more detailed list of specifications.

c. Franklin Treefarmer: www.franklin-treefarmer.com
   Three types of rubber wheeled skidders: the Q70, Q80, and Q90. The models Q70 and 80 are grapple skidders where the Q90 is grapple skidder with cable system capabilities. The winches and grapples are rear-mounted and hydraulically-actuated. All are equipped with a powerful Cummins engine.

d. Morgan:
   http://www.morganforestry.com/morganforestry/products.htm
   Morgan has the SX706 SB model six-wheeled swing boom skidder. This skidder has a 140 degree swing capability, a twelve foot lift height and a fifteen foot reach. It is powered by a Cummins 6 CTA 8.3 liter, 260 horse power engine.

e. Prentice: http://www.blount-fied.com/prodinfo/transporting/skidder.htm
   The Prentice 490 rubber-tired skidder has a tough, durable drive train for smooth power and a steady pull. This allows for good maneuverability on soft ground or steep slopes. The Prentice 490 is equipped with a torque converter. It is also designed so maintenance is easy because the parts are accessible. It has a standard Cummins QSB 173 horse power engine. The buyer of this skidder has choices of either a bunching or sorting head grapple.

f. Tigercat: http://www.tigercat.com/ski.htm
   Tigercat produces three models of rubber-tired skidders: the 620C, 630C, and the 635C. All the models are very similar with some slight variations. The basic design is a hydrostatic rubber wheeled skidder. They have been praised for their ability to skid for long distances over challenging terrain. These models are specifically designed for high

production logging. Most models are powered with a 240 horse power Cummins engine. The engine is isolated from the hydraulic components, for easy maintenance access. The skidders are equipped with a hydrostatic drive system allows for a smooth ride with no rotating gear shifting.

g. Ranger/Allied systems:
http://www.alliedsystems.com/ranger/skidder.htm
Ranger/Allied systems offer a skidder that has been deemed very simple and reliable. It is a durable machine with differentials and axles, driveline, torque controls, and transmission configuration designed from skidders. These skidders are both offered in grapple and cable configurations. It is equipped with a head-to-keel belly guard to protect the undersides from unforeseen obstacles. The grapple has 360-degree rotation capability. They are equipped with large drum capacity winch. The F65C pulls 31,432 pounds, and the model F68C pulls 37,311 pounds.

C. Tracked Skidders

i. "Comparison of Tractor and Tractor/Wheeled Skidder Logging Methods," by Unto Vasinen, Wanabakti, Berau Forest management project. October 16, 1996.
Track type tractors can be used for road construction, clearing skid tracks, as well as skidding. This type of tractor has high traction power and is very balanced so it can move large loads and work on steep slopes very effectively. However, the driving speed of a track-type tractor is low, and they are more expensive to buy than rubber wheeled skidder. It is recommended to use a "track type skidder and wheeled skidder together to allow for longer skidding distances and reduce the density of truck loads" (1). By using rubber-tired skidders on the less steep part of the slopes, and using the tracked skidders on the steeper slopes, a logging operation will be safer and more productive.

ii. "A Comparison of Flexible Track and Rubber Wheeled Skidders on Soil Compaction". By G.J, Sheridan, Australian Journal of Soil Research, 2003
Soil penetration resistance on transverse lane ways was significantly higher in disturbed areas. Once again it was found that there was little difference in the amount of soil penetration resistance that was created by the rubber-tired skidder and the tracked skidder. Tracked skidders put less pressure on the soil than rubber-tired skidders. However, the difference is insignificant; both types of skidding are damaging to the soil. On average, steel-tracked skidders weigh 41% more than rubber-tired skidders, but still produce less ground pressure than rubber wheeled skidders as the weight is evenly distributed over the entire surface area contact with the tracks. Rubber-tired skidders on average have 3.8 times more ground pressure than the steel track skidders. As stated earlier, steel track skidders generally can carry

larger loads dependent on the models used; this does increase the ground pressure caused by the track skidder but reduces the number of trips needed to move all the logs.

iii. Types of track type skidders: Journals of Logging and saw mills, Timber West, May 2004. Product review. http://www.forestnet.com/timberwest/archives/May_June_04/skidder_review.htm

a. Caterpillar: http://www.cat.com/cda/layout?x=7
Caterpillar has two types of track skidder: the 517 and 527. These skidders are praised for their good balance and traction. Roller frames extend to the rear of the machine to improve traction over uphill conditions. Their wide tracks help with traction and reduce the soil compaction caused by the tracks. These machines are protected by an under paneling for protection from underlying stumps and slash. These skidders are powered with a 120 net horsepower engine and have both grapple and cable capabilities.

b. Forcat: http://www.tdb.bc.ca/forcat2000.htm
The Forcat 2000 is a small tracked skidder, it is known for its ability to maneuver in tight conditions and it ability to maneuver next to stems. This skidder is only powered with a small 24-horsepower engine. The operator of the Forcat 2000 can work both tracks independently due to the transmission system. This ability gives the operator better traction and a zero degree turning radius. The Forcat 2000 is equipped with a hydraulic 8,000-pound pulling capacity winch. Logs will follow behind the vehicle. Traction is designed for hilly and wet terrain, and is designed with a high flotation system. The Forcat 2000 is rated at 2-3 psi ground pressure. It is also is fitted with a front blade to move a pile of logs.

c. KMC: http://www.kmc-kootrac.com/
The KMC 2600 is a "soft track" grapple skidder. It is equipped with a swing boom grapple so it can pick up logs on either side of the machine. It can move logs around standing trees. The KMC 2600 is specially designed to shift its weight to help reduce soil compaction. It is designed with dynamic low ground pressure.

d. Trans-Gesco: http://www.transgesco.com/
Trans-Gesco manufactures the TG88D track grapple skidder. It is equipped with a gigantic 45 square foot grapple. This model has a dual boom system, so the booms fold into themselves for improved weight distribution and gives the machine the ability to push itself out of difficult ground situations. This is a relatively cheap skidder for high volume producers. It is powered by a powerful 400 horse power Cummins engine, and is equipped with a hydrostatic drive for traction. It has exceptional maneuverability and speed. The TG88D has 80.5" bogies and track "shoes". Track shoes help lower the ground

pressure and to help the tractor work on soft grounds, deep snow, and steep slopes.

III. Yarding Systems & Equipment

A. Cable Yarding systems: http://www.vannattabros.com/iron20.html

i. High Lead Logging: A butt-rigged log will travel up the mainline to the landing; the log will be dragging on the ground to the double drum yarder. The tail block, where the haulback line is attached near the logging area, can be moved to change the direction of lines in order to drag logs from a different area. The log is elevated so it can move over obstacles with greater ease. Unlike the shotgun systems, the high lead system can work on flat grounds—not just steep slopes. This method is useful up to 800 ft generally and sometimes up to 1000 feet. The high lead systems work the best on steep slopes for dragging logs uphill.
http://www.vannattabros.com/cable2.html

ii. Shot Gun Rigging: This type of rigging system is preferred by most loggers due to the speed at which the carriage can move. The carriage speeds down the slope to the logs. Once at the log the skyline is slacked and the logs are attached to the carriage. Once they are attached, the skyline is raised and the skid line is pulled back to the yarder. Once there, the logs can be unloaded. If the yarder has a swinging boom, the yarder could just swing the boom over to the loader. If the yarder is unable to swing, then it must be placed behind the landing to allow enough room for the loader to load the logs.

a. Note: "This means that a tower is unsuitable for working down a road with a sharp drop off at the edge of the road because there is no place to set the logs while they are unhooked, which is where they can be reached by the loader. By contrast, the swing machine can be driven right up to the very edge of the cliff (actually a preferred location) with the boom actually extending out over nothing in particular, and the logs can be piled off to the side. This ability to work 'close to the edge' provides better ground clearance for the lines for any particular machine height, and this is what cable logging is all about."

b. The deflection of the skyline is the number one most important thing when it comes to this system.

c. Cable loggers will set up the system on top of the mountains, so they do not have to be set up in a creek, or a hill side, and it gives one the elevation the cable system needs for the carriage to work.

d. http://www.vannattabros.com/cable1.html

iii. Skyline logging systems:

a. Idaho Forest Products Commission website:
http://www.idahoforests.org/timber02.htm
These logging units reduce the need for skid trails. Instead of using rubber-tired skidders or tracked skidders, these skyline units drag the

logs up the slope using aerial cables called "skylines". This process is more expensive than ground skidding but it is useful for reducing soil erosion and soil compaction caused by ground skidding operations. These units are designed to sit on canyon tops or on a central road, where they drag the logs to a landing area for log storage, loading, and eventual transportation. Managers pick different locations on the road to set up these landing sites to reduce the need for large log piling areas that are expensive to create. Most importantly, these aerial cable systems help reduce the damage to the soil so the area on the slope can be reforested with greater ease. Also, the producers of these systems claim that the skyline system can remove logs from stream protection zones without degrading the water quality. The Idaho Forest Products Commission recommended for logging slopes that are less than a 30% incline, loggers should use ground skidders instead of skyline skidders. They recommend foresters should plan skid trails and landing areas that take up less than 15% of the total unit area.

iv. Skyline grapple logging system: http://www.vannattabros.com/cable4.html
Skyline logging operations can be very complicated. The operator of the system sends out a grapple hanging on the skyline to the cut logs. The logs could be thousands of feet away from the operators view. There must be spotters out near the log to tell the grapple operator how to grapple the log. Concise communication is required for this type of system to run smoothly. This method is not very productive because one could spend a lot of time tying to grapple the log and only be able to bring back a single piece to the landing area. However, it does avoid the need for choker setters and chasers, whose jobs are very hazardous.

v. "Planning Makes Skyline Logging Work" Forest Engineering Incorporated.
http://www.forestengineer.com/html/bcarticle.html
Skyline systems allow areas to be logged when they could otherwise not be due to environmental conditions. Skyline systems works well on steep slopes where feller bunchers and other skidders would otherwise fail. Planning allows loggers to cut large areas with one permit. Although planning generally takes a fair amount of time, the entire logging operation should run smoother with a plan. According to loggers, "the advanced planning also gives us some security for the future" (2).

vi. Skyline logging equipment:
   a. Bright Water forest equipment:
   http://brightwater.co.nz/bfe/taurus.html
   Bright Water Forest equipment has the TAURUS series of skyline logging systems.
      1. The TAURUS 605 is powered by a 260-330 horsepower Cummins engine and has 4 hydraulic guy winches. It is also equipped with four drums. The 605 has a fifteen meter tower

height, and a working range of 600 to 900 meters. Also, this model has a 7,000-kg maximum carrying weight.

2. The TAURUS 504 is powered by a 126 to 180 horse power Cummins engine. It also has four hydraulic guy winches and is equipped with four drums. The 504 also has a fifteen meter tower. Its working range is 500 to 800 meters, and can carry a maximum of 6000Kg.
3. The TAURUS 302 is powered by a 70 to 90 horse power Cummins engine. It has three drums and four hand guy winches. The 302 only has a seven meter tower. The working range of the 302 model ranges from 300m to 450 m. It can carry a maximum of 3,000 kg.

vii. Logging and Sawmill Journal, July 20, 2003 Helen Jenson: http://www.forestnet.com/archives/Jan_01/tech_update.htm

a. The Owren 400 yarder is a hydrostatically driven cable crane for uphill, downhill, or flat logging operations. The 400 has a reach of 350 meters to 500 meters. It is equipped with a 33.5 foot tower. It has a 13,230 pound pulling capacity. The 400 is powered by a 180-horsepower Detuz turbo diesel engine. http://www.owren.no/owren400.html
b. Global Forest Equipment produces the URUS II Universal 400 and 600 yarder. The 600 model has a 185-horsepower Cummins engine. It is equipped with a 40ft tower, and a hydrostatic winch. The 400 Model is equipped with a 140 horse power Cummins engine. The tower is 36ft tall, and also has a hydrostatic winch.
c. Madill makes the 255B swing yarder. It is powered by a 450 horsepower Cat engine, and has a 50ft tower. Madill also produces the 124 model yarder; it has a 60ft tower. It is powered by a 450 horse power Detroit Engine. It claims to have a 92,000-pound pull capacity. http://www.madillequipment.com/
d. The Skylead Logging Equipment Corp produces the C40 1600 model yarder; it is designed to pull logs either uphill or downhill. It is said to have a fast set up time. It is equipped with a 40 ft tower. They also produce the 6000 series yarder that is powered with a 150 horsepower Cummins engine and has a pulling capacity of 15,428 pounds.

B. Helicopter logging:

i. "Helicopter Logging" http://www.vannattabros.com/iron32.html

a. Helicopters are being used more and more today due to soil degradation resulting from many other logging methods. Helicopters hover over the cut logs and send a line down with some sort of choker to attach to the felled logs. Once the logs are attached to the cable, they are lifted into the air and are transported to a landing area where they are unhooked and loaded onto trucks. Once again the

environmental impacts of helicopter logging are slight, but the economic cost to the logging company is high. On average, rental costs exceed $5,000 dollars per hour, per helicopter. Another disadvantage to helicopter logging is the need for a large ground crew. People must be on the ground in the cutting area to attach each log to the cable, and people must be at the landing to unhook the logs so they can be loaded.

b. "Balloon and Helicopter Logging", http://www.forestlearn.org/forests/logc.htm
    1. Helicopters help eliminate damage done to the residual tree stand. In general, helicopters logging is expensive and must be done in good weather. Helicopters are helping reduce soil degradation but they burn considerable amounts of fossil fuels while operating. Also, the cut logs must weigh less than the helicopter's lift capacity, keeping the weight of the fuel mind; else the load will be too heavy for the helicopter to be able to lift them from the cutting site.

ii. Helicopter Logging companies:
    a. Carson Helicopter services: http://www.carsonhelicopterservices.com/
        1. Carson helicopter services began in 1958. The company currently runs eleven Super S-61 helicopters. This is a powerful helicopter with the ability to lift 11,000 pounds. The helicopter also has the capacity to carry cargo and personnel. Carson helicopters are designed to work at high altitudes and in extreme conditions.
    b. Wild Cat helicopters Incorporated: http://www.wildcathelicopters.com/forestry.htm
        1. Using smaller helicopters, they also transport personnel as well as transport logs from the cutting site to the landing. Their seasoned pilots have an "accident-free" record.
    c. Erickson Air-crane: http://www.ericksonaircrane.com/logging.asp
        1. Erickson Air-crane company has been around since 1971. They use the S-64 helicopter. They claim using helicopters eliminate the need for road construction. The Air-crane uses a powerful hydraulic grapple to snap a prepared stem off its stump and bring the entire length back to the landing.

IV. Conclusion:

There are many different methods of removing cut logs from logging sites. Some methods of skidding are better than other both environmentally and financially. Rubber-tired skidders seem to be the cheapest skidder to use, but they do not have the proper amount of traction that is generally needed to handle steep slope operations. Tracked skidders are more expensive then rubber wheeled skidders but they do have the traction needed for steep slopes. However, both of those skidder types are hard on the soil in terms of compaction and erosion. Cable yarding systems do not harm the soil near as much as the other ground methods of skidding but they are generally more complicated and labor-intensive. Helicopter yarding by far is the best method for reducing the amount of soil damage caused by excavating harvested timber, but the financial cost of using helicopters is exceptionally or even prohibitively high. Logging operations should be well-planned no matter what type of skidding/yarding method is used. The amount of soil damage caused by ground skidding methods can be reduced with designated skid trails. If managers plan landing areas properly, all forms of skidding and yarding will be more productive.