CHAPTER 1. METHODOLOGY

Experimental Approach

The experimental approach was to make repeated passes over the same landscape and measure the effects on the natural resources. More specifically, at each forest location, four loop trails were set up with uphill climbs, downhill slopes, turns, and straight sections.

Sport and utility ATVs were tested with original equipment manufacturer (OEM) tires and a non-OEM (aftermarket) tires. Only one vehicle and tire combination was used on each test section. Trail section condition was assessed prior to traffic using several soil and vegetation condition indices. Table 1 identifies the information collected and when the measurements were taken.

Riders made a fixed number of passes over the test loops. Test-loop condition was assessed and classified into three disturbance classes: low, medium, and high. The low disturbance class was characterized by litter and vegetation largely unchanged from initial conditions, with loose material less than 3 inches deep and shallow wheel ruts. Loss of litter and vegetation up to 50 percent and wheel ruts up to 6 inches deep defined the medium disturbance class. Large tree-root exposure and wheel ruts deeper than 6 inches defined the high disturbance class. When each of the test loops reached one of the defined disturbance classes, traffic ceased on that loop.

Disturbance Classes

One expectation was that wheel slip and vehicle weight would produce a continuum of disturbances from none to unacceptable. Rather than attempt to measure each structural characteristic of the natural resources along this continuum, three disturbance classes were used as defined in tables 4 and 5. The four structural characteristics within the disturbance classes are defined as:

Vegetation and Cover Conditions—Litter, vegetation, tree roots, and rocks dominate. As roots and rocks are exposed, and litter and vegetation is reduced, the disturbance condition

Table 1—Timing of trail measurements.

Measurement	Before Any Traffic Begins	Continuously	Beginning of Each Day's Traffic	During Each Day's Traffic	After Completion of Traffic
Soil relative strength			✓		✓
Soil texture					✓
Air temperature	✓	✓			✓
Precipitation	✓	✓			✓
Soil moisture					✓
Rut depth			✓		✓
Trail width			✓		✓
Vehicle speed				✓	

moves toward high. The high disturbance class is characterized by greater than 60 percent bare soil and exposed roots and rocks.

Trail Conditions—Depth of rutting and trail width are the key indicators in the trail conditions. A trail width greater than 54 inches and ruts greater than 6 inches deep are indicative of a high disturbance class.

Erosion Conditions—Rill networks and dust are used as indicators of erosion conditions. Rills on more than one-third of the trail length, sediment movement off the trail, and a dust cloud more than 6 feet high are used to indicate a high disturbance class.

Soil Conditions—The depth of the A-horizon is the soil indicator for disturbance classes. A loss of more than 50 percent of the A-horizon is cause for classifying a trail section in the high disturbance class.

Disturbance Class Matrix

The idea behind a trail-condition class matrix is well established. The Forest Service (1975) used a Stream Reach Inventory and Channel Stability Evaluation matrix with stability indicators of excellent, good, fair, and poor. There are 15 descriptions for these conditions that correspond to the proposed 9 descriptions in table 2. Using this classification matrix, the verbal description most closely matching the actual conditions on the

Table 2—Trail disturbance class matrix for trails.

Trail Disturbance Class Matrix For New Trail			
	Low Disturbance	*Medium Disturbance*	*High Disturbance*
Vegetation and Cover Conditions			
Litter and vegetation	0-30% bare soil.	30-60% bare soil.	Greater than 60% bare soil.
Tree roots	Small roots exposed.	Small roots exposed and broken.	Large roots exposed and damaged.
Rocks	No more exposed or fractured rocks than natural conditions.	Exposed and fractured rocks.	Large rocks worn around or displaced.
Trail Conditions			
Trail width (both tread and displaced material)	54 inches or less.	Between 54 and 72 inches. Some trail braiding. Evidence of width increasing.	72 inches or greater. Braided trails evident. Trail width is growing.
Trail tread/surface	Loose material up to 3 inches deep and wide.	Loose material 3 to 6 inches deep.	Loose material deeper than 6 inches.
ATV rut depth	Ruts less than 3 inches deep.	Ruts 3 to 6 inches deep.	Ruts greater than 6 inches deep.
Erosion Conditions			
Rill networks	Little or no rilling, less than 1/3 of trail between water breaks has rills.	More than 1/3 of trail between water breaks has rills.	Rills evident on more than 1/3 of trail between water breaks.
Dust	Less than 3 feet high. Traffic does not slow down. Does not obstruct visibility.	3- to 6-foot cloud. Causes traffic to slow down. Partially obstructs visibility.	Greater than 6 feet. Causes traffic to slow or stop. Very thick cloud that obstructs visibility.
Soil Conditions			
Depth of A horizon	Greater than 70% of natural.	70 to 50% of natural.	Less than 50% of natural.
TOTALS			

ground was checked, the number of checks in each class added together, and the condition class rating was determined by the total score. This procedure is illustrated in table 3.

Application of the Disturbance Class Matrix

Table 3 illustrates how the disturbance class matrix was used. An observer walks along a trail section and makes a qualitative judgment, or in a few cases a quantitative measurement, for each entry in the matrix by circling the appropriate description. After all the descriptors have been rated, the circles (disturbance class) are totaled at the bottom of each column. The disturbance class corresponding to the column with the highest total is deemed the condition of that trail section. Ties are rounded down.

In table 3 the total of the factors in the low disturbance class was five, in the medium class was three, and in the high class was one. Since the class receiving the highest total was low, the section was classified as low disturbance.

Two techniques were used for assessing changes to the natural resources as ATVs made repeated passes over the loops. The first assessment was made using the condition-class matrix described

Table 3—Example of trail disturbance class matrix for trails.

Trail Disturbance Class Matrix For New Trails			
	Low Disturbance	*Medium Disturbance*	*High Disturbance*
Vegetation & Cover Conditions			
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Tree roots	Small roots exposed.	Small roots exposed and broken.	Large roots exposed and damaged.
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Trail Conditions			
Trail width (both tread and displaced material)	54 inches or less.	Between 54 and 72 inches. Some trail braiding. Evidence of width increasing.	72 inches or greater. Braided trails evident. Trail width is growing.
Trail tread/surface	Loose material up to 3 inches deep and wide.	Loose material to depth of 3 to 6 inches.	Loose material deeper than 6 inches.
ATV rut depth	Ruts less than 3 inches deep.	Ruts 3 to 6 inches deep.	Ruts greater than 6 inches deep.
Erosion Conditions			
Rill networks	Little or no rilling, less than 1/3 of trail between water breaks has rills.	More than 1/3 of trail between water breaks has rills.	Rills evident on more than 1/3 of trail between water breaks.
Dust	Less than 3 feet high. Traffic does not slow down. Does not obstruct visibility.	3- to 6-foot cloud. Causes traffic to slow down. Partially obstructs visibility	Greater than 6 feet. Causes traffic to slow or stop. Very thick cloud that obstructs visibility.
Soil Conditions			
Depth of A horizon	Greater than 70% of natural.	70 to 50% of natural.	Less than 50% of natural.
TOTALS	*5*	*3*	*1*

above. The second assessment was made using cross-section transects. The cross-section transects were designed to measure changes to the trail tread as vehicles made passes over the loops. These measurements were taken each day at the end of the riding period. See figures 1 and 2. Three transects were placed at each of the four transect areas.

Figure 1—Transect and measurement process.

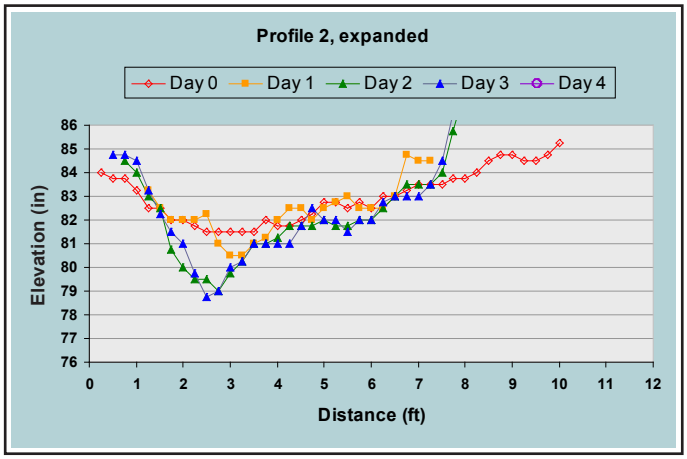

Figure 2—Example of how the information for the transect profiles was recorded on each loop at each transect.

Changes to the trail tread's vertical profile were measured by deploying a fiberglass measuring rod across the trail onto two previously leveled stakes, or plastic jacks, in rocky areas. The stakes or jacks maintained the same elevation throughout the study. It was assumed that as ATV traffic continued, the trail tread could widen. The width of the transect was set at 14 feet, and the measuring rod was placed to measure not only the vertical changes to the trail tread but also changes that occurred in the shoulder areas.

Rainfall simulation to measure erosion-prediction parameters was performed on the undisturbed class and each of the three ATV-disturbance classes. It was not important whether the disturbance class came from an uphill, downhill, straight, or turn segment. What was important was that the soil condition within the erosion test plot was determined by the vegetation cover, trail conditions, erosion conditions, and soil conditions.

The simulation consisted of measuring the runoff and sediment production from a 4-inch-per-hour, 30-minute rainstorm. This rate and duration was selected based on previous rainfall simulations on forest roads, undisturbed forest soils, timber harvest areas, and burned forest areas. The 4-inch-per-hour rate was the minimum that produced runoff on the undisturbed class. This rate also produced runoff on both the medium and high disturbance classes.

Analysis of the runoff and sediment-production data allowed calculation of erosion parameters for use in the soil-erosion prediction model known as Water Erosion Prediction Project (WEPP). This model allowed erosion prediction from each disturbance class at the test locations.

Soils Characterization

Soil samples were taken at each location. The samples, characterized using the USDA Soil-Texture Class and the Unified Soil Classification System, were typically A-horizon soils.

The characterization tests included moisture content and bulk dry density, soil texture (classification) requiring gradation analyses (sieve and hydrometer analysis) and Atterberg Limits, and shear strength testing (using a direct-shear device) to evaluate soil strength parameters cohesion and internal-friction angle. The testing provided uniform sets of results that can be compared to results from other locations.

Relatively undisturbed samples were obtained using a hand-drive sampler (2.0 or 2.5 inches in diameter) in areas generally free of coarse gravel, cobble, and shale fragments. In areas of coarse materials, grab samples were collected. All testing was performed using standardized methods in accordance with Forest Service specifications established by the American Association of State Highway and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM).

ATV Equipment

Two ATV types (sport and utility) and two tire tread types (OEM and a more aggressive aftermarket tire) were selected for this study. The ATVs appear to be the most popular. Table 4 lists the ATV characteristics used in the study.

The tire pressure, rim size, and tire width were according to ATV-manufacturers' specifications. The OEM was a general-purpose tire with lug height not to exceed ½ inch and lug width not to exceed 1½ inches. The aftermarket tire for each location was the non-OEM tire most often used by local riders and accepted by the local regulatory authorities. Consequently, different aggressive-tread tires were tested at each site.

The ATVs' speed in the test loops was defined by the 85-percent speed standard in the Manual for Uniform Traffic Control Devices. This speed standard generally equates to 10 to 17 miles per hour. Radar measured vehicle speed.

Measurement Parameters and Data-Collection Devices

Each vehicle was equipped with a data collection and recording device. Sport vehicles were equipped with AIM MyChron 3 XG Log dataloggers. This datalogger measured front- and rear-wheel speeds, lap times, lap distance, and lateral acceleration. Longitudinal acceleration was calculated from vehicle speed and distance.

Utility vehicles were equipped with AIM MyChron 3 Gold dataloggers. This datalogger measured vehicle speed based on the rear wheel. Lap times, engine speed (revolutions per minute [rpm]), and loop distances were also measured. Like the XG Log datalogger, longitudinal acceleration also was calculated. The riders viewed vehicle speed and lap times on a liquid crystal display mounted on the handlebar. See figure 3.

Table 4—ATV Characteristics

	Sport Type	**Utility Type**
Weight (pounds)	350 – 450	540 – 610
Stroke cycle	4	4
Transmission/drive	Manual or automatic	Automatic
Number of drive wheels	2	4
Final drive	Chain drive, solid axle	Shaft drive, rear differential
Front suspension type	Double A-arm	Double A-arm
Rear suspension type	Swing arm	Double wishbone

Figure 3—Datalogger.

A Hall-effect sensor measured vehicle speed. The sensor uses a magnet and a pickup that senses a small voltage each time the magnet passes the sensor. The wheel circumferences were measured and entered into the datalogger, which provided an accurate distance measurement. See figure 4.

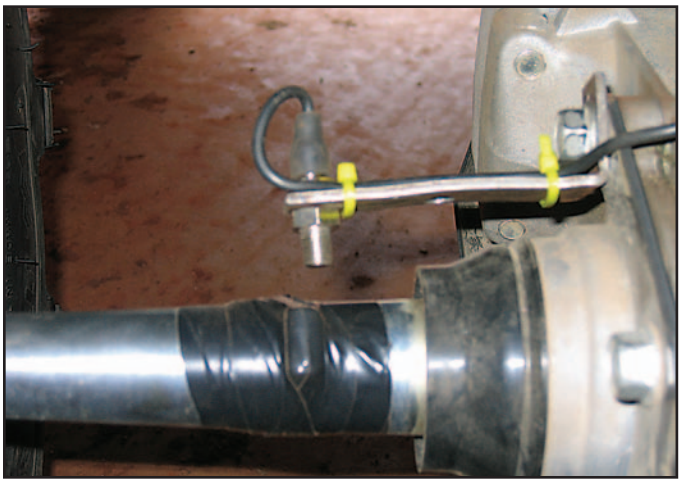

Figure 4—Hall-effect sensor.

Accelerometers, mounted behind the riders along the vehicle's centerline, measured acceleration. The accelerometers were calibrated at the start of each day. See figure 5.

Lap timers started when the datalogger received an rpm or speed signal. An infrared receptor sensed a signal from a trail beacon. A lap was complete when the sensor *saw* the beacon.

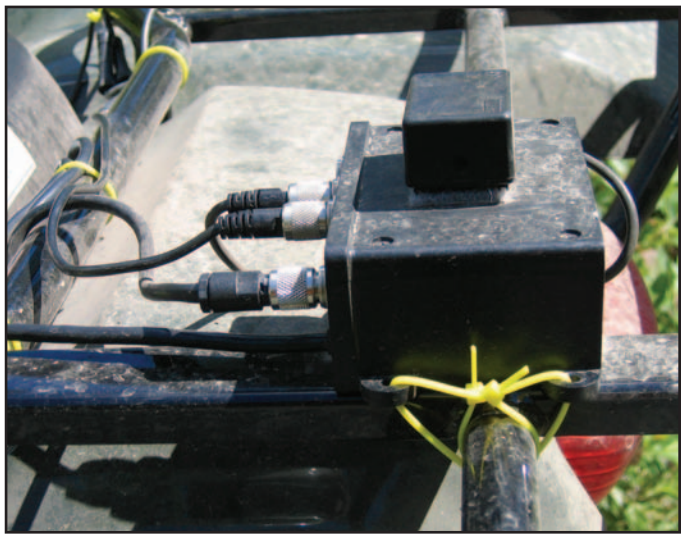

Figure 5—Datalogger instrumentation.

Datalogger data are downloaded to a laptop computer every 40 laps. Riders' names are recorded with the download data. See appendix B for additional ATV and rider information.

Test Locations

The study was conducted on seven forested areas throughout the United States representing a diverse group of ecological provinces. The locations and ecological provinces are shown in table 5.

Table 5—National forests and ecological provinces study sites.

Location	State	Ecological Province
Beaverhead/Deerlodge NF	MT	Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow
Kisatchie NF	LA	Outer Coastal Plain-Mixed Forest
Land Between the Lakes, NRA	KY	Ozark Broadleaf Forest-Meadow
Mark Twain NF	MO	Eastern Broadleaf Forest (Continental)
Minnesota State Forest	MN	Laurentian Mixed (Power) Forest
Tonto NF	AZ	Arizona-New Mexico Mountains Semi-Desert-Open
Wenatchee NF	WA	Marine Regime Mountains-Cascade Mixed Forest Coniferous/ Meadow