The Geomorphic Road Analysis and Inventory Package (GRAIP)

Volume 1: Data Collection Method

Thomas A. Black, Richard M. Cissel, and Charles H. Luce

2012 Edition

United States Department of Agriculture / Forest Service

Rocky Mountain Research Station
General Technical Report RMRS-GTR-280WWW

May 2012

Citation

Black, Thomas A.; Cissel, Richard M.; Luce, Charles H. 2012. **The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 1: Data Collection Method.** Gen. Tech. Rep. RMRS-GTR-280WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 110 p.

Abstract

An important first step in managing forest roads for improved water quality and aquatic habitat is the performance of an inventory. The Geomorphic Roads Analysis and Inventory Package (GRAIP) was developed as a tool for making a comprehensive inventory and analysis of the effects of forest roads on watersheds. This manual describes the data collection and process of a GRAIP road inventory study using GRAIP v. 1.0.8 and the field data dictionary INVENT 5.0.

The GRAIP model uses field data collected with a GPS and a specific data dictionary using drop-down menus that is designed to be imported into an ArcGIS model. The inventory data are used to describe the road-stream sediment delivery and hydrologic connectivity; gully, landslide, and stream crossing failure locations and risk; and the condition of the existing road drainage network. Point data are collected for each point where the road water leaves the road surface describing the stream connection, condition, and discharge location of the drainage feature. Detailed information is collected at stream crossings to allow for risk assessment of blockage by woody debris and sediment, as well as the potential for flow diversion. For the road, data are collected as a line describing the locations of flowing water, flow path vegetation, surface type, and the condition of the flow paths and road surface. Point data are also collected for each gully and landslide, as well as for photos, gates, and other features. This document describes the field process as well as each feature in the data dictionary. It also addresses frequently asked questions and specialized field processes used during data collection. The GRAIP road inventory and model work together to provide a flexible tool box to quantify the impacts of roads on watersheds and aquatic systems.

Available only online at http://www.fs.fed.us/rm/pubs/rmrs_gtr280.html.

THE GEOMORPHIC ROAD ANALYSIS AND INVENTORY PACKAGE (GRAIP) VOLUME 1: DATA COLLECTION METHOD

Thomas A. Black, Richard M. Cissel, and Charles H. Luce

Current as of May 9, 2012
For field data dictionary INVENT 5.0 and GRAIP v. 1.0.8

Commercial Endorsement Disclaimer

Acknowledgements

We would like to thank the following people for their contributions in developing and testing the GRAIP model and field and office procedures: Scott Bergendorf, Dan Cenderelli, Kim Clarkin, Caty Clifton, Mary D'Aversa, Cliff Fanning, Chase Fly, Randy Foltz, Leslie Freeman, Kari Grover-Weir, Jeanny Miles, Eric Monschein, Brian Staab, John Thornton, Mike Turaski, Barry Williams, Leigh Woodruff, and Jim Zokan.

The following people have helped to make the model and GRAIP processes to run more smoothly through field and office use: Katelin Alldritt, Mike Barr, Ian Bell, Blaise Bernal, Jim Bitzenburg , Nathaniel Bogie, Carolyn Bohn, Rumika Chaudry, Kate Day, Terry Dever, Michelle Fast, Laurel Faurot, John Green, Chet Hagan, Alice Hatch, Ben Holcomb, Adrianna Hummer, Laura Hutchinson, Megan Jenkins, Joe Johnson, Gail Jorgenson, Jeremiah LaRocque, Richard Lee, Dan Little, Mike Marsh, Curtis Martin, Ernesto Matal Sol, Casey McCormack, Sarah McCune, Tom McMillan, Paul Micheletty, Scott Miller, Aaron Prussian, Jake Robertson, Rachel Rowland, Erik Smith, Terry Smith, Kenyon Solecki, Matt Steiger, Matt Taylor, Tyrel Trainor, and Sarah Weeks.

Thanks also to Dan Cenderelli, Kate Day, and Aaron Prussian for suggesting improvements to the manuscript.

Table of Contents

INTRODUCTION

This introduction describes how this manual is organized, what a road inventory is, why road inventories are necessary, and the general method to use when conducting a road inventory with GRAIP.

This Manual

This manual is the first of two documents that describe all steps of a GRAIP study. This is Volume 1 and describes the field data collection process. The Geomorphic Road Analysis and Inventory Package (GRAIP) Volume 2: Office Procedures describes how to complete the office analysis portion of a GRAIP study. These manuals apply to GRAIP version 1.0.8 and the field data dictionary INVENT 5.0. Check the GRAIP website (http://www.fs.fed.us/GRAIP/index.shtml) to keep apprised of the latest versions and to download each manual.

The purpose of this manual is to describe the mechanics of collecting a data set that can be easily used in GIS to support scientifically sound watershed analyses. This manual describes the ideas behind, and how to conduct, the field portion of a GRAIP study, and provides a reference for crews in the field. The manual is organized so that the theory is presented first, followed by a step-by-step guide, and finally a description of each feature a crew might encounter in the field. Also included is a FAQ section for some confusing features, a copy of the latest data dictionary (INVENT5_0 at time of writing), and a guide to appropriate and necessary gear. The best approach is to read and understand the theory before you get to the specifics. The feature descriptions and data dictionary are most useful in the field to answer questions.

Conventions and Terms

There are some conventions used in the manual that warrant explanation. *Italics* indicate the title of an option in a menu (e.g. *Map*), a field in a window (e.g. *CONDIT*), or a button or a selection in a window inside TerraSync (e.g. *GPS* or *STRM_CROSS*). In the Glossary, **bolded** words are used for the TerraSync menu items, etc. An effort has been made to capitalize the same words and letters that are capitalized in the various menus, titles, etc. within TerraSync and the data dictionary. The symbol -> is used to indicate a series of steps that do not need further explanation (e.g. click *This*-> click *That*-> navigate to field X-> type Z, etc.). Generally, a specific series of steps is only described in detail the first time because it is assumed that you will be following the steps consecutively.

Cutslope……………….	The cutslope is the steep slope on the uphill side of a road, which is the result of the removal of hillslope material to make a flat surface for the road. See Figure 1.
Fillslope………………...	The fillslope is the steep slope on the downhill side of a road,

	which is the result of the addition of material, often from the cutslope, to make a flat surface for the road. See Figure 1.
Road prism…………….	The road prism is composed of the road surface, the cutslope, and the fillslope. It includes features like the ditch. It is the section of the hillslope, flat, ridge, etc. that has been directly affected by the construction of the road (Figure 1).
Inboard and outboard….	Refers to the sides of a road. The inboard side of the road is the cutslope side, and the outboard side is the fillslope side.
Road line……………….	The surface of the road, as seen on a map. See the Glossary for more information.
Drain point…………….	A drain point is any place along a road where water from the road flows off of the road and away from the road prism. See the Glossary for descriptions of all of the drain points GRAIP can document.
Flow path…………….	The course flowing water takes, or would take if present. Here, this is applied to the road prism, so a flow path is the course flowing water takes or would take within the road prism.
Inslope………………….	Refers to the surface of the road. When a road surface has been canted down towards the inboard side of the road so that any water on the road would flow towards the cutslope and into a ditch (if present), the road is said to be insloped. See Figure 2.
Outslope………………...	Refers to the surface of the road. When a road surface has been canted down towards the outboard side of the road so that any water on the road would flow towards the fillslope and generally out of the road prism, the road is said to be outsloped. See Figure 2.
Crowned road…………..	Refers to the surface of the road. When the fillslope side of the road has been canted down towards the outboard side and the cutslope side of the road has been canted down towards the inboard side, the road is said to be crowned. Flow paths are generally diffuse and ditch. See Figure 2.
Active channel…………	An active channel is the part of a stream channel that regularly flows water on an annual basis. In the summer, the active portion of the channel may be above the portion that currently contains water.
GPS……………………...	Global Positioning System. The network of satellites and infrastructure that provides location information to GPS-compatible antennas and receivers.
GIS………………………	Geographic Information System. A set of software and/or hardware that is used for the storage and analysis of geo-referenced spatial data.
Wheel track or wheel rut..	Parallel depressions or worn areas along the length of the road, due to the frequent travel of motor vehicles. They often route water down the road. Tracks are generally shallower than ruts.

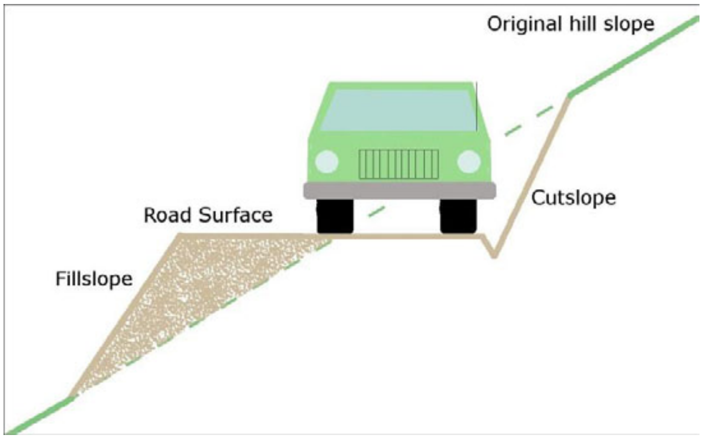


Figure 1. Diagram of the road prism (brown).

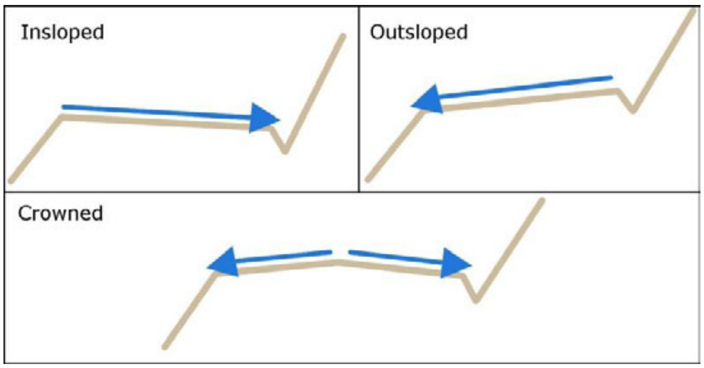


Figure 2. Diagram of the road surface angle terms.

Road Inventories

An important first step in managing forest roads for improved water quality and aquatic habitat is the performance of an inventory (USDA Forest Service 1999). Methods for making a comprehensive inventory of forest roads and analysis of that inventory for watershed analysis are needed. The design of such methods must consider how roads affect the hydrology and water quality in forested watersheds (McCammon et al. 1998).

The hydrologic and geomorphic effects of forest roads are closely linked to the linear nature of roads. Roads have a tendency to capture water and discharge it in one location. They may also route water across topographic gradients, redistributing and concentrating the flow and thereby increasing the probability of landslides, gully formation and sediment transport below the road drains (Megahan and Ketcheson 1996, Flanagan et al. 1998, Montgomery 1994, Wemple et al. 1996, Luce and Wemple 2001). Beyond the rerouting of water, roads also directly contribute sediments eroded from their surfaces to water bodies (Washington Forest Practices Board 1995, Cline et al. 1984, Megahan 1974, MacDonald 1997, Luce and Black 1999). The fundamental considerations in the design of a road inventory and analysis procedure for assessing watershed related effects of roads should focus on the questions; 1) Where are runoff and sediment generated or intercepted by roads, and 2) Where do the water and sediment go?

The inventory methods proposed in this document and analysis methods detailed in accompanying documents were designed with these principles in mind. It is expected that the GPS and GIS will be the primary tools in the implementation of the inventory and analysis. Because there are errors in location information from GPS and in digital elevation models, some redundancies are built into the procedure to ensure that water movement is specified in the field.

Road inventories completed in this manner are a valuable tool for prioritization of road maintenance and watershed restoration efforts. They are probably one of the least expensive tools applied to the problem of road maintenance and restoration. Engineers, hydrologists, biologists, foresters, and road managers from federal agencies and private forestland companies have eagerly used data collected with these methods for many projects.

General Method

There are two general scales at which to apply the GRAIP method. The principal method is to inventory all of the roads in a watershed, with the goals of determining where problems are located, so that they can be fixed, and quantifying the sediment risks and mass wasting risks that are associated with the road network in that watershed (e.g. Nelson et al. 2010, Fly et al. 2010). The secondary way is to apply GRAIP on a small scale as a project monitoring tool (e.g. Cissel et al. 2011, Black et al. 2009). A road or set of roads is inventoried before and after a road treatment (such as decommissioning or water-bar installation) in order to determine the effectiveness of that treatment. In this second method, untreated control roads that have similar properties to the treatment roads are also inventoried so that the effectiveness of the treatments can be gauged by re-inventorying all of the roads after a large storm event.

The primary goal of a road sediment inventory is to document the sources of sediment and how they interact with the road and are ultimately routed to the hillslope and stream network. It is useful to break the road drainage system up into three components. We examine the road prism and ditches as one component of the system, where much of the water and sediment are generated. Points where the flow is diverted off of the road are examined as the second component to determine where they occur and how they function. The third component examines the type of surface and flow path where the water is discharged below the road drain point. Basic information about the hillslope flow path below the discharge point will allow us to make inferences about the sediment delivery to nearby streams.

This method is designed to quantify the rate of surface erosion related to overland flow of water. It can also be used to assess the risk of mass movement, gullying, and stream capture. The GRAIP inventory also provides an updated map of the extent of the road network and an inventory and condition map of road assets such as culvert pipes, water bars, gates, and road closures. It is possible to use this inventory opportunity to provide a first order assessment of fish passage potential at stream crossing culverts. Significant improvement in fish passage assessments may be achieved by application of a more thorough inventory and analysis procedure such as Fish Xing (Clarkin et al. 2005).

When a road inventory is conducted for watershed analysis, the road network will likely include multiple ownerships. The quality and extent of available data on roads may vary dramatically by ownership and region. Due to these limitations of data availability on forest roads and their hydrologic properties, we have chosen to utilize a GPS device to collect the location information on point and line features associated with the road network. Predictions of road sediment production are made for each road segment utilizing the information on road attributes, condition, length and slope. These predictions are made based on either locally collected sediment plot data for typical road segments (Luce and Black 1999, Luce and Black 2001) or values from comparable regions available in the literature (Megahan and Kidd 1972, Megahan 1974, Reid and Dunne 1984, Swift 1984, Bilby et al. 1989, Ziegler et al. 2001). An outline of a simple method for setting up local road erosion plots is available (Luce and Black 1999).

The road network is divided into road line segments, where the entirety of that road segment shares the same condition attributes. The data dictionary allows for a thorough documentation of the parameters of the road (see Road Line Features in the Glossary of Features section). The attributes of the road line, such as the surface type and flow path vegetation percentage, are divided into classes in the appropriate menu. The road line is ended and a new segment begins when a new drain point is encountered, a grade reversal occurs, or one of the attributes changes from one class to the next. The road line describes three types of information; 1) the location of concentrated flow on the road (flow path, e.g. ditch location), 2) the drainage feature receiving discharge from that road segment, and 3) the physical condition of the road prism.

In order to follow the flow path of water and sediment on the road from start to finish, it is useful to begin data logging at the point where the water exits the road. In mountainous terrain this generally occurs at designed features such as culverts, stream crossings and lead off ditches. In terrain that has a low gradient and on roads without designed ditches, water may exit the road more frequently in the form of unchanellized flow or small rills. At each road drainage feature, evidence is collected documenting the ultimate destination of the water as it encounters the hillslope (whether or not the water reaches a stream). Each drain point is associated with the contributing road segments using the time stamp given when the drainage feature is opened. As the inventory progresses up the road network from this drain point all road line segments that route water to this point will be assigned this tracking number. It is helpful to begin data collection at the drain point and move upwards through the network. In this way the inventory is structured around the drainage features, and no road segments are left without a drainage destination.

SECTION I: THE GRAIP PROCESS

This section describes how to conduct the field portion of a GRAIP study. The necessary gear, the data collection program (TerraSync), and data organization are described in addition to detailed instructions that can be followed in the field.

Field Gear

For more information on field gear, see Appendix E: More Details on Field Gear. There are quite a few items that are necessary to bring to the field for a GRAIP study. You will need a GPS receiver that is capable of about 2 meter resolution and that meets the U.S. National Map Accuracy Standards, a roof and backpack mountable antenna, and a data recorder to accompany it. The data recorder can be either a laptop, recommended for roads that can be driven, or a handheld field computer, recommended for roads that must be walked. TerraSync v. 3.0 or higher is required on the data collector. An in-vehicle mount is useful to hold the laptop without sliding, and a trackball or hand-held mouse is usually better than using the laptop touchpad.

For taking stream crossing data, you will need a 25 ft stadia rod in tenths of feet, and an accompanying hand level with stadia lines. You will need a 20 ft or longer measuring tape, a digital camera, and a waterproof field notebook and pen or pencil. Two-way radios are useful for inter-crew communication when the crew members are separated. A rangefinder that can tell both distance and angle is useful. A detailed map of the field area is required. Flag tape makes it much easier to know where a crew stopped data collection at the end of a day, and can be used for other purposes. USB flash drives are an easy way to transport data to the office. Backup and spare batteries that are fully charged will be necessary.

Bright safety vests are especially useful during hunting season, and hard hats are a good idea (or required) in many locales. A hand saw and an axe or Pulaski can prevent a crew from getting stuck on the wrong side of a newly fallen tree. Gloves are useful in field areas with thorny vegetation. Tire chains and basic tools for the field vehicle are a good idea. The field vehicle itself should have high ground clearance and four-wheel-drive, as well as lockable space to store all gear, and tires that can stand up to driving on rocky and rough forest roads. Short-wheelbase vehicles are best due to their better maneuverability.

Safety

Safety is a critical concern in an operation requiring large amounts of driving on forest roads. Stay alert for log trucks and other traffic. Check for postings on active haul roads indicating what CB channel the trucks are using. Monitor their CB channel if possible and announce your presence and location. Be aware of other forest road traffic.

When it is necessary to stop on a road with the possibility of traffic, use caution, listen for vehicle noise and stay visible to oncoming traffic. Use the hazard lights and stay to the shoulder if possible. A roof mounted flashing beacon has been used in areas where visibility is poor and heavy truck traffic is expected. Orange "Survey Crew" road signs located no more than 1 mile from your location on the road will alert other traffic to your presence.

Be careful when collecting data on closed or decommissioned roads. Excavated stream crossings are sometimes deep, steep, and muddy. Carry a radio or satellite phone in the case of an emergency. Additionally, stream crossings on open roads are sometimes steep, and the fill around any culvert may not be stable. Carry a two-way radio that you can use to communicate with the other member of your crew when one person is out of sight or hearing of the other. During hunting season, wear bright clothing. Check in with a supervisor every night with a radio or satellite phone.

Quality Assurance and Quality Control

Efforts have been made to make the data collection process as simple and objective as possible. Subjective judgments are minimized by the drop-down menu style of data entry, as well as the clear definitions given to the data features and attributes. However, even with these measures in place, it is necessary to ensure that each crew and individual is consistent over time, with one-another, and with an expert-defined standard. A previously used quality assurance plan can be obtained via the GRAIP website (http://www.fs.fed.us/GRAIP/downloads/manuals/GRAIP_Field_QAPP_May13_2009.pdf).

Intercrew data issues can include differing road surface type, flow path, percent vegetation, and stream connection interpretations. A good way to minimize these issues is to attend a training session put on by the Boise Lab of the Rocky Mountain Research Station. Additionally, other measures should be implemented throughout the field season.

Other measures can include "quality assurance" roads, where an expert inventories 2-3 miles of road, and then each crew repeats that segment. This data should be collected within a narrow window of time to assure road conditions remain consistent and be quickly analyzed, so that intercrew differences can be exposed and corrected.

Expert ride-alongs are a good idea, where an expert observes each crew as they work along a road, and advises and corrects their judgments. Experts should evaluate and advise on all aspects of the inventory process, but especially concentrate on stream connection, correct flow paths, vegetation cover percent, road surface type and flow routing. Experts should be experienced GRAIP field personnel, and have completed at the least a GRAIP training at the Rocky Mountain Research Station in Boise, ID, as this will ensure the best data consistency between otherwise unrelated GRAIP projects.

In a road project monitoring study, where each road is surveyed twice (before and after a treatment is applied) and untreated control roads are used, then the crew that collects the post-treatment data should also re-survey 2-3 miles of the control road, which generally remains the same over time. This data can be used to compare the pre-treatment and the post-treatment crews, to ensure that the data is fully compatible. Also, for these project monitoring studies, if the entirety of the road has not been altered (tilled, ripped, re-graded, etc.), such as if the treatment was the installation of new water bars, then the post-treatment crew should have the data that the pre-treatment crew collected with them so that they can reference it and make sure they agree.

General Field Procedure

Before leaving the office, plan the travel route for the day. It is difficult to predict road inventory mileage on any given day. Daily mileage is affected by many variables, including road conditions, GPS reception, and variability in the road parameters. An average production rate of 2-3 miles per day has been typical, but the range has been less than 1 mile to nearly 10 miles. It is useful to start and finish the day at a major drain point such as a ditch relief culvert. Hanging a flag at the last logged point is also a useful reminder.

The data dictionary is the interface that allows inventory data to be associated with the GPS location information. Upon reaching the field area, start TerraSync on the data recorder (laptop or handheld field computer) and open a new data file. The file will automatically be assigned a name based on the date and time the file was opened. Note this name in the field notebook, along with the road that it is associated with. Select the most recent or most appropriate data dictionary.

Once TerraSync is running, the computer makes a connection with the GPS receiver and is ready to begin gathering data. Detailed instructions are given later in this section. The Glossary section contains explanations of all of the attribute names and what they describe.

The data collection process begins at a drain point, moves through the road network draining to that point and is completed when all of the segments leading to that drain are described. To begin the inventory, move the vehicle to the desired road drainage feature. With a new data file open, create the appropriate drainage feature and begin to describe it using the drop-down menus in TerraSync. When a feature is created, the GPS unit begins logging position points immediately. For each feature recorded, there are a number of attributes for which values must be entered. Most of the attribute values are menu-based. The data dictionary supplies a limited set of choices and you must pick the one that best describes the situation. The CTime, CDate, and Vehicle ID fields are filled in automatically, and are used to associate each drain point to one or more road segments.

Point features are adequately located by collecting 60 GPS locations. This takes 60 seconds under ideal conditions and can take significantly longer depending on the topography and canopy closure. It is sometimes necessary to move the vehicle up or down the road a few feet to allow the antenna to receive the satellite's radio signal through the canopy. The default for minimum position numbers is set in the data dictionary, and some non-drain feature values may be set with minimum numbers less than 60. Close the drain point when enough GPS locations have been collected.

Once the initial drain point or points are collected, create the new road segment that drains to the drain point or points. Describe the new road segment using the drop-down menus in TerraSync, as above. Each road segment must be associated to a drain point using the CTime CDate, and Vehicle ID from that drain point. The CDate and Vehicle ID in the road segment are filled in automatically (because neither will change over the course of a day), but you have to enter the CTime of the drain point or points that the road segment drains to manually. This field must be entered as a four-digit numeral (e.g. *0935*, *1654*; *935* or *blank* will not work) and must be a valid time (e.g. *6581* will not work). The only valid non-time, non-four-digit entry is *999*, which can be used as a placeholder (note that *9999* will not work).

Line features, which are collected while moving, are composed of connected single GPS locations that are collected once every three seconds. If the GPS receiver stops collecting points because of non-ideal conditions, stop the vehicle and wait for the GPS receiver to begin collecting again. If it takes a long time for the GPS receiver to begin collecting locations, it may be necessary to move the vehicle slightly further down the road. When the grade direction changes, a new drain point is encountered, or one of the road attributes changes, you must start a new road segment. In addition to describing the flow path of the water, the road line feature describes the type of road surfacing, the percentage cover of the surfacing, and the condition of the segment. The line contains information on the cutslope height and condition where applicable.

A single drain point can drain multiple road segments. Often, a single flow path continues through multiple road segments before it terminates at a drain point. Two drain points that drain two flow paths on the same set of road segments are not always located at the same place, and this leads to complicated and interrelated sets of road segments and drain points.

The road line feature records the flow path of the water in the road prism and describes the condition on the road surface, cutslope and ditch. Many roads are not constructed with a ditch, yet water is still confined on the road prism by wheel ruts or by a berm. The flow path vegetation and flow path condition can then be applied to the road itself, or water flowing against a berm. Each road segment must be 20 meters or more in length. If a road attribute is not consistent for 20 meters, it is lumped in with neighboring values. For example, if the road has a surface type of native for most of the 70 meter segment, but changes to gravel surface for a 15 meter section, the road would still be classified as native, and no new segment would be collected. This spatial averaging allows the dominant type to be recorded without dwelling on the finest scale variability.

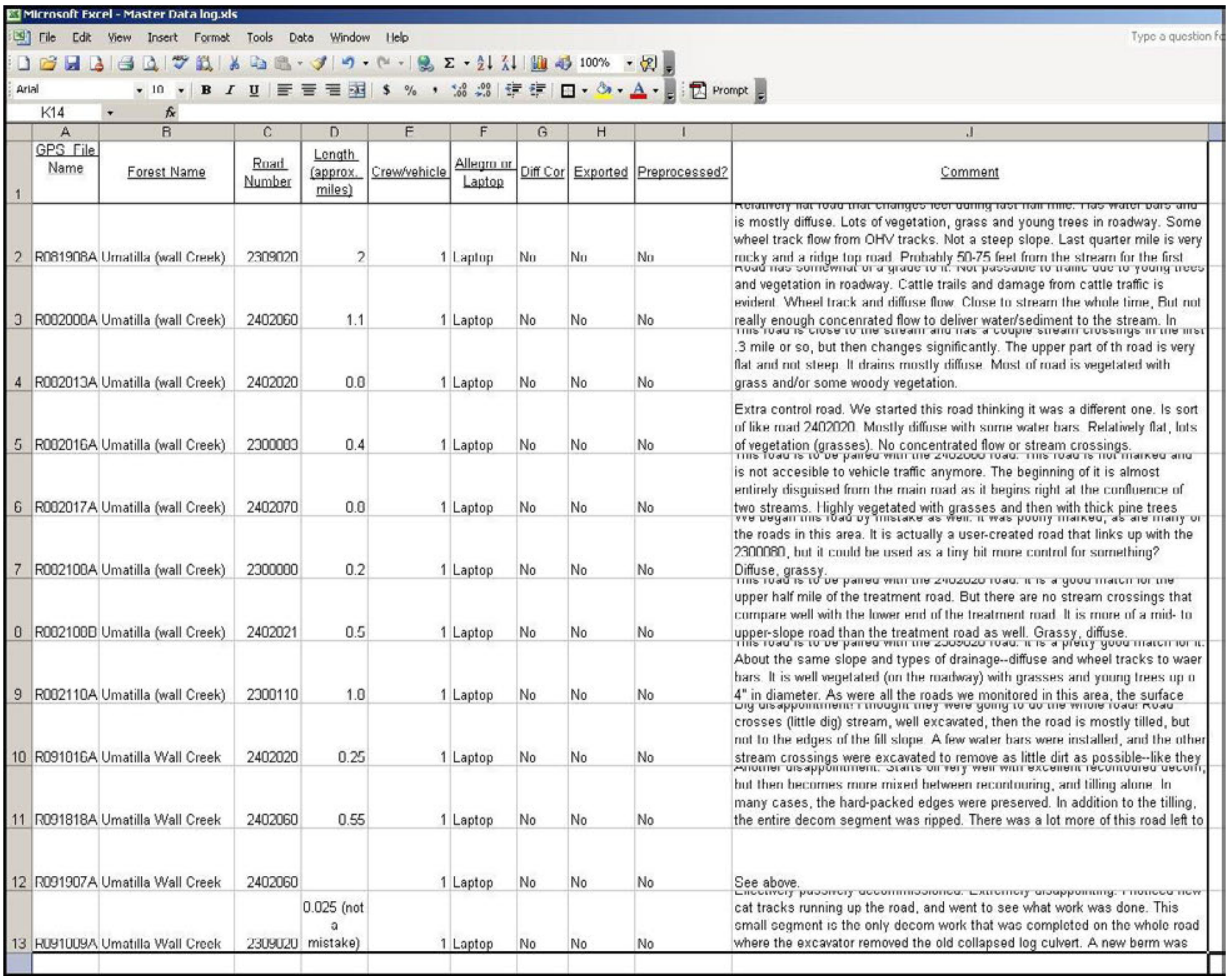
Nine road hydrologic features are used to describe the way in which water leaves the road prism (the drain points). These are Ditch Relief Culvert, Stream Crossing, Lead-Off Ditch, Waterbar, Broad Based Dip, Non-Engineered Drainage, Sump, Diffuse Drainage, and Excavated Stream Crossing. Stream-crossing culverts are separated from ditch relief culverts because they perform different functions. Streams have channels maintained by flowing water for some part of most years. Stream crossings allow water collected from the drainage basin to pass under the road. Ditch relief features collect runoff from the road prism and ditch and pass it below or away from the road. There is a variation on the stream crossing feature called the Excavated Stream Crossing, which is a stream crossing on a decommissioned road where the culvert pipe has been removed. This is not the same as a stream ford.

When you reach the end of a road, close the TerraSync file (also called a rover file), making sure you have noted which road that file contains in the field notebook (by road number). Begin a new TerraSync file for the next road. If you finish the day in the middle of a road, flag the spot at which you stopped so that you can easily find it the next day. The data for each day or week should be preprocessed to check for errors (see

Volume 2: Office Procedures). If there are errors that cannot be reconciled in the office, the field crew should return to the location of the error in order to fix it.

Organizing and Keeping Track of Data

Many data files are generated over the course of a GRAIP inventory. Each road has one or more associated TerraSync files, and each TerraSync file is composed of eight to nine separate files with different extensions. As such, it is extremely important to have a system in place for keeping track of which TerraSync file goes to which road or segment of road, as well as the state of that data (i.e. if the data is raw, preprocessed, etc.), what equipment was used to collect the data, which crew collected the data, the length of the road in the data, and comments about the type and condition of the road. Figure 3 shows an example spreadsheet that associates all of these things.



	GPS File Name	Forest Name	Road Number	Length (approx. miles)	Crew/vehicle	Allegro or Laptop	Diff Cor	Exported	Preprocessed?	Comment
2	R081908A	Umatilla (wall Creek)	2309020	2	1	Laptop	No	No	No	is mostly diffuse. Lots of vegetation, grass and young trees in roadway. Some wheel track flow from OHV tracks. Not a steep slope. Last quarter mile is very rocky and a ridge top road. Probably 50-75 feet from the stream for the first
3	R002000A	Umatilla (wall Creek)	2402060	1.1	1	Laptop	No	No	No	and vegetation in roadway. Cattle trails and damage from cattle traffic is evident. Wheel track and diffuse flow. Close to stream the whole time, But not really enough concenrated flow to deliver water/sediment to the stream. In
4	R002013A	Umatilla (wall Creek)	2402020	0.0	1	Laptop	No	No	No	.3 mile or so, but then changes significantly. The upper part of th road is very flat and not steep. It drains mostly diffuse. Most of road is vegetated with grass and/or some woody vegetation.
5	R002016A	Umatilla (wall Creek)	2300003	0.4	1	Laptop	No	No	No	Extra control road. We started this road thinking it was a different one. Is sort of like road 2402020. Mostly diffuse with some water bars. Relatively flat, lots of vegetation (grasses). No concentrated flow or stream crossings.
6	R002017A	Umatilla (wall Creek)	2402070	0.0	1	Laptop	No	No	No	is not accesible to vehicle traffic anymore. The beginning of it is almost entirely disguised from the main road as it begins right at the confluence of two streams. Highly vegetated with grasses and then with thick pine trees
7	R002100A	Umatilla (wall Creek)	2300000	0.2	1	Laptop	No	No	No	the roads in this area. It is actually a user-created road that links up with the 2300080, but it could be used as a tiny bit more control for something? Diffuse, grassy.
8	R002100B	Umatilla (wall Creek)	2402021	0.5	1	Laptop	No	No	No	upper half mile of the treatment road. But there are no stream crossings that compare well with the lower end of the treatment road. It is more of a mid- to upper-slope road than the treatment road as well. Grassy, diffuse.
9	R002110A	Umatilla (wall Creek)	2300110	1.0	1	Laptop	No	No	No	About the same slope and types of drainage--diffuse and wheel tracks to waer bars. It is well vegetated (on the roadway) with grasses and young trees up o 4" in diameter. As were all the roads we monitored in this area, the surface
10	R091016A	Umatilla Wall Creek	2402020	0.25	1	Laptop	No	No	No	crosses (little dig) stream, well excavated, then the road is mostly tilled, but not to the edges of the fill slope. A few water bars were installed, and the other stream crossings were excavated to remove as little dirt as possible--like they
11	R091818A	Umatilla Wall Creek	2402060	0.55	1	Laptop	No	No	No	but then becomes more mixed between recontouring, and tilling alone. In many cases, the hard-packed edges were preserved. In addition to the tilling, the entire decom segment was ripped. There was a lot more of this road left to
12	R091907A	Umatilla Wall Creek	2402060		1	Laptop	No	No	No	See above.
13	R091009A	Umatilla Wall Creek	2309020	0.025 (not a mistake)	1	Laptop	No	No	No	cat tracks running up the road, and went to see what work was done. This small segment is the only decom work that was completed on the whole road where the excavator removed the old collapsed log culvert. A new berm was

Figure 3. An example field data tracking spreadsheet.

Each field crew should use a waterproof field notebook to note which file goes with which road whenever a new file is created. Each road should also receive a comment on its condition and type. At the end of the day or week, the relevant data files should be transferred to an office computer for the initial preprocessing and error checking (see Vol. 1: Office Procedures). In the office, the information about the data should be added to a master data log file (Figure 3), and any errors that cannot be resolved in the office should be noted on a map so that the field crew can go back to that spot.

The TerraSync files are created with the name format RmmddhhA, where mm is the month, dd is the day, hh is the hour (in 24-hour time), R stands for Rover, and A stands for the file sequence within the hour. So, the TerraSync file R062915A was created on June 29, between 3 pm and 4 pm, and R062915B was created during the same hour, but after R062915A. The file name can be edited or changed before it is created, so the files from each crew can be distinguishable if more than one crew created a file during the same hour on the same day. The easiest thing to do is add the crew number to the default name, so R062915A2 was created by crew 2.

Using the above naming method, every file name will be unique, and can be referenced to the road it contains by using the spreadsheet in Figure 3. As such, the file system used for keeping track of the raw data files for a project is simple. Put all raw data files for a certain project or watershed in the same folder, named to make it clear which project or watershed the files refer to. It is a good idea to put the year of collection in this folder name, because the TerraSync files do not reference the year. See Vol. 1: Office Procedures Section 1 for more details on organizing raw and other files.

If a watershed-scale inventory is being conducted, it is a good idea to have a map of the watershed with all of the roads on it. As each road is completed, that road and its inventory crew should be marked on the map to indicate that it is complete. Highlighters of different colors (for the different crews) are good for this.

If GRAIP is being used as a road treatment monitoring tool, there are additional columns for the master data spreadsheet. The name of the forest, project, or watershed should be included with each road entry. The type of treatment (e.g. decommissioning, water-bar installation, control) should be noted as well. The comments for each control road should include whether or not the selected control is suitable for its treatment pair.

The comments for each road should include the surface type, the condition of the surface, what typical flow paths and drain points are, whether the road is stream-side or not, slope position, vegetation cover in flow paths, if the road is open to highway vehicle traffic or not, and if the road is well-used or not. Also include anything unusual about the road, such as if there are a lot of gullies or landslides along its length, or if the road is covered in small trees or anything else that might cause it to be difficult to discern flow paths or drain points.

Using TerraSync

TerraSync is the program that interfaces between the GPS receiver and the data recorder. Note that not all GPS receivers and antennas are compatible with TerraSync. The GPS receiver and antenna are generally controlled by TerraSync, running on the data recorder. Additionally, TerraSync, coupled with the correct data dictionary, is what is used to collect and record data. The data dictionary is the interface that allows inventory data to be associated with the GPS location information. It is extremely important to maintain the integrity of the data dictionary values as the GRAIP model is sensitive to small changes in the data dictionary. Trimble TerraSync v. 3.0 or newer is required. TerraSync is available via the Trimble website (www.trimble.com). Follow the instructions available there to install the program. You will have to set up the program before use. Place the data dictionary file (e.g. INVENT5_0.ddf) under C:\My Documents\TerraSync.

When you open TerraSync, you will notice that the screen is divided into three parts. In the upper left-hand corner of each part is a drop down menu that lets you choose between five different windows (Figures 4 and 5). Displaying by default are the *Data* window, the *Status* window, with the *Skyplot* option showing, and the *Map* window. Note that many field data recorders have a small screen and cannot display more than one of these windows as once.

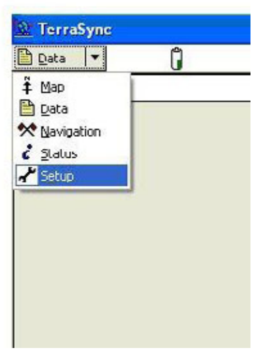


Figure 4. The drop-down menu that lets you change between TerraSync screens. There is a similar menu in the upper right-hand corner of each of the three windows.

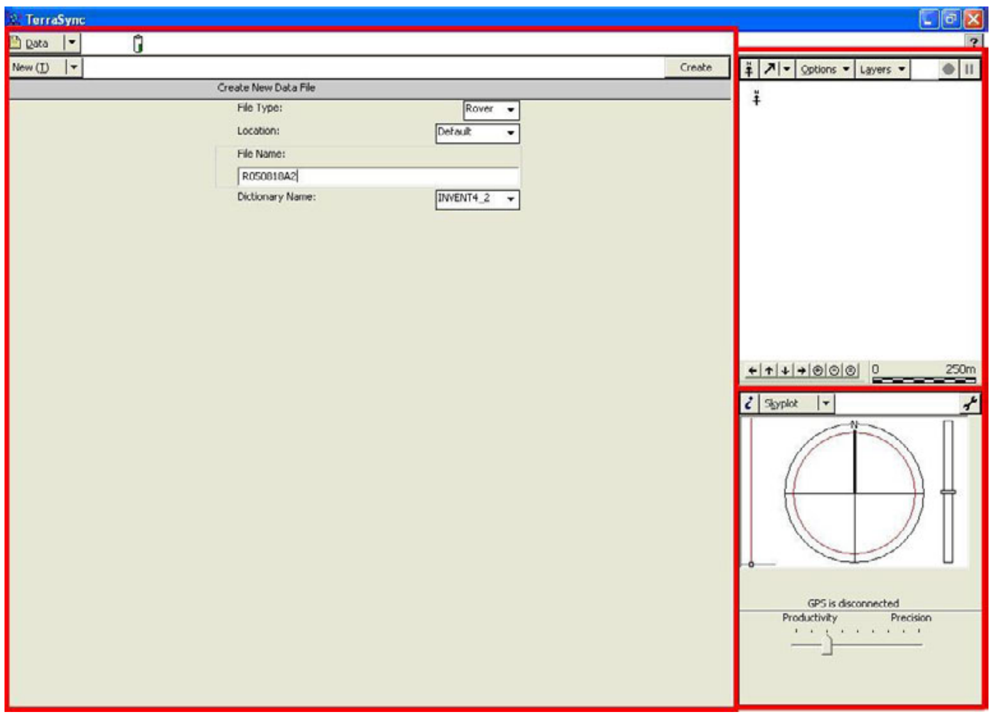


Figure 5. The three windows of TerraSync.

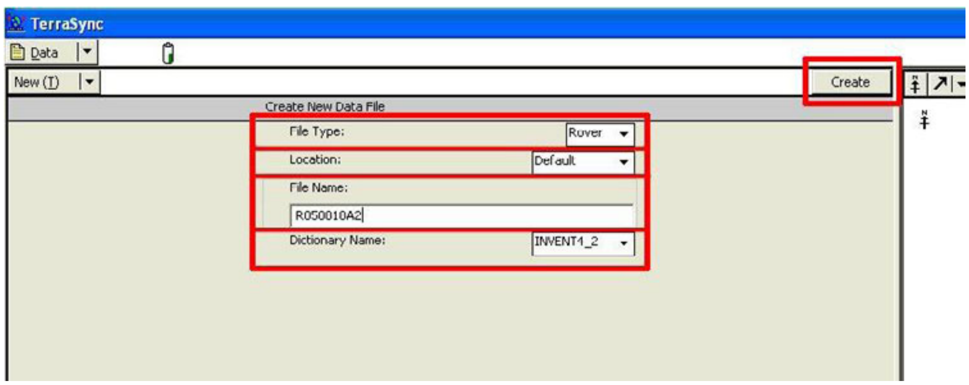
The *Data* window is the main window where you will enter data, modify features, and open and create data files. The *Status* window shows data about the satellites that the GPS receiver has detected or could or should detect. The *Skyplot* screen, selectable by clicking the drop-down to the immediate right of the *Status* drop-down symbol, shows a radar-style map of the locations and status of each of the satellites detected by the GPS receiver. You can change maximum PDOP setting with the slider bar under the *Skyplot* map (PDOP is discussed below). The *Map* window shows a map of the data collected for whichever file is open, as well as your current location (if the GPS receiver and antenna are connected and running). There are different tools and options that can be used to manipulate the map, selectable from the three drop-down menus to the right of the *Map* drop-down symbol. The *Navigation* window can be used to set way-points and perform other navigation functions, but this will probably not be necessary during a GRAIP study. The *Setup* window allows you to change the settings of the program and GPS receiver.

For more information about using TerraSync, see the TerraSync reference manual, or seek help via the Trimble website. For additional information about your GPS receiver and your data recorder, see the appropriate manuals or seek help online. Those manuals and online help resources will also have more information on GPS in general. Instructions below are specific to TerraSync 3.0/4.0 and may differ slightly for newer or older versions.

To set up TerraSync:

1. Open TerraSync and go to the *Data* window (the largest part of the screen).

a. Use the drop-down menu next to *File Type* to select *Rover*. Set *Default* as *Location*. Select the relevant data dictionary next to *Dictionary Name*.



b. Use the default *File Name*, but add the crew number to the end.

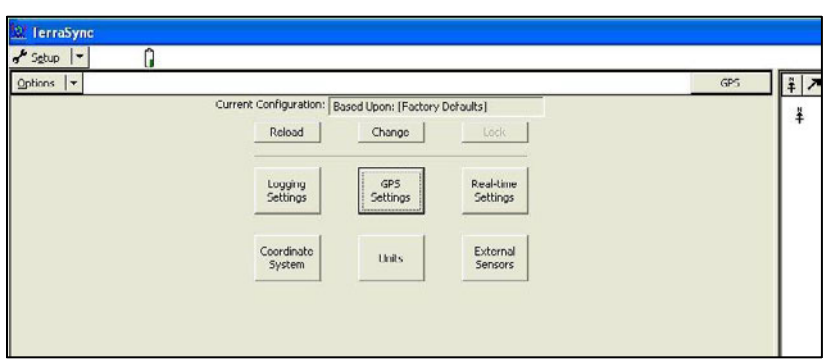
i. The default R061208A becomes R061208A1 if crew 1 creates the file.

c. Click *Create* in the upper right part of the window to create the new file.

i. A message box will appear that says *Confirm Antenna* Height in the header. The field inventory is not sensitive to accurate elevation data, so there is no need to measure the actual antenna height. Estimate a height, enter it in the *Height* field, and leave the *Measure To* field as default. Click *OK*.

ii. The *Collect Features* screen appears in the *Data* window.

2. Go to the *Setup* window by clicking the *Data* window drop-down in the uppermost-

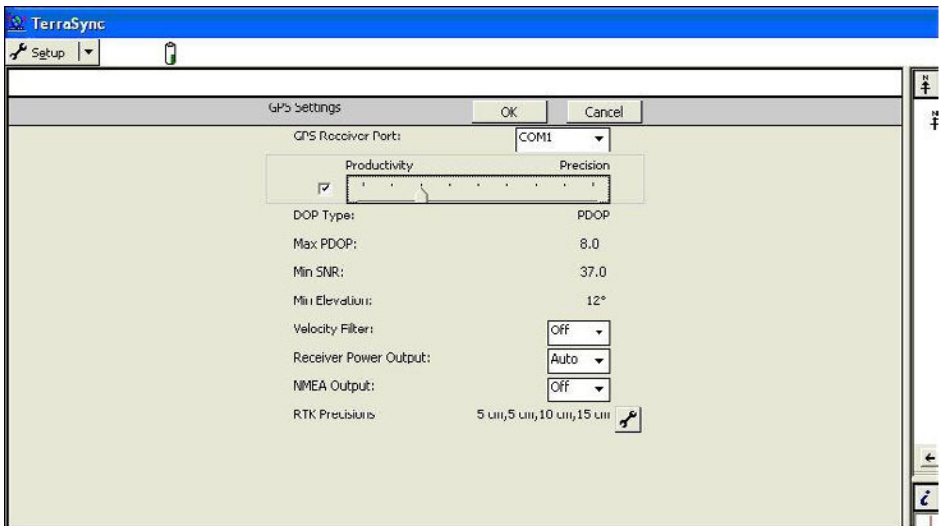


leftmost corner of the screen and selecting *Setup*.

a. Click on *GPS Settings*.

b. Select the correct *GPS Receiver Port* to select the correct COM port.

i. If you have connected the GPS receiver with a serial cable, select either *COM1* or *COM2*. If you have connected the GPS receiver via Bluetooth, you will have to find the correct Bluetooth COM port in a Windows Control Panel. See the GPS receiver or data recorder manual for assistance or seek help from the GPS receiver manufacturer or data recorder manufacturer.



c. The sliding bar with *Productivity* on one end and *Precision* on the other end controls the maximum allowable PDOP and minimum allowable signal to noise ratio (SNR). Lower PDOP and higher SNR results in more accurately located data. You can see the current settings for each of these in the field underneath the sliding bar.

i. The ideal PDOP maximum setting is 6.0. However, in many locations, it is not realistic to use that setting, because topography and canopy cover are such that the PDOP will rarely get below 6.0. For this reason, set the maximum allowable PDOP to 8.0 by sliding the bar until *8.0* is next to *Max. PDOP*. The *Min. SNR* should be *37.0*.

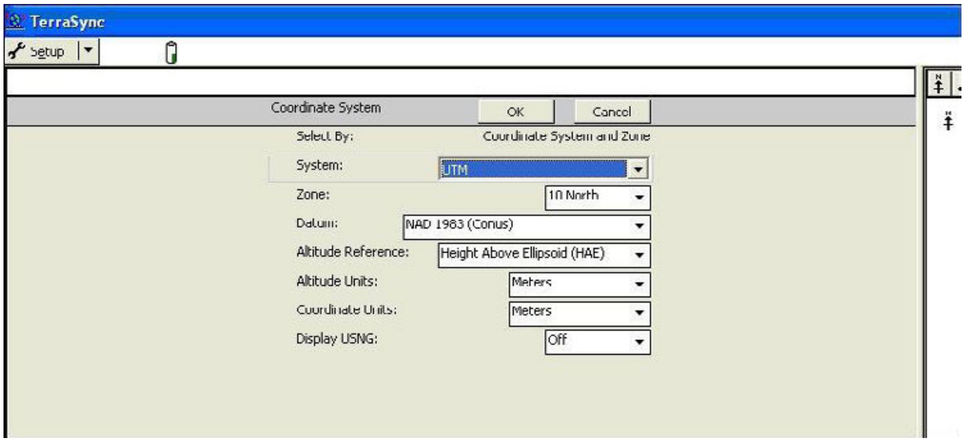
ii. In some places, even a maximum PDOP of 8.0 not enough to collect data. In these cases, move the slider bar until the *Max. PDOP* is *12.0*, but do not go above that value.

d. The other three drop-down menus can be left as default.

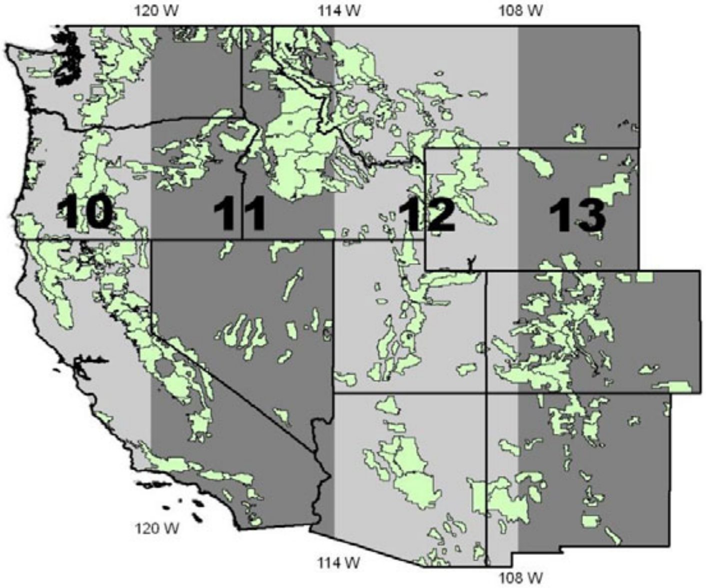
- **i.** The default for *Velocity Filter* is *Off*, for *Receiver Power Output*, *Auto*, and for *NMEA Output*, *Off*. Leave *RTK Precisions* as the default, as well.

e. Click *OK* in the top center part of the window to return to the main *Settings* menu. Click on *Coordinate System*.

- **i.** Field data should be collected in the same coordinate system and datum as the DEM that will be used for the project. In most cases this will be Universal Transverse Mercater (UTM) in the North American Datum of 1983 (NAD 1983).



  – To select the above settings, select *UTM* in the *System* field as the projection. Consult a map of the UTM zones to locate your zone, and select it next to *Zones*. Boise, Idaho is in UTM zone 11 North. In the *Datum* field select *NAD 1983 (Conus)*, assuming you are working in North America. Select *Height Above Ellipsoid (HAE)* next to *Altitude Reference*, and *Meters* for both *Altitude Units* and *Coordinate Units*. Select *Off* for



Display USNG.

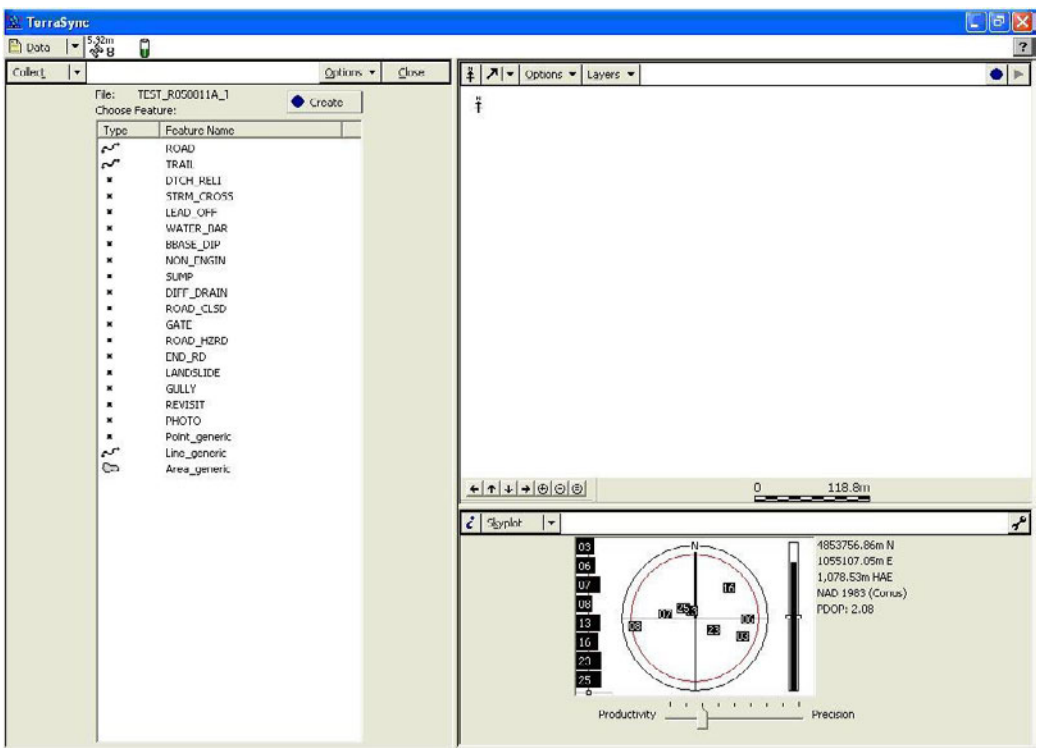
f. Click *OK* in the top center part of the window to return to the main *Settings* menu. Leave everything else as default. The important settings are now set.

g. Connect to the GPS receiver. Click *GPS* in the upper-right corner of the *Settings* window. This will connect to the GPS receiver if the receiver is on and the COM port is selected correctly. It may take a few seconds. A little cable connection icon will flash next to the *Setup* window drop-down menu as it connects. It will stop flashing and turn into a satellite icon when connected.

i. Wait for the receiver to begin receiving signal from GPS satellites (the number next to the satellite icon which is next to the *Settings* drop-down menu indicates how many satellites you are receiving good signals from).

3. Go back to the *Data* window. You can now begin collecting data.

4. You can change the relative size, both vertically and horizontally, of each of the windows.



a. Move the mouse over the divider between the windows until the icon changes to two parallel lines with arrows. Click and drag until the window is the appropriate size.

   b. You may want to make the *Map* window larger.

5. You can edit the data you have collected in each file, including deleting features or changing attribute values in features.

   a. From the *Data* window, click the drop-down menu that says *Collect*, and click *Update Features*.

   b. From here, you can select features and edit their attributes (click the *Begin* button) or delete them (select them, click the *Options* drop-down, then click *Delete*).

Satellites

GPS systems are only as easy to use as GPS satellites are to find. There are a number of things that can get in the way of a good GPS signal to your GPS receiver. Steep topography limits the GPS antenna's view of the sky in an absolute way. If a satellite is behind a ridge, you will have to wait for it to move into view, wait for another satellite to move into view, or come back later. Dense canopy cover can also limit the GPS antenna's view of the sky. However, there are often enough holes in the canopy to allow the GPS antenna to see a hidden satellite if you move the antenna a little in one direction or another. Water droplets on leaves have a similar effect. In some places two or all of these obstructions combine to make it almost impossible to collect any data. At least four satellites with good enough reception are required to take data.

There are some tricks that might result in better reception. If you encounter poor reception, the first thing to do is to wait. Often, reception will return in a couple of minutes. The next step is to move the vehicle a few feet (or yourself, if the GPS antenna is backpack-mounted). Many times, the antenna is barely hanging onto a certain satellite, which is suddenly blocked by a tree trunk or something similar. You can also move the actual antenna. The antenna works best if it is level (as in, a carpenter's level would be level in both front-back and side-side directions), which it is often not if mounted on a curved roof on a vehicle on an angled road, or on a backpack. Try moving yourself or the antenna to a level position on the fillslope side of the road. In cases of very steep topography, it can be advantageous to actually angle the antenna slightly outwards, away from the cutslope and uphill side of the road. The last thing you can do is to mark your place on the road with flagging, and come back later. Satellite geometry relative to that spot will change, and will likely be better at a different time of day. You can try to use the *Plan* feature available in the *Status* window of TerraSync to determine when the optimal number of satellites will be overhead.

A common occurrence is the loss of satellite reception after the road rounds a ridge, or enters a stream valley. The solution is often to move to a part of the road on the original side of the ridge, or out of the stream valley, and come back later. If you stay in the valley or on the wrong side of the ridge until the satellites move into acceptable position, you may lose reception when you move back to the other side of the ridge, or out of the valley. However, sometimes, there is almost nothing that you can do. If you are under dense canopy cover, and in a deep and steep valley, it may be that there is no time of any day that will provide enough satellite reception to be efficient. You may just have to wait it out.

Dry Tutorial

Two scenarios are presented here, with detailed instructions for each scenario. The first scenario is set up to be fairly simple, so that it is easier to see how each step is completed. The second scenario is more complicated, so that the reader will see how to deal with the many possible special situations in the field. The best way to learn how to use this tool is to actually use it in the field, especially with an experienced user present with whom unique situations may be discussed.

The field work for GRAIP is most efficiently done by a crew of two people. Generally, one person will drive the vehicle and get out to look at the road and its features, while the other person operates the computer. The computer operator can operate while the vehicle is in motion, which saves time.

It is easiest to work from the base of a hill upwards, so that you see the drain point before you see the flow paths on the road. This allows you to know where the uphill water is going, and allows you to easily associate the drain point with the road segment. When you reach the top of a hill, you can either go to the bottom of the hill and turn around, so that you are working uphill, or you can work downhill. If you work downhill, you will see the road segment before you see the drain point. As is explained below, when you collect a road segment, you will use the CTime from the drain point where the water from that road segment exits the road to associate the road and that drain point. If you collect the road segment first, you will have to close the segment, collect the drain point, then re-open the road segment to enter the CTime. This becomes cumbersome with more complicated road flow paths.

More information and photos about the below described features are available in Section II: Glossary of Features.

Scenario A: A single road segment with a single flow path

This scenario contains a single flow path that drains to a single simple drain point. Single flow paths are relatively uncommon in many places, but the drain point, the ditch relief culvert, is very common in most places in the western U.S.

You and your crew mate are moving along the road, and you come to a culvert that goes under the road. Your vehicle is pointed uphill. TerraSync is already set up, and running the correct file, which has been noted in the field notebook as being associated with the road that you are on. A laminated data dictionary, such as can be found in Appendix F: The Data Dictionary, can be a useful tool for the person who is looking at the road and its features to have with them, so they can refer to it and not forget to look at any attribute. The goals are to describe the type of drain point and its attributes, any problems associated with the drain point, and whether or not water draining at the drain point ever reaches a stream (Figure 6).

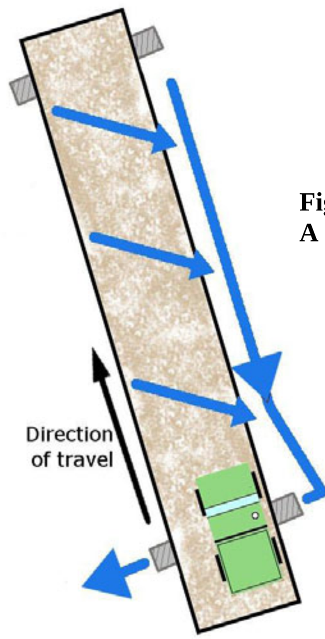
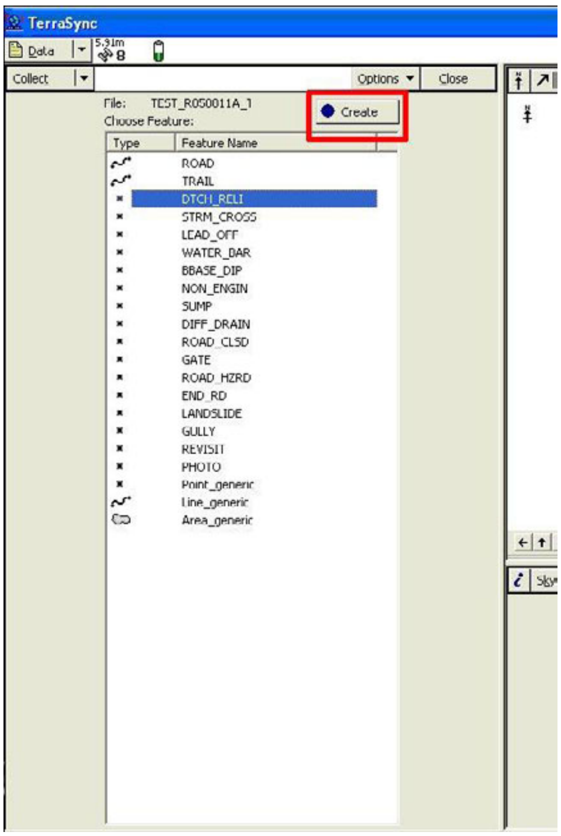
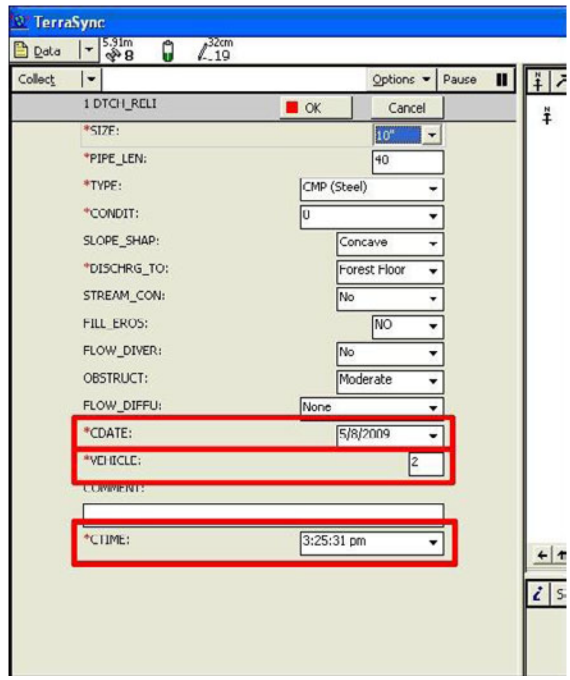


Figure 6. Map of the Scenario A road.

1. **1.** Stop the vehicle so that the GPS antenna is directly over the culvert. Determine what kind of culvert it is.
   - **a.** It can be either a ditch relief culvert, or a stream crossing. See Section II: Glossary of Features and Appendix A: Frequently Asked Questions About the Features sections for more information on distinguishing between the two.
   - **b.** It is a ditch relief culvert.
2. **2.** Create a new ditch relief point in TerraSync.
   - **a.** From the *Collect* screen of the *Data* window (see Using TerraSync, above), either double click *DTCH_RELI*, or click *DTCH_RELI*, and then *Create*, above the feature menu.
   - **b.** The computer operator can enter information about the culvert while the driver looks at the culvert and communicates what to enter.

c. Notice that the *CDATE*, *VEHICLE*, and *CTIME* fields have been automatically filled in. Write down the CTime in the field notebook, along with the type of drain point it is. Use the 24-hour HHMM format, with 30 seconds rounding up and 29 seconds rounding down, so that 3:25:30 in the ditch relief CTime becomes 1526 in the notebook (and later, in the road segment that drains via the ditch to this culvert).

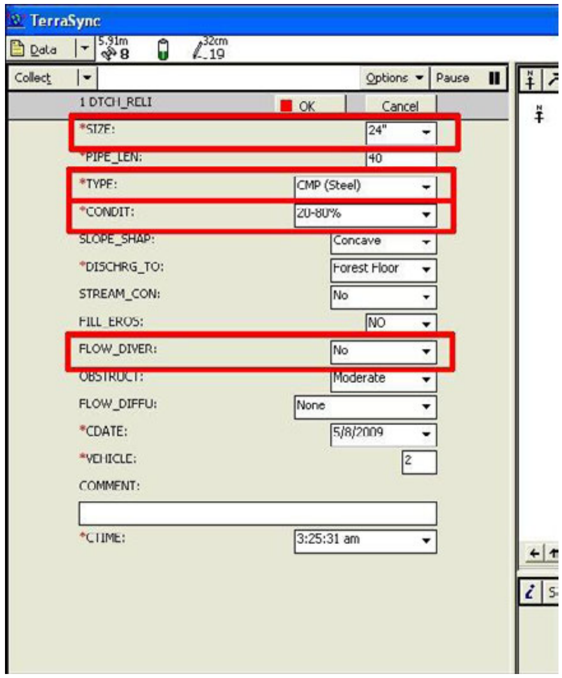




3. Look at the ditch relief culvert and enter the data into TerraSync.

a. Find the inlet. Use a measuring tape to measure the diameter of the culvert. Look at the material the culvert is made from. Most culverts are steel, which has a ring to it if tapped with metal and can rust. Some culverts are aluminum, which has a duller sound, is softer than steel, and cannot rust. Other culverts may be plastic, concrete, or logs. Look for occlusion (blockage) at the inlet, and rust, crushing, or evidence of water flowing around the culvert (all of which take precedence over occlusion in TerraSync). Look to see if the culvert drains or has drained a diverted stream. Check to make sure this drain point drains water from the ditch (if it did not, it would be an orphan drain point).

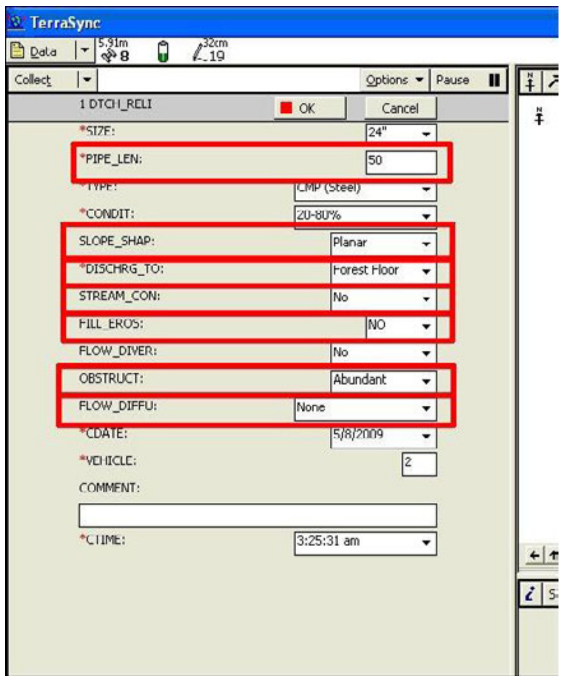
i. For our purposes, the culvert is 24 inches in diameter, steel, about 40 % occluded, drains ditch water, and does not divert any stream flow. For more options and a description of each of these, see the Glossary.



b. Enter the above data in TerraSync. Use the drop-down menus next to each field to select the appropriate option. Next to *SIZE*, select *24"*. Next to *TYPE*, select *CMP (Steel)* (default). Next to *CONDIT*, select *20-80%*. Next to *FLOW_DIVER*, select *No* (default). Next to *ORPHAN*, select *No* (default).

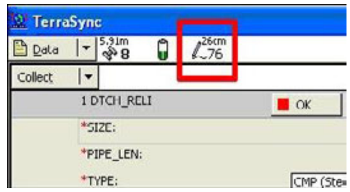
i. Find the outlet of the culvert. Pace, or use a measuring tape or rangefinder to find the length of the culvert (in feet). Check to see if there is any kind of flow diffuser under the culvert outlet. Look at the slope to either side of the culvert to determine its shape. Look below the culvert to see where the water discharges to. If there is evidence suggesting that water has flowed away from the culvert (a gully, sediment deposition, transported leaves or debris, etc.), follow it until there is no longer any evidence, or until the water would intersect with a stream. Look at the fill around the culvert for fill erosion of more than 5 cubic feet. Finally, look below the culvert outlet and along any flow path from the culvert for large (wrist-size or larger) obstructions that would get in the way of flowing water.

ii. For our purposes, the culvert is about 50 feet long, there is nothing to diffuse flow, the slope is planar in shape, the water discharges onto the forest floor (it does not have to be a forest proper, but could be a grassland, or any other terrain not specifically covered by the drop-down menu in TerraSync), and there is no evidence that the water flows away from the culvert (and so there is no stream connection). There is no fill erosion. There are many fist-size rocks and downed logs below the culvert, so the obstruction is abundant.



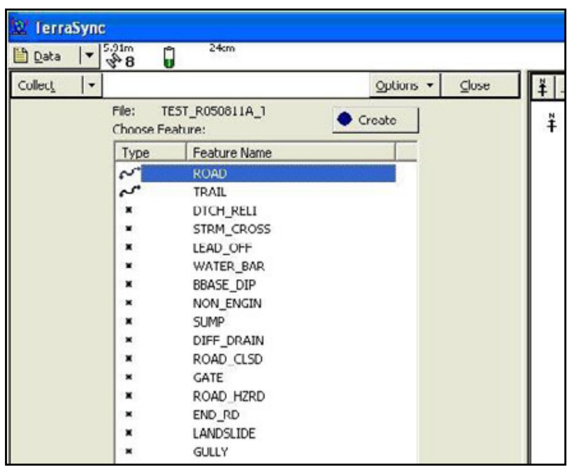
c. Enter the rest of the data into TerraSync. Type the length into the *PIPE_LEN* field (which is *50*). Use the drop-down menus next to the rest of the fields to select the appropriate option. Next to *SLOPE_SHAP*, select *Planar*. Next to *DISCHRG_TO*, select *Forest Floor* (default). Next to *STREAM_CON*, select *No*. Next to *FILL_EROS*, select *NO*. Next to *OBSTRUCT*, select *Abundant*. Next to *FLOW_DIFFU*, select *None*. If there was anything unusual about this drain point, such as if no water drained to it because one end was completely buried, you would enter a *COMMENT*.

d. Ensure that at least 60 positions have been collected. You can see the number of positions that have been collected so far in the center of the screen, in the white bar above the *Data* window and below the *TerraSync* title bar. When 60 positions or more have been collected, click *OK*, in the center of the *Data* window, just above the data entry drop-down menus.

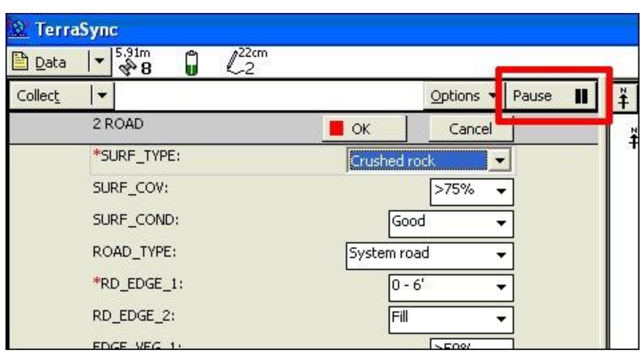


You have completed the collection of the ditch relief culvert drain point. Now, you must collect data for the next road segment. The goals are to find and document the flow path(s) of water on the road, the surface of the road, the cutslope condition, the amount of vegetation on the surface of each flow path, and to relate the flow path(s) back to one or more drain points using the CTime of the drain point.

4. Before you get back in the vehicle and start driving look at the road to determine its attributes and flow path(s). Create a *ROAD* segment in TerraSync.



a. Collect 2 positions, and click *Pause*, in the upper right of the *Data* window. This prevents the GPS from collecting positions while you are not moving so that the road line does not have rat's nests, which are time consuming to remove later.



b. The first thing is to determine what the flow path or paths is or are. If there is a ditch on the cutslope side of the road, that is one flow path. Look for evidence of a concentrated flow path: water flowing down the road in the wheel tracks, down the centerline of the road, against the cutslope (if there is no ditch), against a berm on the fillslope side of the road. Finally, look for evidence of a diffuse flow path: water flowing off the road in many small flow paths (if the road is outsloped, this can happen).

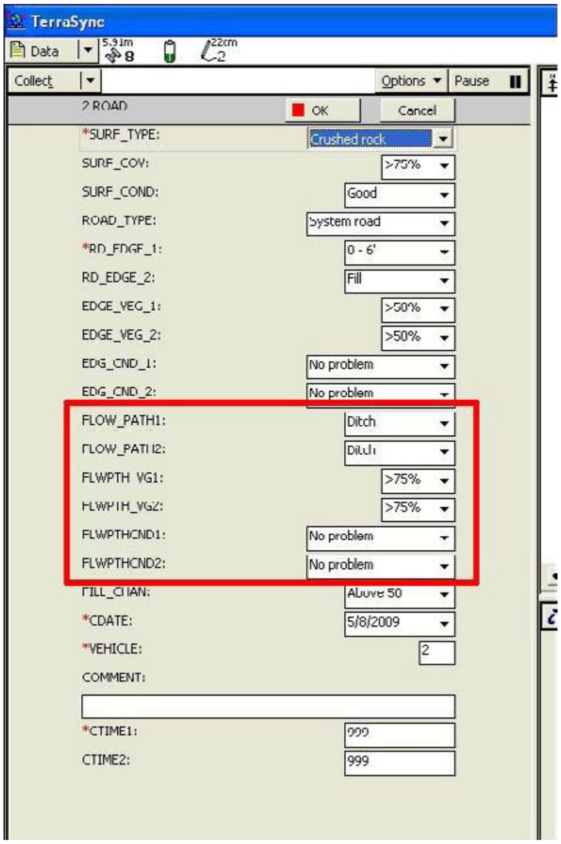
i. Here, there is a ditch, and the road is insloped, so that water from the road surface flows into the ditch. This means that there is only one flow path, and it is the ditch.

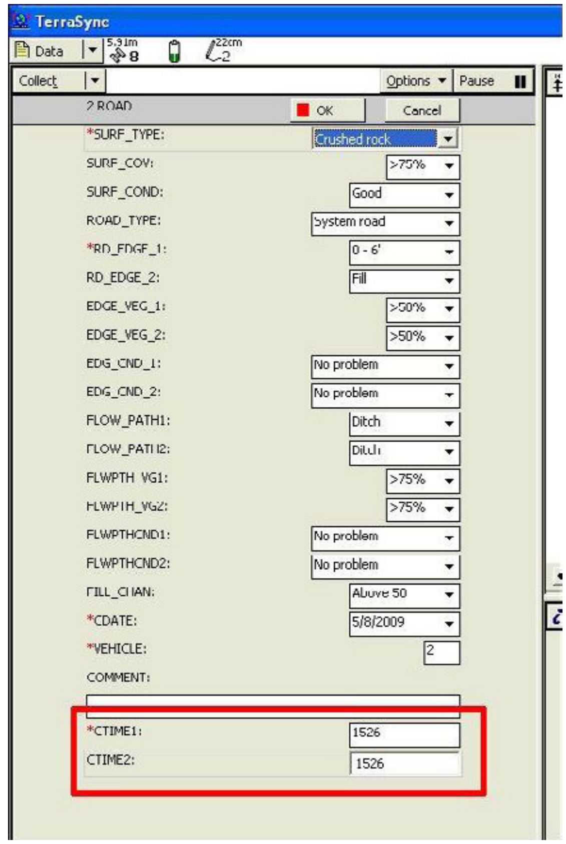
c. Determine the percent vegetation in the flow path (i.e. the ditch). This is the percentage by area of vegetation, living and dead, that is actually in contact with the ground. See Appendix A: Frequently Asked Questions About the Features for more information on percentage vegetation. Determine if there are any problems with the ditch, such as a gully or some kind of blockage.

i. Here, the ditch is well vegetated, at about 85%. There are no problems with the ditch.

d. Enter the information about the flow path in TerraSync, in the same way as above. Because there is only one flow path, you will enter the information for that flow path in the fields for both flow paths. If there were two flow paths, the information of each flow path would be entered in each flow path field.

i. Next to *FLOWPATH1* and *FLOWPATH2*, select *Ditch*. Next to *FLWPTH_VG1* and *FLOWPTH_VG2*, select *>25%*. Next to *FLWPTHCND1* and *FLWPTHCND2*, select *No problem*.





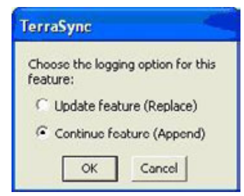
e. Now you must relate the flow path on the road to the point at which it drains from the road prism. This point is the ditch relief culvert you collected above. This relation is accomplished by entering the CTime of the ditch relief into the road segment. Note that the CDate and Vehicle ID in the road segment and ditch relief culvert must match, which they automatically will if both features are collected on the same day. In both *CTIME1* and *CTIME2*, enter the CTime for the ditch relief culvert from the field notebook, which is 1526.

f. Look at the rest of the road features. Determine the original surface type of the road, and if there is any other material covering it. Determine if there are any problems with the condition of the road surface, like rills, washboard, ruts, etc. Determine if the road is passable by passenger cars or not. Look at the cutslope. Determine its height range and if there are any problems associated with the cutslope, such as raveling, rilling, seeping water, or slumping. Look at the base of the fill slope and determine its distance range from the nearest stream. You only need to place it in one of four categories, which are 0 feet, 1-20 feet, 21-50 feet, and more than 50 feet. Finally, observe and note any unique features about the road segment.

i. The surface is fully graveled, and in good condition. This is a passenger car road. The cutslope is about 10 feet tall, and there is significant raveling present. There is no nearby stream. This is a fairly typical road segment with nothing unusual.

g. Enter the above information in TerraSync. *SURF_TYPE* is *Crushed rock* (default). *SURF_COV* is *None* (default). *SURF_COND* is *Good* (default). *ROAD TYPE* is *Passenger car road* (default). *RD_EDGE1* is *> 6'* (default). *RD_EDGE2* is *Fill* (default). *EDG_CND_1* (which applies to the cutslope) is *Badly ravelling*. *FILL_CHAN* is *Above 50* (default). There isn't any *COMMENT*.

5. You can now collect the GPS positions for the rest of the road segment. Click *Log* in the same place where the *Pause* button was, selecting the option that allows you to append data to that already collected. Start driving the vehicle up the road slowly, at about 5-10 mph.

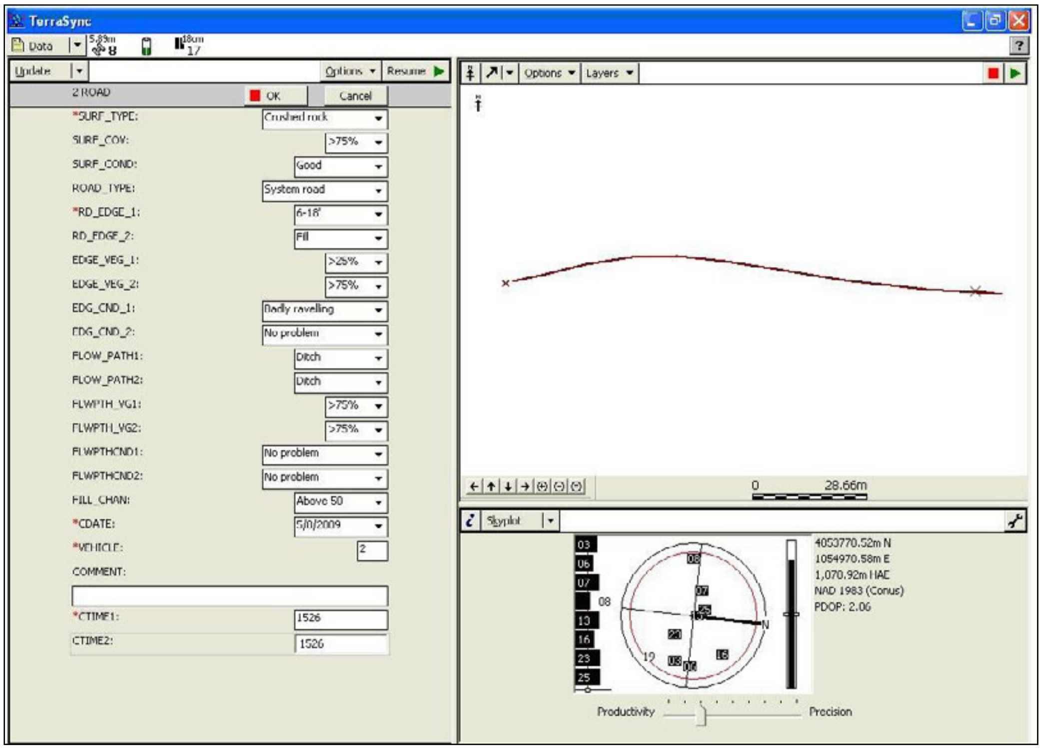


a. While driving, keep looking at the road prism properties to see when they change. Also look for drain points. You will have to stop the vehicle frequently so that you can get out to look more closely at the road prism and for drain points.

b. Often, the attributes you selected that were entered into TerraSync are based on a small section of road. When you drive down the road, you may find that one of the attributes you entered does not continue long enough to make a road segment (i.e. the attribute is under 20 meters), or that the sample you had was not representative of the whole road segment. If this is the case, simply edit the road segment in TerraSync to represent reality.

c. Whenever you stop the vehicle, also pause the GPS position collection to ensure that extra positions are not collected.

You come to another culvert that goes under the road. Stop the vehicle with the GPS antenna over the culvert, and at the same time, stop collecting GPS positions by clicking *OK* at the top of the *Data* window. Repeat the above processes until you reach the end of the road, or the section of road that you require. If it is the end of the road, collect an *END_RD* point. When finished, close the TerraSync file by clicking *Close* in the upper right corner of the *Data* window. Click *Yes* on the error message that says "Close this file. Are you sure?" At the end of the day, exit TerraSync and shut down the data collector.



<u>Scenario B: Multiple road segments with multiple flow paths</u>

This scenario contains multiple flow paths on multiple road segments, with a few different varieties of drain points and problems. This is a more realistic situation than that above. The steps taken in TerraSync are not described in as much detail, because the program interface is straightforward and similar for each feature.

You and your crew mate are at the beginning of a closed road with a gate, and neither of you have the correct gate key (Figure 7). You will have to walk this road. There is a significant stream nearby. The road goes uphill from where you are. Open TerraSync and set up the program and file, associating the file name with the road number or name in the field notebook.

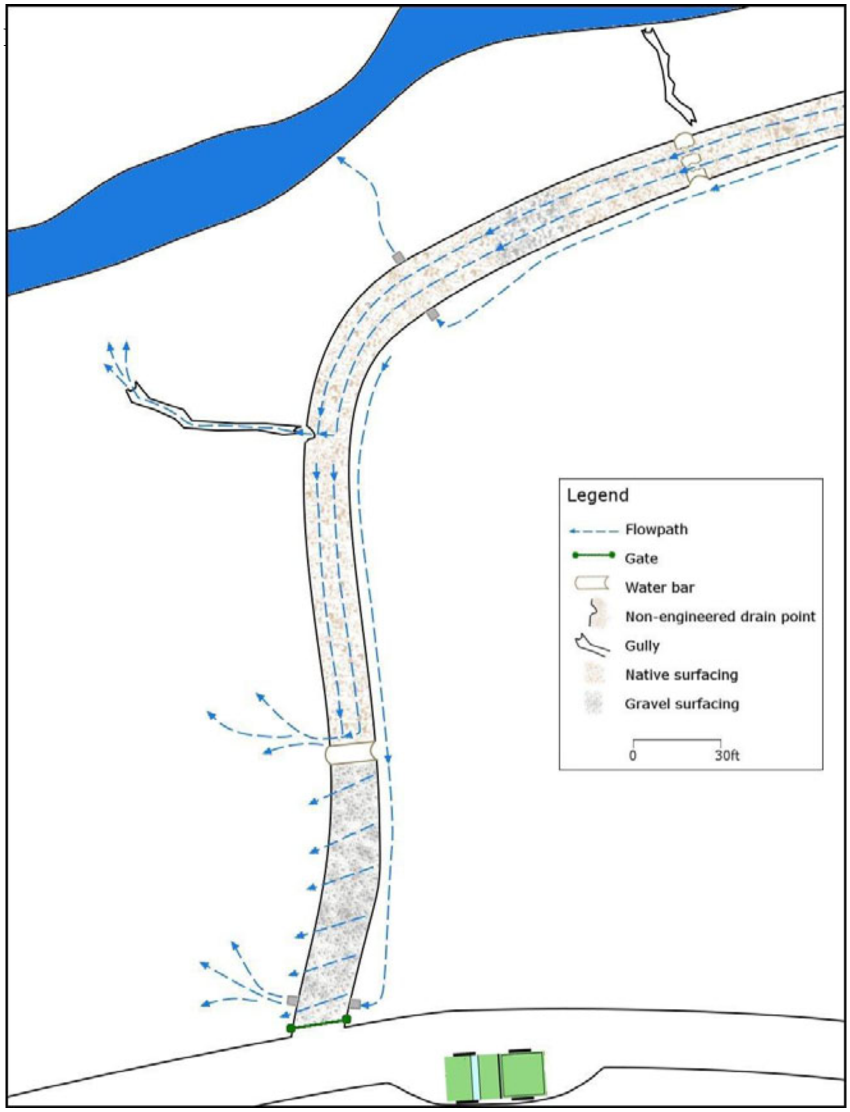


Figure 7. Map of the Scenario B road.

1. Since this is the start of a file, you will have to figure out where the water from the lowest segment on the road drains to. This requires you to look at the road first, before you collect a drain point, because you do not know which drain point to collect.
    a. Walk up the road a little ways and find the flow paths. Look for a ditch, and look for evidence of down-road or off-road flow, or diffuse flow. On this particular segment, there is a ditch, and a ditch relief culvert at the lower end of the road. The road is outsloped in this location, and there are some small patches on the top of the fillslope where sediment deposition has occurred. You determine that, since the road is outsloped, these areas of sediment deposition just off the road surface indicate that the road has diffuse flow.

2. Begin collecting data. Start with the gate by collecting a *GATE* point. Enter any unusual attributes of the gate in the *Description* field. Next, collect the ditch relief culvert (*DTCH_RELI*) as in the above example.
   a. Every drain point that you can describe in TerraSync reflects an actual point on the ground that is draining water from the road, except the *DIFFUSE* drain point. This point describes a road segment that does not move water down the road, just off and away from the road (as opposed to off the road and into the ditch). For this reason, it does not matter where along the road segment you collect the diffuse drain point. It is good to be consistent in the placement of the diffuse drain point along the road segment to make it easier to understand in the office.
   b. Collect the diffuse drain point (*DIFFUSE)* at the start of the road segment to make it easy.
   c. You notice some slight scouring below the ditch relief culvert. You follow it, but it does not go very far before there is no longer any evidence of flow.
   d. The CTime for the ditch relief culvert is 0912, and 0915 for the diffuse drain point.
3. Begin collecting data for the road segment. The surfacing is gravel, and the cutslope is in good condition. There are no problems with the road surface, but it looks like recent work has been performed on this section (there is some fresh gravel).
   a. You enter the ditch (*FLOW_PATH1*) and diffuse (*FLOW_PATH2*) as the flow paths, relating them to the drain points already collected by entering their CTimes. *CTIME1* is *0912* and *CTIME2* is *0915*.
   b. You enter a *COMMENT* about the fresh gravel.
      i. Example: “Fresh gravel, looks like recent work.”
4. Move up the road segment, looking for changes in the road prism attributes and new drain points.
5. You come to a water bar across the road. Collect a *WATER_BAR* point. You can see nothing out of the ordinary about this feature. The CTime is 0922.
6. Begin collecting a new road segment. You notice that the surface has changed to native soil, and there are distinct concentrated flow paths in the wheel tracks.

   - **a.** There has not been any change in the ditch, nor has there been a new ditch relief culvert.
   - **b.** You enter the ditch (*FLOW_PATH1*) and concentrated (*FLOW_PATH2*) as the flow paths, relating them by entering their CTimes. *CTIME1* is still *0912* and *CTIME2* is now *0922*.

7. Move up the road segment as before. You come to a place on the road where water flowing down the road has run off the road, eroding some fill with it. Upon closer examination, you see that water from both wheel tracks flows off of the road at this point. There is no evidence that water was intended to run off the road here, so this is a non-engineered drain point.

8. Collect the non-engineered drain point (*NON_ENGIN*). You estimate that about seven cubic feet of fill have been eroded here. Enter *7* next to the *FILL_EROS* field. You notice that there is a gully below the drain point. Make sure to select *Gully* next to the *DISCHRG_TO* field in the drain point in TerraSync. The CTime of the non-engineered drain point is 0931.

9. Collect a *GULLY* point.

   - **a.** Follow the gully until it ends, estimating or measuring its length, width, and depth. A gully must be at least 10 feet long and 6 inches deep to be recorded by the survey. Enter these measurements in the appropriate fields in TerraSync.
   - **b.** This gully terminates on a wide flat area. There is sediment deposition at its terminus.

10. Take a photo of the gully. A scale, such as a field notebook or measuring tape is helpful. Collect a *PHOTO* point, entering the time stamp on the photo as the *CTIME*, and a brief description of the photo in the *COMMENT* field.

   - **a.** Comment example: "Gully from non-eng drain, ends on wide flat."
   - **b.** You should take a photo of every gully, landslide, stream crossing, non-engineered drain point, anything unusual, as well as plenty of the typical road.

11. Begin collecting a new road segment. As before, the surface is native, there is a ditch, and water has flowed down the road surface in a concentrated manner.

   a. You enter the ditch (*FLOW_PATH1*) and concentrated (*FLOW_PATH2*) as the flow paths, relating them by entering their CTimes. *CTIME1* is still *0912* and *CTIME2* is now *0931*.

12. Move up the road. You round a corner, and come to another ditch relief culvert. Collect a *DTCH_RELI* drain point. You notice some evidence of flow in the form of slight scour at the base of the culvert. You follow the path of the scour, and it makes it all the way to the now nearby stream channel.

   a. Enter *Yes* in the *STREAM_CON* field. The CTime of the ditch relief culvert is 0945.

13. Begin collecting a new road segment. The surface is still native, and the flow paths are still ditch and concentrated. However, now the stream channel is very close to the road. You estimate that the stream is about 35 feet from the road.

   a. Enter *21-50* for *FILL_CHAN*.

   b. You enter the ditch (*FLOW_PATH1*) and concentrated (*FLOW_PATH2*) as the flow paths, relating them by entering their CTimes. *CTIME1* is now *0945* and *CTIME2* is still *0931*.

14. Move up the road segment. You come to a place where the cutslope drops from about 15 feet to about 3 feet, and the surface of the road changes to fresh gravel. You pause the GPS receiver to make further observations at this spot. You notice that the gravel does not last very long, only about 10 meters, before the surface goes back to native. After about 10 or 15 meters the cutslope goes back to being about 15 feet high. You suspect that there might be a landslide or a stream crossing at this location, but there is no evidence for either. Since this anomalous segment is less than 20 meters long, you do not need to start a new road segment. Make a comment about the road surface and cut, and then continue up the road.

   a. Comment example: “Short segment w/ gravel surface and 3 ft cut, ~10m.”

15. You come to another water bar. This water bar has been extensively damaged by vehicle wheels, and you can see that water now flows past, and the water bar no longer successfully drains anything. This is known as an orphan drain point (see Appendix A: Frequently Asked Questions About the Features). Additionally, you observe a gully at the base of the water bar (formed before the water bar was damaged). Make sure to change *DISCHRG_TO* to *Gully* and *CONDIT* to *Damaged*. Enter *Yes* for *ORPHAN*. Make a comment about the orphaned state of the water bar.

- **a.** Comment example: "Orphan, water runs past, see photo."

16. Follow the gully and take a photo, then take a *GULLY* and *PHOTO* point, as before. Also take a photo of the damaged water bar, and add its information to the existing *PHOTO* point.

- **a.** This gully goes all the way to the stream, so the water bar is connected to the stream. Make a comment for the gully about its connection to the stream.
    - **i.** Comment example: "Gully connects directly to stream."
- **b.** Since the gully connects to the stream, the water bar is connected as well. Go back and edit the water bar point so that the stream connection is *Yes*.

17. Begin a new road segment. The flow paths are the same as before, and the road is still about 35 feet from the stream channel. However, the concentrated flow path does not drain to the water bar you just collected, but instead to the same location as the concentrated flow path in the previous road segment, which is still CTime 0931.

- **a.** You enter the ditch (*FLOW_PATH1*) and concentrated (*FLOW_PATH2*) as the flow paths, relating them by entering their CTimes. *CTIME1* is still *0945* and *CTIME2* is still *0931*.

You continue up the road in this way, until the road ends, or you have collected data for the section of road you need data for. Close the TerraSync file, and close TerraSync at the end of the day. When you finish a road, make some comments in the field notebook about that road that will be transcribed to the master data log (described in the Organizing and Keeping Track of Data section, above) when the data is transferred to an office computer for analysis.

18. Example of a comment about a road: "Road is in OK shape. Surface is mostly native, with spots of gravel. Mostly ditch with concentrated (wheel tracks), some outsloping. Lots of water bars. The gradient is fairly shallow, and there are some rough spots and big water bars. Road is located at or near stream level for most of its length. Some gullies, a few small stream crossings. Road is closed by a gate, looks like there is some traffic."

SECTION II: GLOSSARY OF FEATURES

This section describes each of the features, and their properties, available in the GRAIP data dictionary (INVENT 5.0). An effort has been made to describe the situations in which you would and would not use certain features to describe certain attributes of the road. An annotated image accompanies the description where appropriate. The photos are located after each feature's properties have been described. Items are ordered by their general type, and are alphabetically listed within their sub-sections.

The Road Line Feature

The road line is a linear feature that describes the road prism attributes. Each of these attributes is described or explained here.

Road Line (ROAD)

- **Road Number** (ROAD_NUM): Type the road number you are on here. This helps office workers to identify each road during data analysis.
- **Surface Type** (SURF_TYPE)**:** Observe the dominant material that makes up the road surface and enter here. Choices are:
  - **Crushed rock** - crushed rock with flat faces, often gray to black in color.
  - **Native** - no appreciable surfacing besides compacted soil.
  - **Paved** - with asphalt.
- **Surface Cover** (SURF_COV)**:** Most roads we travel are basalt aggregate or native surfaced and have < 25% vegetation cover. However some roads have not been maintained and have more vegetation. If more than one option applies, choose the dominant surfacing. Choices are:
  - **None** - road surface has < 25% vegetation cover.
  - **Grass and herbs** - > 25% of the road surface is covered in grass or broad leaf non-woody vegetation such as wildflowers.
  - **Live woody veg** - > 25% of the road surface is covered in living woody vegetation such as small trees or shrubs.
  - **Straw** - > 25% of the road surface is covered in straw, common on decommissioned roads.
  - **Organic debris** - > 25% of the road surface is covered by downed trees, branches, or other debris that has been placed on the surface of a decommissioned road
- **Surface Condition** (SURF_COND)**:** Description of condition of the road surface.
  - **Good** - no obvious defects, minimal washboard or very shallow rutting would be permitted.
  - **Rilled/eroded** - water channels on the road surface that exceed 0.25 inches in depth and may be very large.
  - **Washboard** - high frequency bumps that appear in the road perpendicular to the travel direction, should occur for more than half of the road segment.

- **Rutted** - wide deep depressions in the wheel tracks typically due to wet weather traffic or over-loading of the road surface. A threshold of 2 inches in depth along the length of the road segment is used.
- **Rocky** - common exposed boulders impeding the quality of travel.
- **Ripped** - decommissioned road that has been torn up with a ripper, etc.
- **Decom potholed** - decommissioned road (not typical potholes on open roads), the road surface has been partially excavated to mimic potholes that prevent run off.
- **Recontoured** - decommissioned road, the fill slope has been excavated and placed on the remaining width of road to imitate the natural contouring of the hillslope .
- **Tilled** - decommissioned road, surface has been torn up and made loose to prevent run off from the road surface and encourage revegetation and infiltration.

Photo A. Ripped road.

Photo B. Recontoured road.

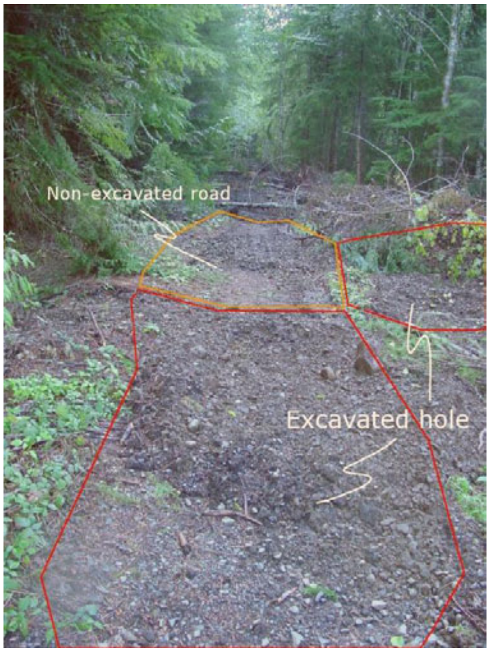


Photo C. Decom potholed road.

Photo D. Tilled road with water bar.

- **Road Type** (ROAD_TYPE)**:** Based on the type of travel possible on the road.
  - **Passenger car road** - typical well maintained road in the forest passable to all types of passenger vehicles, including typical passenger sedans.
  - **High clearance road** - a lower standard road that has challenging stretches passable only by high clearance vehicle. This includes deep ruts, deep waterbars, or thick brush in the middle of the road.

  - **Not trafficable** - a road that is not passable to highway vehicles of any kind due to a closure berm, very large water bars, slope failure, etc. May be passable to ATV traffic, has a compacted surface, and is not physically decommissioned.
  - **Decommissioned** - a road that has been permanently closed, with culverts removed, no longer passable to any vehicle, typically has tilled, ripped, or recontoured surface
- **Road Edge** (RD_EDGE1 and RD_EDGE2)**:** Data on the cutslope(s) and/or fillslope(s) is entered here. There is a category for each side of the road.
  - **Fill** - indicates that the road is built up on the downhill side; or on both sides to cross a creek, swale or valley. Note that both sides of the road can be fill in some cases.
  - **0', no ditch** - indicates that this side of the road has no cutslope, fillslope or ditch.
  - **Height categories (0-6' and > 6')** - refers to places where the road is cut into the hillside. The height is measured from the bottom of the ditch to the top of the cut, where the original slope resumes. One or both sides of the road can be cutslopes.
- **Edge condition** (EDG_CND_1)**:** Intended to describe problem spots on the cutslope or fillslope where mass movement or unstable soil material is creating a chronic erosion problem. If both sides of the road have a problem, describe the worse problem here.
  - **No problem** - the default where vegetation is growing and/or erosion is not an obvious problem.
  - **Badly rilling** - describes a situation where the cutslope has many continuous small gullies (rills) caused by water flowing over bare soil.
  - **Badly raveling** - describes a condition on a steep cutslope where the material is unstable and erodes during the dry season. Badly raveling cutslopes lack obvious rills and have the appearance of cone shaped piles of granular material building up in the ditch and onto the road. Vegetation is likely minimal and subject to burial.

Photo E. Badly rilled cut slope following high intensity rainfall event.

- **Badly slumping** - describes an unstable site that is moving into the road and ditch in the wet season due to the forces of gravity and because of poor drainage or saturated conditions. The material moves as a cohesive unit of semi-saturated soil. In contrast, an eroding area that is moving mostly water and suspended or bed load sediment in a series of channels would be classified as rilling.
- **Seep spring** - describes a cutslope where there are one or more seeps contributing water to the ditch.
- **Bedrock** - describes when the edge of the road is bedrock.

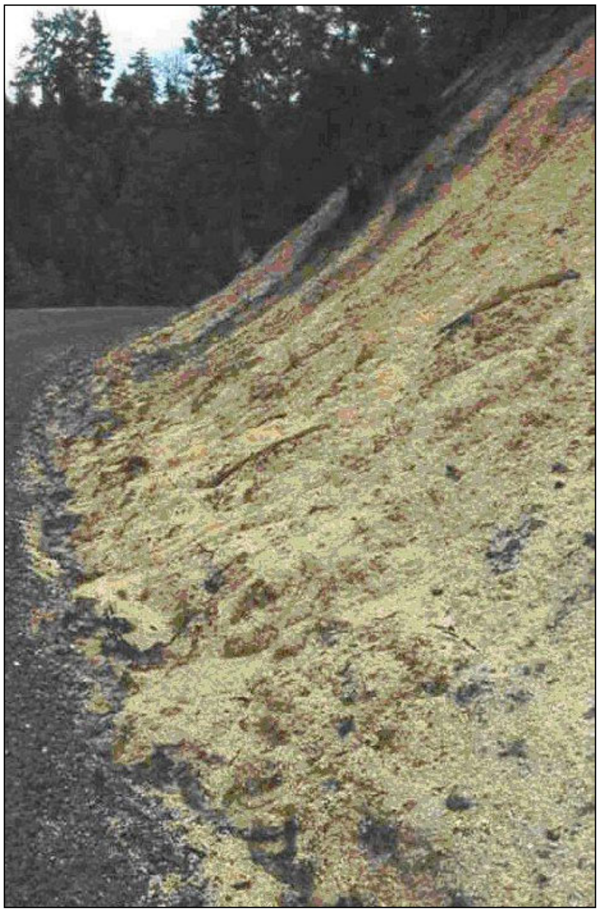


Photo F. A severely raveling cutslope in granitic saprolite. The ditch has been obscured by the accumulated apron of debris

Photo G. A slumping cutslope.

- **Flow Path Location** (FLOW_PATH1 and FLOW_PATH2)**:** Describes where water is being concentrated and flowing, in what is called the flow path. There are two flow path categories (FLOW_PATH1 and FLOW_PATH2). If there is only one flow path, enter the information for that flow path in both categories.
  - **Ditch** - the typical case is when the water flows along an inboard ditch.
  - **Concentrated** - when flow concentrates and flows down the surface of the road. This can occur where the water flows down the wheel tracks, along a berm, or anywhere else on the surface of the road

- **Diffuse** - describes flow that runs perpendicular to the direction of travel and off of the road surface without concentrating into a substantial rill, or a loose or extremely vegetated road surface that does not concentrate any surface water (water that hits the road surface infiltrates instead of runs off). This is common on outsloped roads, and on roads that have been tilled, recontoured, etc.

- **Flow Path Vegetation** (FLWPTH_VG1 and FLWPTH_VG2)**:** Describes the average cover of living or dead plants on the bottom of the ditch, road surface, or wherever the water is flowing. Describe the percentage vegetation cover or mulch where the water actually flows. The categories are **< 25 % or >25%.**
- **Flow Path Condition** (FLWPTHCND1 and FLWPTHCND2)**:** Describes erosion problems that may occur in the flow path. **No Problem, Gullied, Buried ditch, Stream course, Rocked,** and **Eroded** are the categories. No Problem describes a flow path with no condition issues. If the flow path is gullied, there is no need to take a separate Gully point. Buried ditch condition describes when a ditch has been plugged by slope material or a slump (keep the ditch flow path through these sections). Stream course is used when the flow path is or has in the past diverted the course of a stream. Rocked is used when coarse rock is lining the ditch. Eroded is used when there is significant erosion (> 2" depth) of the flow path due to flowing water.

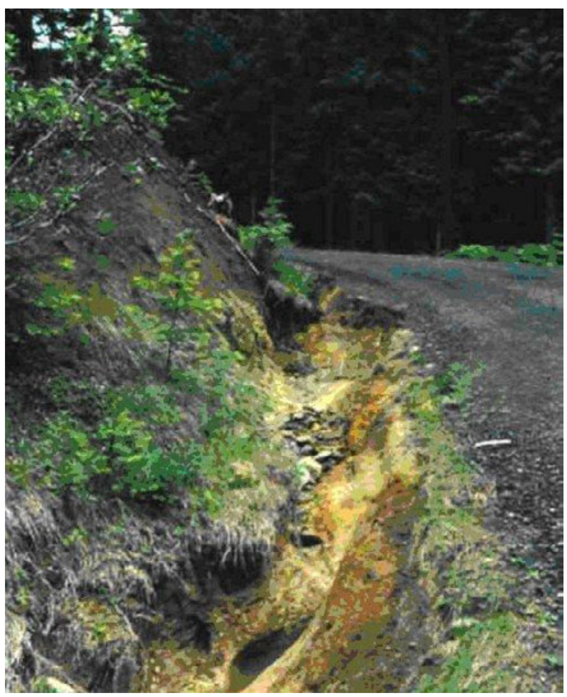


Photo H. Badly gullied ditch after large runoff event

- **Fill to Channel** (FILL_CHAN)**:** Describes locations where the road prism or fill impinges on the floodplain of the channel. In most cases the road will be **above 50** feet from the channel, so this is the default setting. The first option is **0** for the case when the road is built on top of the floodplain or the fill material enters the natural active channel. The intermediate choices are **1-20** feet from the toe slope of the fill to the channel bank, and **21-50** feet.

- **CDate** (CDATE)**:** Data collection date automatically assigned in MM/DD/YYYY format.
- **Vehicle ID** (VEHICLE)**:** ID number for the collecting vehicle or crew, automatically assigned.
- **Comment** (COMMENT)**:** The field where you can make comments about anything extraordinary about the road prism.
- **CTime1** (CTIME1)**:** This is the 4-digit number that uniquely ties the road segment to the drainage point. The format is 24 hour time with no colon. This value is the CTime value obtained from the receiving drain point for flow path 1, rounded to the nearest whole minute (30 seconds rounds up, 29 seconds rounds down). This field must be entered as a four-digit numeral (e.g. *0935*, *1654*; *935* or *blank* will not work) and must be a valid time (e.g. *6581* will not work). The only valid non-time, non-four-digit entry is *999*, which can be used as a placeholder (note that *9999* will not work).
- **CTime2** (CTIME2)**:** The ID for the secondary flow path (or the duplicate of the primary when there is no secondary). In many cases, there will be a secondary drainage feature on the road such as a wheel path rut, second ditch or diffuse. The secondary road drainage features will be assigned a CTime2 which may end up being the same number as that for the primary if the water exits the road in the same place or it may be unique if the drain points are different. If a secondary flow path does not route at least 30% of the flow on the road segment, then enter the CTime for the primary flow path. This field must be entered as a four-digit numeral (e.g. *0935*, *1654*; *935* or *blank* will not work) and must be a valid time (e.g. *6581* will not work). The only valid non-time, non-four-digit entry is *999*, which can be used as a placeholder (note that *9999* will not work).

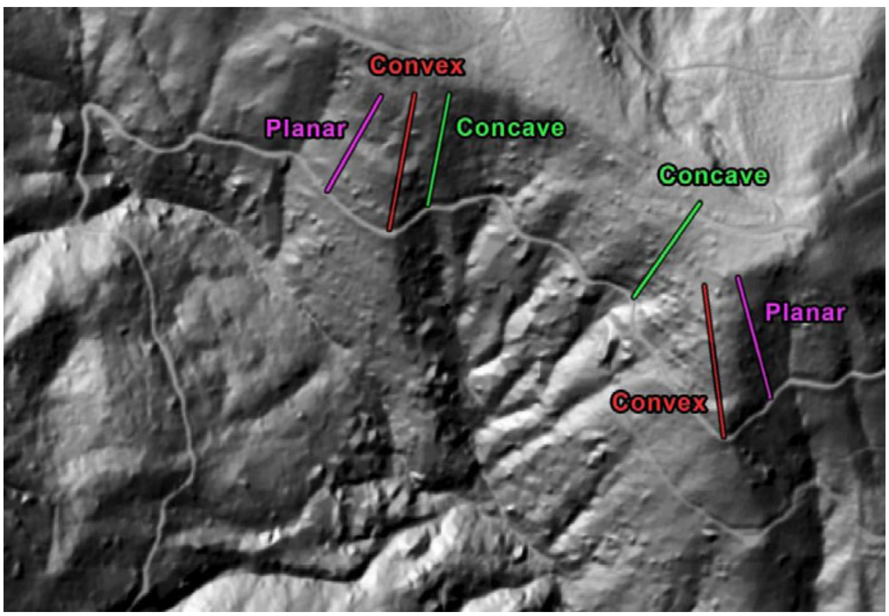
Drain Point Features

Drain points are the places along a road where water leaves the road prism. There are nine different kinds of drain points. Each is described here. All of the data dictionary attributes for each drain point are described or explained, as well. The features are presented in alphabetical order.

Standard Drain Point Attributes

The below described attributes are in the data dictionary for all or most drain points. Not all drain points have all of these attributes, but for those that do have them, the description of them is the same. See Appendix F: The Data Dictionary for a complete list of all attributes for each drain point type.

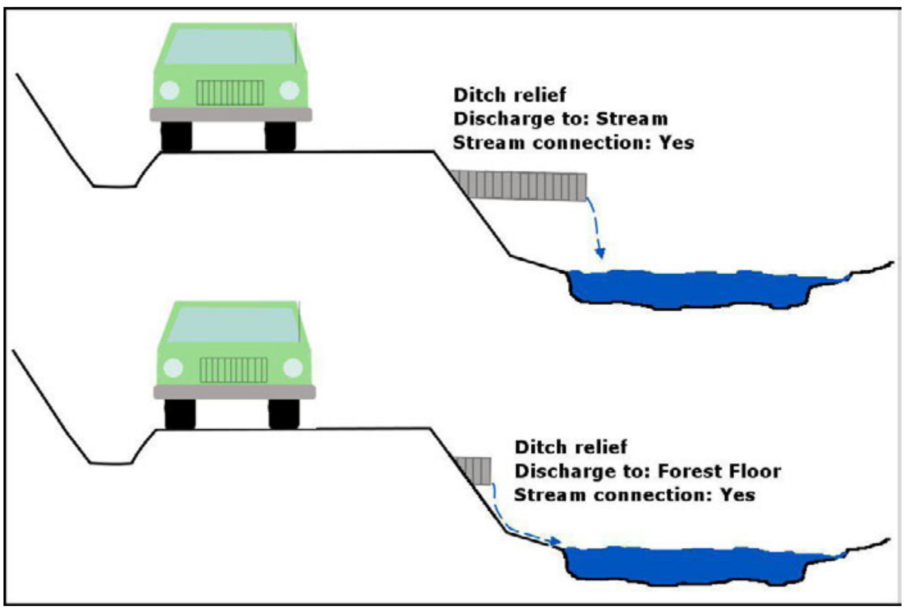
- **Slope Shape** (SLOPE_SHAP)**:** This field describes the horizontal hillslope cross section below the drain point. A valley or swale has a **Concave** slope, a ridge or nose has a **Convex** cross section and the zone between them has a **Planar** cross section.



- **Discharge to** (DISCHRG_TO)**:** In order to know what happens to the road drainage when it leaves the road network, it is necessary to examine the discharge point and in some cases walk a distance along the path that flowing water would take. Evidence of the flow path may include past sediment deposition, a gully, a channel, moisture-loving plants, organic debris that floated into place, or scour of the soil surface.
  - **Forest Floor** - describes the case where the flow discharges onto the soil surface without downcutting.
  - **Gully** - describes the case where there was no stream channel upslope of the road but there is an incised feature that extends below the road fill slope due to the culvert discharge repeatedly cutting through the organic soil into the mineral. Gullies are deeper than 6 inches, and extend at least 10 feet downslope of the edge

of the fill slope. Active gullies have steep sides. If a gully is located it should also be mapped as a separate feature under the **Gully** point in order to fully describe its features. A picture should be taken to document the gully and a **Photo** point captured. If the gully does not begin directly below the drain point, but instead further down the hillslope, the drain point still causes or influences the gully, so choose this option in those cases.

– **Ditch** - describes the case where the flow discharges into another roadside ditch on a road below the first. There are also cases when a culvert is used in an intersection to route flow under a branch road. Remember to use the **CTime** of the final destination of the flow in these cases.
– **Landslide** - describes the case where the flow discharges into a landslide that has been active since the road was in the present location. This may occur downslope of the culvert outlet when excessive flow saturates an unstable slope or road fill. A separate **Landslide** point must be mapped when flow is routed to a landslide, as well a photo and **Photo** point. Similar to the gully option, this option should be chosen even if the landslide occurs further down the slope so long as it occurs because of drainage from the drain point in question.
– **Wetland** - describes the case where the flow discharges into a saturated area or standing water beside the road.
– **Stream** - describes the case where the flow discharges into a stream. In order for this to be the case, the drain point must discharge directly into a stream, without running over fill or anything else. This generally applies to culverts only.

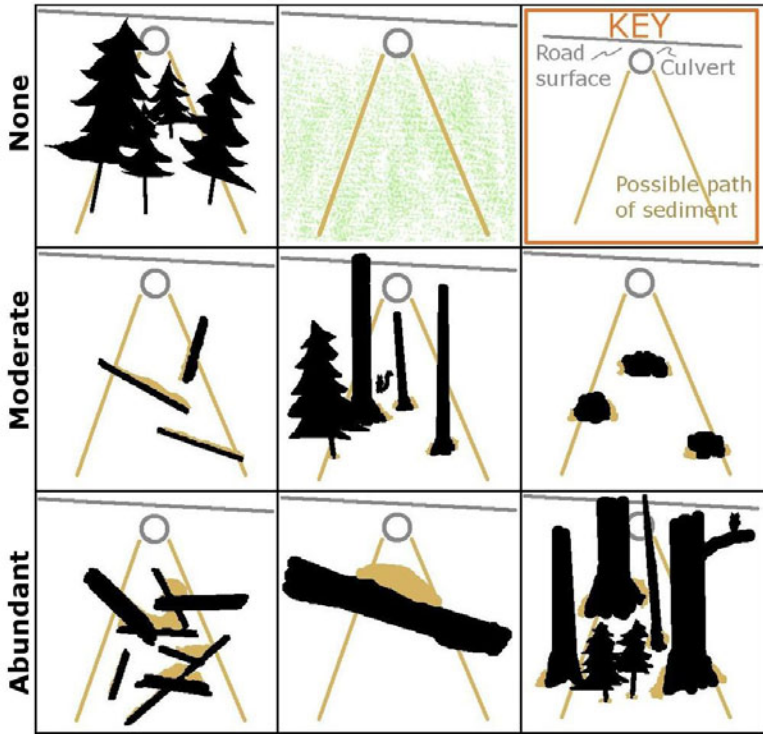


- **Stream Connection** (STREAM_CON)**:** In the Idaho batholith, the median transport distance below ditch relief culverts was found to be 53 meters in a previous study by Megahan and Ketcheson (1996). At each drain point, walk down the hillslope below the drain point and examine evidence for flowing water and sediment. If careful examination shows that road derived flow is most likely reaching the channel from the drainage point, it is assigned the status of **Yes.** Walking down slope from the discharge point, look for evidence such as gullying, transported leaves, matted vegetation, parabolic conifer needle flow forms and deposited sediment. If the slope is concave, it is more likely to be saturated during the snowmelt season and allow water to flow across the soil surface. Think of the distance that the flow has to travel overland to reach the channel. If there is no evidence of overland flow reaching the channel then it is assigned **No**.

- **Fill Erosion** (FILL_EROS)**:** If the fillslope of the road prism is being actively undercut at the drain point outlet, it is recorded as fill erosion. If there is evidence of sapping or washing out of at least 5 cubic feet of fill (about a bathtub worth) then calculate the volume of the erosion and enter it here. Otherwise, enter **0**. This type of erosion is different than gullying in that it typically only affects the road fill. It is often due to excessive drop below a culvert pipe or poor design or function as opposed to gullying which is associated with excessive water routed to a point. Gullying will continue down slope while fill erosion will typically be a localized phenomenon.

Photo I. Fill erosion caused by flow around culvert pipe.

- **Obstruction** (OBSTRUCT)**:** Barriers or impediments to water flow below the discharge point on the hill. These may be logs, boulders, trees or brush that contact the ground and act to slow the flow and cause sediment deposition, and should be wrist-sized or larger. These should be assessed on the hillslope flow path below the discharge point as far as a flow path or deposited sediment can be seen, or for 30 meters, whichever is less. The categories are:
  - **None** - grass, very small-diameter standing trees, herbaceous vegetation, and no debris, logs, rocks. Effectively low obstruction.
  - **Moderate** - a few logs, medium-sized standing trees, a few boulders.
  - **Abundant** - many logs, a single large log or rock that prevents sediment from passing, standing trees > 12” in diameter, rip rap, large stumps, slash pile.



- **Orphan** (ORPHAN)**:** An orphan drain is a feature that was designed to drain water or has drained water in the past, but does not drain anything at the time of data collection. If the drain point currently drains water from the road prism, select **No**, and if the drain point does not drain water, select **Yes**. See Appendix A: Frequently Asked Questions About the Features for more information on orphan drain points.
- **CDate** (CDATE)**:** The data collection date automatically assigned in MM/DD/YY format.
- **Vehicle** (VEHICLE)**:** This is the unique vehicle or crew identifier, automatically assigned.
- **Comment** (COMMENT)**:** The comment field can be used to add additional data to the drain point if there is something unusual about it, such as a problem that is not covered by the data dictionary.
- **CTime** (CTIME)**:** The collection time is automatically assigned when the point is opened. It is displayed in the drain point in12 hour format as HH:MM:SSam/pm (for example, 03:43:24pm) but must be entered into the road line in 24 hour format as HHMM (for example, 1543). Since you will use the 24 hour format to associate the flow path on the road line to its drain point, it is best and easiest to record the CTime in the same 24 hour format in the field book. 30 seconds rounds up, and 29 seconds rounds down.

Broad Based Dip (BBASE_DIP)

A broad based dip is a large grade reversal in the road either designed into the road grade or that is there as a result of two hillslopes meeting. This feature is large enough that the entire vehicle should be inside the feature when capturing the GPS data. See Appendix A: Frequently Asked Questions About the Features for information about the differences between a broad based dip and a water bar.

- **Type** (TYPE)**: Grade Reversal** refers to a naturally occurring broad based dip, where two opposing hillslopes meet, such as in a valley bottom. **Constructed** occurs where the road has been designed to have a broad grade reversal in order to drain water from the road and/or ditch. This feature is designed into the grade of the road.
- **Condition** (CONDIT)**: No problem**, **Puddles on road**, **Wetland in ditch**, and **Saturated fill** are self-explanatory. **Does not drain** is used for a situation where water that drains to the broad based dip cannot escape, such as if there is a roadside berm that prevents drainage. A broad based dip that does not drain is not an orphan.
- **Material** (MATERIAL)**:** Describes the material at the surface in the broad based dip. The choices are: **Crushed rock**, **Native soil**, **Vegetated**, **Paved**, or **Cinder**.

Photo J. A broad based dip with a vehicle parked at the midpoint.

<u>Diffuse Drainage</u> <u>(DIFF_DRAIN)</u>

Diffuse drainage describes a type of road which does not concentrate flow. Examples of this situation are the classic outsloped road and the crowned road with a ditch (there are two flow paths in this case—the ditch and diffuse). Water does not exit the road in a ditch or concentrated flow path, but in a series of small minor flow paths that run directly off of the road. This point feature should be used to describe a stretch of road that has no other way of relieving the water. This point drainage feature is used to describe where water goes even though it is not concentrated into a single channel as the other hydrologic features do. For that reason, it is unimportant where the drain point is collected, so long as it is on the road segment that has the diffuse flow path. Each road segment with a diffuse flow path needs its own diffuse drain, even if two diffuse road segments are consecutive. This is to assist office workers during the error correction phase of data processing (see Vol. 1: Office Procedures). Note that even small depressions or ruts in the road surface can concentrate flow and prevent a road that appears to be diffuse from draining diffusely. There are no special attributes for a diffuse drain point.

Photo K. This outsloped section of road drains diffusely. Note that the photo is level and the surface of the road is outsloped.

<u>Ditch Relief Culvert</u> <u>(DTCH_RELI)</u>

A ditch relief culvert drains water from the inboard ditch under the road onto the hillslope. These culverts drain water from the road and cutslope, not from a continuous channel. See Appendix A: Frequently Asked Questions About the Features for more information on differentiating ditch relief culverts from stream crossing culverts.

- **Size** (SIZE)**:** Measured as the diameter of the un-deformed pipe inlet in inches. The options are **< 15”**, **15”**, **18”**, **24”**, **30”, >30”**, **NA**. Ditch relief culverts are generally one of these standard sizes. Use NA when there is a log culvert (explained below).
- **Pipe Length** (PIPE_LEN)**:** Measure the total pipe length in feet.
- **Type** (TYPE)**:** Description of the material that the culvert is made of. **ALM (Aluminum)** culverts are fairly rare and can be differentiated from **CMP (Steel)** with the aid of a magnet if necessary. Also, aluminum does not rust. The other options are **CON (Concrete)**, **ABS (Plastic)**, and **WDN (LOG).**
- **Culvert Condition** (CONDIT)**:** Assessed by examining the inlet and outlet ends of the pipe. Examine the bottom of the outlet for rust, holes, or evidence of drainage escaping around the sides. If there is doubt whether the pipe is solid, a couple of hammer blows will help differentiate a solid piece of steel pipe from a pipe rusted through in the center. If there are multiple issues to be noted, select the worst by type of failure. Lower risk items are listed first here, and higher risk items are listed last.
  - **0** - denotes no occlusion and no other problems
  - **1-20%**, **20-80%**, **80-100%** - occlusion percentage options; occluded by sediment refers to the amount of cross-sectional area that is occluded by sediment or non-pipe obstructions within the pipe, at the inlet, or at the outlet that would not be removed by normal yearly flow.
  - **Buried** - indicates that the inlet or the outlet of the culvert has been completely buried by sediment and the culvert can no longer function. If the culvert does not drain water, then is an orphan.
  - **Partially Crushed** or **Totally Crushed** - self-explanatory and refer to a pipe that has been significantly pinched by a machine during cleanout.
  - **Rusted Significantly** - indicates that rust has penetrated the culvert bottom, or that a hammer blow makes a dull thud, not a clean ring.
  - **Flows around Pipe** - refers to water channeling below or besides the culvert instead of in the culvert.

Photo L. Steel 18” culvert inlet, 20-80% occluded by sediment. Note that there is some crushing, but this is not significant because it does not cause any problems, and occlusion is the main issue here.

- **Flow Diversion** (FLOW_DIVER)**:** Applied when there is evidence that at present or in the past a stream channel has been captured by the road or ditch and delivered to this point. This evidence will be a dewatered channel, scouring in the ditch or on the road, blockage of the upslope stream crossing pipe, or severe erosion of the fill or hillslope. Options are **YES** or **NO**. This can happen in a location where an uphill stream culvert overtopped and flowed down the road, or if a new channel on the hillslope intersects the road and flows down the road.

Photo M. Scour of the road surface resulting from capture of an ephemeral channel by the road. Flow Diversion is *Yes* at this drain point.

- **Flow Diffuser** (FLOW_DIFFU)**:** A flow diffuser is a device used to reduce the velocity of water leaving the culvert before it reaches the fillslope or hillslope or prevent the culvert water from incising into the fillslope or hillslope. It may be a **Culvert extension**, a **Fabric hose** or **Rip rap** on the slope.

<u>Excavated Stream Crossing</u> <u>(EXCAV_STRM_CROSS)</u>

This is a stream crossing on a decommissioned road where the crossing culvert and fill have been removed. The fill is usually pulled back to create a more natural stream bank. There is a set of additional data that are necessary to collect at these points in a separate spreadsheet. See Appendix C: Decommissioned Roads for Legacy Roads Monitoring for more information on decommissioned stream crossings. Note that if one or both of the side slopes are longer than 20 m, then you should make a road line with a concentrated flow path that drains to the excavated stream crossing. Depending on the objectives of the study, the project manager should determine if excavated stream crossings on decommissioned roads within the project area should be collected as Excavated Stream Crossing features or as regular Stream Crossing features. For example, certain attributes collected at an Excavated Stream Crossing feature, such as channel cross-sectional profiles, may not be relevant to the objectives of a watershed-wide road inventory.

Photo N. Two views of an excavated stream crossing. Notice the straw and logs on the side slopes.

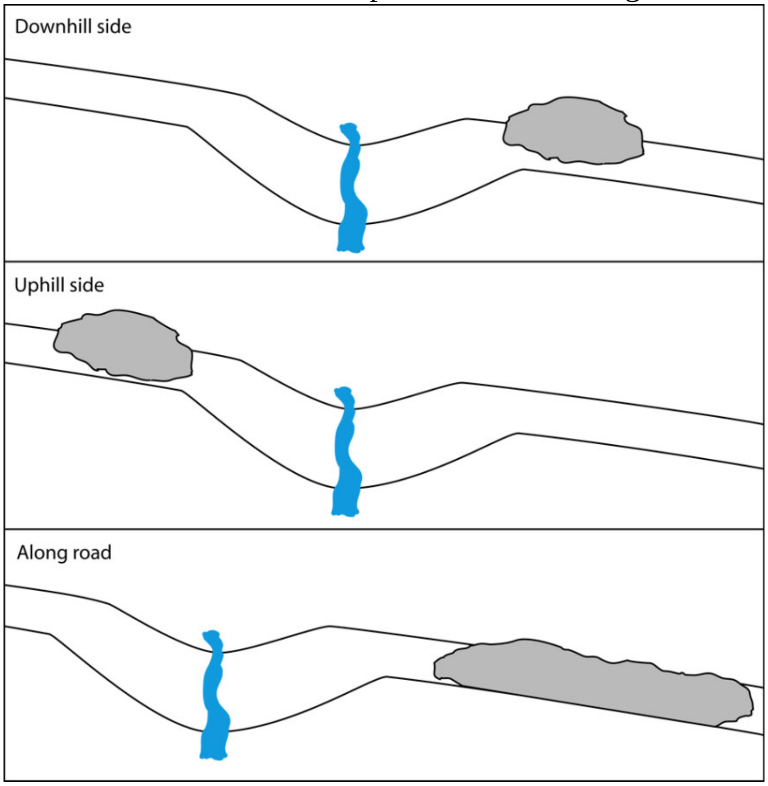
- **Flow Presence** (FLOW)**:** If the stream has flowed over the crossing since it has been decommissioned and excavated, choose **Yes**. If not, choose **No**. Evidence of flow includes scour, incision, etc.
- **Side Slope Covering** (SIDE_SLOPE)**:** Often, a covering is placed on the newly excavated side slopes to promote stability and/or growth of new vegetation. Options are **Straw, None, Rip rap, Logs, Grass, Brush or live trees,** or **Multiple, comment**. If there is more than one covering on the side slopes (such as logs over straw), chose the last option and include the coverings in the comment for the feature.

- **Condition** (CONDIT)**: No problem** refers to a crossing that is in good shape. If there is any incision or lateral erosion, mark this as **Erosion**. If you can hear water under the bottom of the fill, or if there is a stream above and below the crossing, but not in the crossing, then the stream **Flows under fill**. If there are one or more landslides in the side slopes, mark **Side slope landslide**.

Photo O. This excavated stream crossing has been incised.

- **Channel Width** (CHAN_WDTH)**:** Measured in feet at the green line of the active channel above any pools on the upstream side of the road. The green line is the place on the bank where green plants begin to grow. Below the green line, plants do not grow due to the persistent flow of the stream water. The goal is to measure the natural channel width that it out of the influence of the obliterated road. Go at least 20 feet above the crossing, or to where the channel is no longer influenced by the road, whichever is farther, and take the average of three measurements five feet of stream length apart.
- **Upstream Wolman Data Points** (UP_WOLMAN)**:** In some cases, it will not be possible to collect the full 100 Wolman pebble count data points from the upstream side of the crossing. In this field, indicate the status of that pebble count. Options are **100 pts, < 100 pts,** and **none**. Additionally, current practice is to not collect any Wolman pebble counts in most crossings (see Appendix C: Decommissioned Roads for Legacy Roads Monitoring).
- **Location of Removed Fill** (FILL_LOC)**:** Describe where along the road prism the excavated road fill was placed. In most cases, the road grades down into and then down away from each crossing.
  - **Downhill side** - the fill was placed in a pile on the road surface on the side of the stream crossing that grades away from the road.
  - **Uphill side** - the fill was placed in a pile on the road surface on the side of the road that grades into the crossing.

- **Along road** - the fill was placed along the road on either side or both sides of the crossing. There is no singular dome or half dome shaped pile.
- **No pile** - there is no pile or other obvious location of the excavated fill. This generally means that the fill was transported off site during excavation.



- **Comment** (COMMENT)**:** At excavated stream crossings, it is necessary to add a comment about anything unusual. Indicate if the stream crossing is on a main channel or a side channel. If the TauDEM stream layer is available in the field, indicate if the point is located on the TauDEM stream or not. Note if the stream appears ephemeral (flows water in the spring season only). Note the general shape of the stream valley (V-shape, broad U-shape), and if the stream has a steep, moderate, or shallow gradient. The COMMENT field must be filled out for all excavated stream crossing points, so note anything else unique about the crossing.

Lead Off Ditch (LEAD_OFF)

A ditch that moves flow from the roadside ditch and leads it onto the hillslope. This feature is also known in some areas as a daylight ditch, or a mitre drain. Lead off drain points have mostly standard attributes.

- **Condition** (CONDIT)**: Excess deposition** refers to a lead off ditch that has become clogged with sediment. Its functionality is significantly reduced. **No problem** is self-explanatory.

Photo P. Lead off ditch discharging to hillslope.

Non-Engineered Drainage (NON_ENGIN)

This type of feature describes a situation where the water leaves the ditch or road in an unplanned manner. This can occur where the ditch becomes dammed by debris or where a rut diverts over the fillslope. Water flowing against a berm may erode through and escape over the hillslope to create a non-engineered drainage as shown in the photo below. This drainage feature has mostly standard attributes.

- **Condition** (CONDIT)**:** Refers to the causative mechanism. Options include **Diverted flow path** and **Broken berm**. **Blocked ditch** occurs when a blockage in the ditch causes water to flow over and then off the road. **Gully crosses road** refers to a gully that begins above the cutslope and continues below the fillslope, and is not a stream channel. If a short section of the road is outsloped, and a concentrated path exits the road in a concentrated way at that point, the condition is **Outsloped**.

Photo Q. A non-engineered drainage at a broken berm. Water flowing along an outside berm is diverted over the fillslope. The fill erosion in this case would meet the 5 cubic foot minimum.

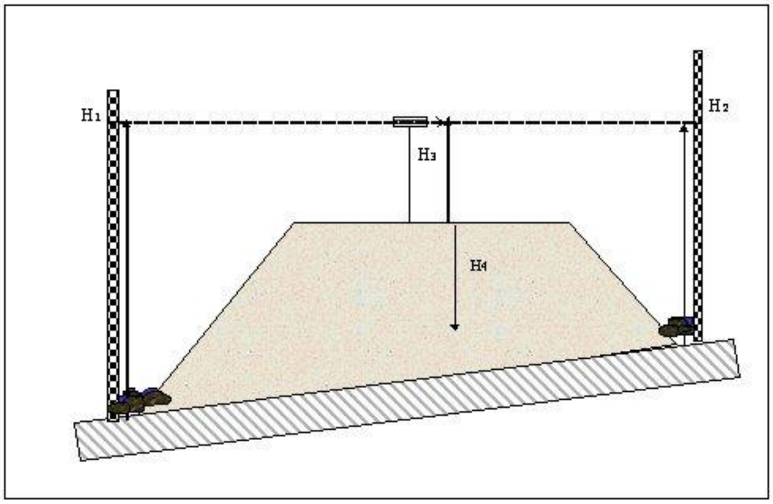
Stream Crossing (STRM_CROSS)

A stream crossing occurs when an established stream channel that has flow for at least part of most years crosses the road. These features may drain water from the road and cutslope, but their primary purpose is to route water flowing down the hillslope in stream channels under the road. See Appendix A: Frequently Asked Questions About the Features for more information on differentiating stream crossings from ditch relief culverts. Always take photos and accompanying **Photo** point at every stream crossing. Take at least three photos; of the inlet, the outlet, the road over the crossing, and anything else that may be unusual about the crossing. Note that there is a different point that you should take it the stream crossing has been excavated (the excavated stream crossing point). There are additional attributes available in INVENT 5.0W for aquatic organism passage if desired (Appendix D: Additional Stream Crossing Attributes for Watershed-Wide Road Inventories).

- **Type** (TYPE)**:** Ways that roads can cross flowing water.
  - **Steel culvert round** - the most common.
  - **Steel culvert oval** - large diameter culverts that have been compressed to be wider than they are tall.
  - **Steel arch bottomless** - corrugated steel culvert-like arches, may have concrete footings in the channel.
  - **Plastic, Aluminum** and **Concrete culverts** - self-explanatory.
  - **Baffled culvert** - the culvert has fins on the bottom to increase roughness and slow the water velocity
  - **Log culverts** - made of several large stems laid under the road parallel to the direction of water flow. They are uncommon.
  - **Concrete ford** - a crossing spot where the road goes through the stream, but has been reinforced with concrete.
  - **Natural Ford** - an un-reinforced crossing where the road goes through the stream.
  - **Bridge** - self-explanatory.
- **Pipe Diameter** (PIPE_DIA)**:** Refers to the standard pipe diameters in inches. Use **N/A** when there is no culvert. If the culvert is oval, measure the horizontal diameter and record it here. Culverts are typically a standard size: **12”, 15”, 18”, 24”, 30”, 36”, 48”, 60”, 66”, 72”** and **> 72”**. If the culvert is not a standard size, round to the nearest standard size and make a comment.
- **Pipe Length** (PIPE_LEN)**:** Measured in feet with a stadia rod and stadia level. The stadia marks are used to measure distance and the slope at the same time. See Appendix B: Using the Stadia Rod at Stream Crossings.
- **Channel Width** (CHAN_WDTH)**:** Measured in feet and tenths of feet at the green line of the active channel above any pools on the upstream side of the road. The green line is the place on the bank where green plants begin to grow. Below the green line, plants do not grow due to the persistent flow of the stream water. The goal is to measure the natural channel width that it out of the influence of the road. Go at least 20 feet above the culvert, or to where the channel is no longer influenced by the road, whichever is further, and take the average of three measurements five feet of stream length apart.

Photo R. Measuring channel width.

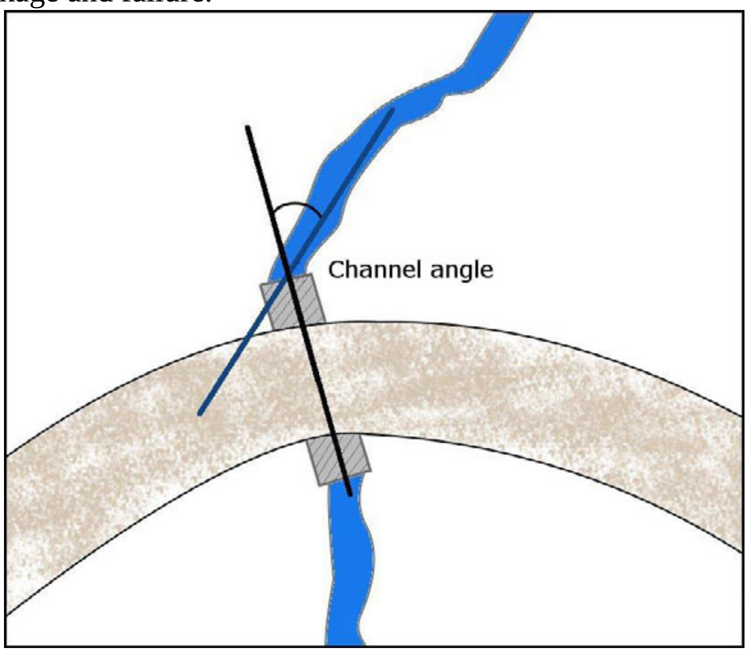
- **Pipe Number** (PIPE_NUM)**:** Applies only to culverts. It is rare that there is more than one pipe.
- **Fill Depth** (FILL_DEPTH)**:** Describes the depth of fill at the center of the road at the point where the pipe crosses the road. Fill depth is measured at the center of the road above the pipe with a stadia rod and level. Record the average of the depth of fill above the pipe at either end of the culvert. This is illustrated below, where fill depth (H4) is computed as ((H1+H2)/2)-H3). In the case of a bridge abutment, measure in the center of the fill leading to the bridge. See Appendix B: Using the Stadia Rod at Stream Crossings.



- **Stream Crossing Condition** (CONDIT)**:** Describes the condition of the crossing, listed from best case to worst case. Choose the worst problem present.

- **Open and Sound** - no problems.
- **Partially** and **Totally blocked** - partially or completely occluded by sediment or non-pipe obstructions.
- **Partially** and **Totally crushed** - self-explanatory and refer to a pipe that has been significantly pinched by a machine during cleanout.
- **Rusted significantly** - indicates that rust has penetrated the culvert bottom, or that a hammer blow makes a dull thud, instead of a clean ring.
- **Flows around pipe** - refers to water channeling below or beside the culvert.

• **Channel Angle** (CHAN_ANGL)**:** Describes the angle between the pipe and the trend down the center of the channel. When the two are parallel the angle is zero. The choices are; **<25 degrees, 25-45 degrees, 45-75 degrees**, and **> 75 degrees**. Flanagan et.al. (1998) found that the more acute the angle between the stream and the pipe, the greater the risk of blockage and failure.



• **Problem Type** (PROB_TYP)**:** Problems with the crossing in general that are not necessarily problems with the culvert itself. These are listed from best case to worst case. If more than one problem is present, choose the worse problem/

- **No** - indicates that there is no other problem with this crossing.
- **Sediment plume** - a volume of sediment that has been deposited upstream of the culvert, generally as a result of water backing up behind the pipe.
- **Organic debris pile** - a stack of organic debris such as branches and logs that has backed up behind the culvert due to high flow and may be blocking the culvert inlet to some degree.
- If the stream has overtopped the culvert and eroded away some of the surfacing, then the crossing is said to have a **Scoured road**. You may still be able to drive past this problem.

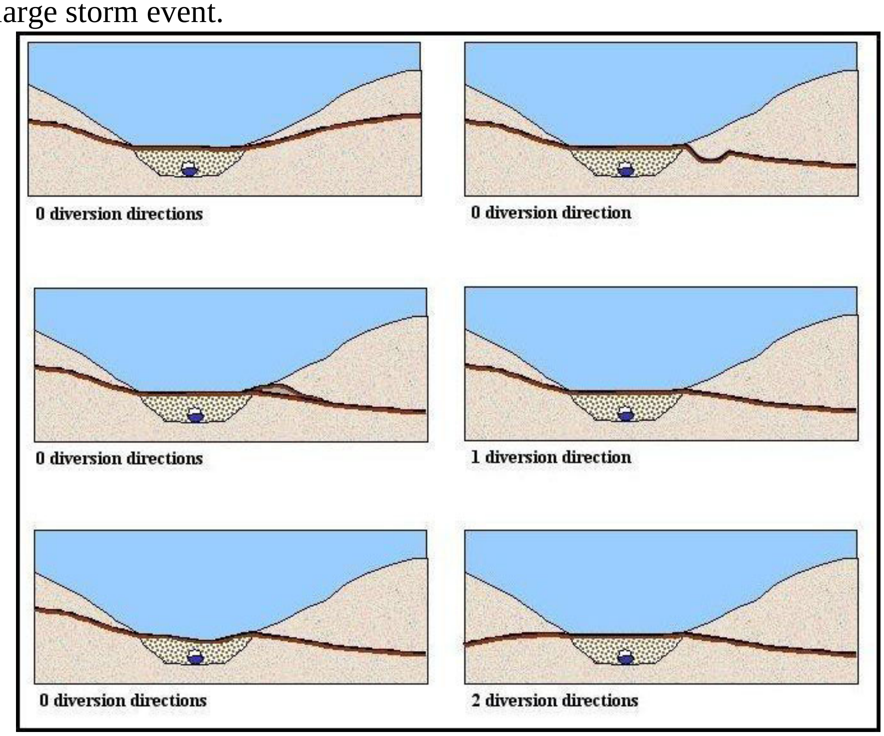
- **Washed out road** - refers to crossing fill that has been washed downhill by high stream flows and/or a plugged crossing (so that water runs over the road). Unless the crossing is very small, you will not be able to drive past this problem

Photo S. A washed out stream crossing.

- **Pipe Gradient** (PIPE_GRADE)**:** This parameter is measured with a stadia rod and stadia level. The observer on the road reads the height of the rod at the inlet side (H2) and at the outlet side (H1) to obtain a vertical drop. This vertical distance is divided by the horizontal distance computed above to obtain a slope in percent. See Appendix B: Using the Stadia Rod at Stream Crossings. Make sure to enter a positive number (if it comes out negative, just enter the same number as positive).
- **Crossing Substrate** (SUBSTRATE)**:** This field describes what type of material the stream travels over as it flows under the road. Inspect the inside of the pipe to confirm that the substrate is indeed **Culvert Material**. The substrate could also be S**and, Gravel, Boulders,** or **Bedrock**.
- **Debris Flow** (DEBRIS_FLW)**:** This field records whether there is evidence of a mass movement called a debris flow at the stream crossing. Debris flows move quickly and are coarse unsorted mass movements that may pass through the area or come to rest at the culvert. Evidence includes large scale scouring of the channel (if the flow passed through), or significant deposits of unsorted material, including buried branches and logs (if the flow was stopped by the road). The amount of vegetation growth on the surface will help indicate the age of the deposit. Note that if a debris flow is not stopped by the culvert, it will generally overtop and scour or wash out the crossing. This damage may have been repaired by the time of the survey, so also look for evidence of recent work above crossings, or places where the road grade is different from the rest of the road. Options are **YES** or **NO**.

Photo T. Debris flow at a stream crossing. Notice the mass of sediment intermingled with buried logs.

- **Diversion Direction(s)** (DIVERSION)**:** Describes the potential for a stream to become diverted down the road if it leaves the natural channel in an overtopping event. This can occur when the stream crossing structure becomes occluded by sediment or by wood. Diversion is possible when the road grade is constructed such that the road slopes downhill from the point of the stream crossing. If the road slopes downhill immediately past the crossing without first heading up hill, the value will be **1**. If this occurs in two directions from the channel, the value is **2**. When the road is optimally constructed and slopes uphill from the stream crossing in both directions, the value is **None**. The flow diversion field in the ditch relief drain point documents locations where the diversion has actually occurred, and is not the same. Additionally, water bars and broad based dips that are placed within the crossing area on the downhill side of the stream can prevent diversion in that direction. In addition to the road grade, observe any additional features below the crossing for evidence that they would be effective in preventing a flow diversion. These features must drain the whole road prism (ditch and road surface) during a large storm event.



- **Comment** (COMMENT)**:** At stream crossings, it is necessary to add a note to the comment field to indicate what channel the pipe is located on. This is because, in areas of high drainage density, there may be multiple streams close together. Indicate if the stream crossing is on a main channel or a side channel. If the TauDEM stream layer is available in the field, indicate if the point is located on the TauDEM stream or not. Note if the stream appears ephemeral (flows water in the spring season only). Note the general shape of the stream valley (V-shape, broad U-shape), and if the stream has a steep, moderate, or shallow gradient. The COMMENT field must be filled out for all stream crossing points, so note anything unique about the crossing.

Sump (SUMP)

A sump is defined as a closed depression where water is intentionally sent to infiltrate. These can occur where two roads join, or where the ground is very flat and little water accumulates. A sump is generally a designed feature in the roadway intentionally used to route water with no outlet such as a holding pond. A sump can also be any place where water enters and does not escape, such as a very flat section of road where water ponds and puddles on the surface. Sump drain points have mostly standard attributes.

- **Condition** (CONDIT)**:** This describes the potential problems with the feature such as **Fill saturation** or **Puddles on the road**. **Flat grade** describes the situation in which the road is so flat, that no water flows down the road, and instead puddles on the surface. See Appendix A: Frequently Asked Questions About the Features for more information.
- **Type** (TYPE)**:** This describes whether or not the sump is an engineered feature such as a holding pond, or an unintentional feature such as a flat grade or cattle guard that has no outlet. Options are **Constructed** or not constructed (**Not constrc**).

Photo U. A *Constructed* sump in good condition.

Water bar (WATER_BAR)

A waterbar is a water diversion feature cut into the road surface with a grader blade or other equipment. They are smaller than broad based dips. Water bars are typically 5-10 feet in road length and 1 to 4 feet deep. Fabricated water bars are usually wooden or rubber flow diversions across the road used to channel water to the ditch or hillslope. They have mostly standard attributes. A highway vehicle may not be able to pass some very large water bars. See Appendix A: Frequently Asked Questions About the Features for information about the differences between a water bar and a broad based dip.

- **Type** (TYPE)**: Road material** or **Fabricated material**. Occasionally water bars are not just composed of road material, but can be wooden or rubber flow diversions placed on top of or within the road surface.
- **Condition** (CONDIT)**:** This attribute describes the things that can go wrong with a water bar.
  - **No problem** - self-explanatory.
  - **Damaged** - water flows over or around the water bar because of some kind of damage.
  - **Too small** - the water bar receives more flow than it was designed for, and water flows over or around.
  - **Drains inboard ditch** - can be intentional, self-explanatory.

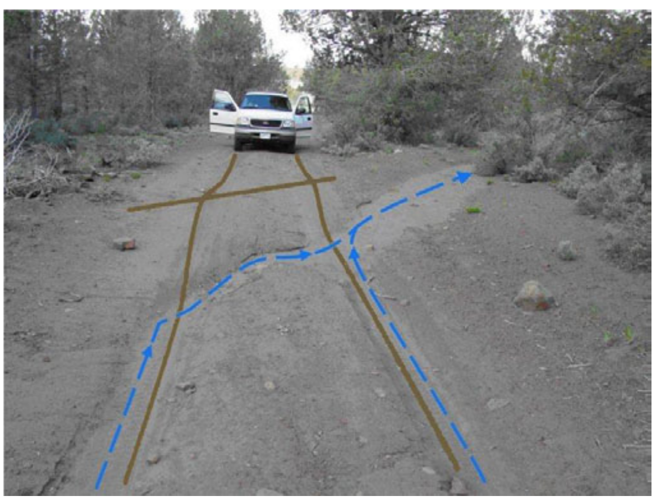


Photo V. An annotated water bar. The wheel tracks, flow paths, and the top of the water bar are marked.

Photo W. Another annotated water bar, with the top and bottom of the water bar marked.

Other Features

There are nine features available in the data dictionary that are not drain points. These are used to describe features of the road, erosion problems along the road, etc. All of the data dictionary attributes for each drain point are described or explained. The features are presented in alphabetical order.

End of Road (END_RD)

This feature describes where a road actually ends and water is no longer traveling on a man-made feature. This helps the office team distinguish between a road line feature that was ended when GPS signal ended and where the road actually ceases to be a road.

- **Description** (Description)**:** Enter a brief description of the end of the road, such as, "Rd ends in wide turn around, above clear cut."

Gated Road (GATE)

Gated Roads are distinguished from closed roads. Presumably these roads are drivable and the owners have decided against allowing public access. You should take a GATE point any time you encounter a gate, even if it is open.

- **Condition** (CONDITION)**: Functional**, **Damaged**
- **Access** (ACCESS)**:** An **UNLOCKED GATE** is effectively open, while a **LOCKED GATE** is closed.

<u>Gully</u> <u>(GULLY)</u>

A gully is an erosional feature that results from excessive discharge at a given point. A minimum threshold of 6 inches deep and 10 feet in length is used to distinguish a gully from localized fill erosion. Gullies are typically wider than they are deep and may occur due to poor design routing excessive water to an unstable location or due to large storm events. Take a photo and **Photo** point of every gully on the slopes along the road that you encounter. Remember that if a drain point discharges to a gully, the **DISCHRG_TO** field must be changed to **Gully**.

- **Road Associated** (ROAD_ASSC)**:** Defined for a gully to mean that it is due to the building of the road, i.e. the gully would not exist if the road did not exist. A gully that started above the road and crosses the road would not be road associated but should be mapped nonetheless. For some study purposes, it may be beneficial to only map and estimate, but not measure gullies that are not road related. Options are **YES** or **NO**.
- **Activity** (ACTIVITY)**:** Determined by assessing the shape and fill. If a gully is **STILL ERODING**, it will typically have sediment transported by flowing water visible in the bottom. There will be little vegetation growing on the steep and unstable side slopes or in the bottom. An older, **NOT ACTIVE,** gully will have grass or vegetation growing within it and may be filling in with slope transported sediment.

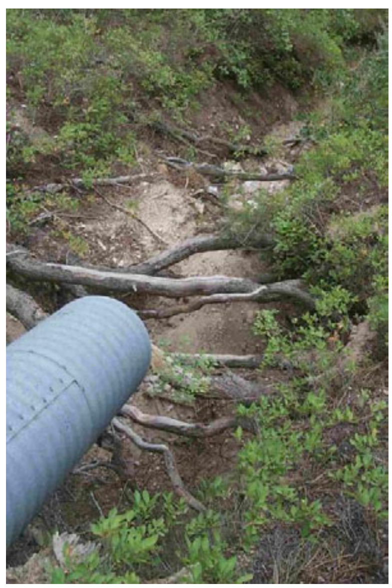


Photo X. Active gully below culvert incised through roots and exposing bedrock.

- **Wet swale** (Wet swale)**:** It is important to know if the gully is located in a wet swale area of the hillslope. For these purposes, a swale is a valley bottom without a stream that fits the definition used here and not any steep hillslope concavity. Indications that a swale is wet include an abundance of moisture loving plants, such as devil's club or moss, and can apply to any location where there is much more or greener vegetation than elsewhere along the slope. Also look for ground that is more moist than elsewhere on the slope, especially if you are in an arid area. Options are **Yes** and **No**.
- **Location of gully** (LOCATION)**:** This attribute describes the location of the gully within or out of the road prism.
  - **Fillslope** - The gully occurs entirely within the fillslope.

- **Hillslope** - The gully occurs entirely on the hillslope below the road.
- **Fill and Hill** - The gully starts on the fillslope and continues onto the hillslope.
- **Above Road** - The gully occurs above the road.

- **Contributing factors** (Contributor)**:** If there are any contributing factors to the gully that are not the road surface directly, note them here. **Spring** means that there is a spring or seep in the cutslope somewhere up road of the gully that contributes water to the point at which the gully initiates. If this is the case, be sure to note which road segment includes the spring or seep by changing the **Edge condition** of that road segment to **Seep spring**. **Swale** means that the gully is located in a swale (see definition , above) that may contribute non-road hillslope water to the gully. Choose this any time the gully is located in a swale. **Flow diversion** means that there is a stream crossing up road of the gully that has in the past or present been diverted down the road and discharges at least in part at the location of the gully. If the drain point that emits the diverted stream onto the slope is a ditch relief culvert, be sure to change **Flow diversion** to **Yes** in the ditch relief culvert point. Also be sure to note any problems that remain with the stream crossing.
- **Terminates** (Terminates)**:** This describes the location at which the gully ends. Choose **Hillslope** if the gully ends at any place that is not another **Gully** or a **Stream**. If the gully runs into another gully, be sure that the other gully is inventoried as well. If the gully runs onto a floodplain but not directly into a stream pick the **Stream** option, anyway. Note that any drain point that discharges to the gully would also be stream connected. Note that a floodplain is the bench area directly above the green line.
- **Length** (LENGTH)**:** Estimated, measured (with a tape or a rangefinder), or paced, and should document the total length of the feature. Measured in feet from the uppermost to lowermost location where incision exceeds 6 inches below the soil surface. In many landscapes, gullies may be discontinuous features. In discontinuous cases, the upper most and lower most locations where the gully incises deeper than 6 inches will be used to estimate total length.
- **Width** (WIDTH)**:** Measured in feet (6 inches is 0.5 feet) and describes the average width of the entire feature.
- **Depth** (DEPTH)**:** Measured in feet (6 inches is 0.5 feet) and describes the average depth.
- **CDate** (CDATE)**:** Data collection date automatically assigned in MM/DD/YYYY format.
- **Vehicle ID** (VEHICLE)**:** ID number for the collecting vehicle or crew, automatically assigned.
- **CTime1** (CTIME1)**:** This is the 4-digit number that uniquely ties the gully point to the contributing drain point. The format is 24 hour time with no colon. This value is the CTime value obtained from the contributing drain point, rounded to the nearest whole minute (30 seconds rounds up, 29 seconds rounds down). If the gully is not road related, leave this attribute as the default value (999).

Photo Y. Active gully below culvert due to excessive contributing road length. Note the V-shaped cross section and steep side slopes. This active feature continues over 700 feet to the main valley bottom.

- **CTime2** (CTIME2)**:** The ID for the secondary contributing drain point. In some cases, there will be a secondary drain point on the road that contributes its water to the gully. The secondary drain point will be assigned a CTime2. If there is no secondary contributing drain point, leave this attribute as the default value (999).

<u>Landslide</u> <u>(LANDSLIDE)</u>

A landslide is a type of mass wasting feature associated with an over-steepened slope, excessive water, excessive fill placed on an unstable location, or from the destabilization of a slope. In many landscapes, they can be triggered when excessive road drainage is routed to steep colluvial hollows below the road. A landslide is typically at least 2 feet to several tens of feet in thickness and longer than it is wide. In many cases the bottom will expose bedrock when the feature is fresh. There may be a steep head scarp at the upper edge of the feature and a deposit of debris at the lower end. Landslides may occur above or below the road and all should be noted with a landslide point if close to the road. If the road suddenly narrows, look down slope to be sure that the fill has not been removed by a landslide. A failure above the road may also be quite visible when debris enters the roadway For the purpose of the inventory a landslide involves more than 10 feet in slope length, more than 6 feet in slope width, more than 1 foot depth, and should be noted with a point.

- **Road Related** (ROAD_RLTD)**:** Those that are likely caused by excess water drainage. In this case a culvert pipe may be visible in the failure area. Road related slides may also be caused by undercutting of a steep slope by the road. Slides that are visible from the road but not necessarily road related may have occurred higher up on the slope and deposited debris on the road. Cutslope failures are road related Options are **YES** or **NO**.

Photo AA. Road related landslide. This fill failure initiated at the point where a culvert discharges to the hillslope.

Photo Z. Landslide above road on the hillslope associated with recent fire. It would not be called road related.

- **Location** (LOCATION)**:** Indicates the location of the landslide.
  - **Hillslope failure** - landslide is not in the road prism, but may be road related if water discharging from the road caused it.
  - **Cutslope failure** - landslide in the cutslope.
  - **Fillslope failure** - landslide in the fillslope.
- **Position** (POSITION)**:** Location of the slide with regard to the road. Options are **Below_rd** or **Above_rd**.
- **Length** (LENGTH)**:** Measured in feet. The goal is to describe the average volume of the mass of landslide which can be modeled as an ellipse. Measure length from the upper edge of the head scarp to the lower end of the scar.

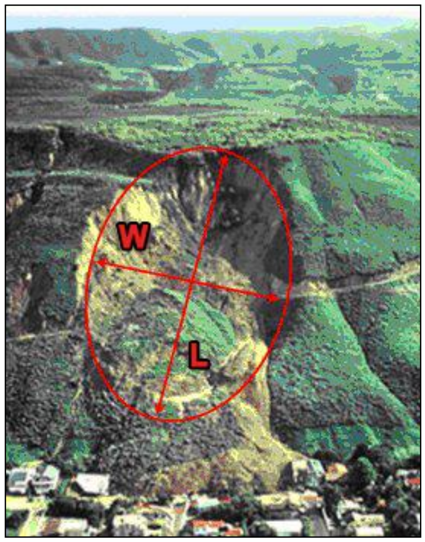


Photo BB. Hillslope scale landslide showing length and width measurements. Photograph of the La Conchita landslide by USGS staff.

- **Width** (WIDTH)**:** Measured in feet, and describes the maximum width of the landslide scar as shown in the photo above.
- **Depth** (DEPTH)**:** Measured in feet and describes the average depth of the scar.
- **Age** (AGE)**:** Estimated by the freshness of the scar, age of vegetation, and any repairs that have been made to the road. Many slides are associated with large storm events. If applicable, consider how long it has been since the last memorable storm event that may have caused the slide. Options are **<5 YEARS, <10 YEARS,** and **<15 YEARS**.
- **Confidence** (CONFIDENCE)**:** Recorded because some individuals may not be confident in their age classifications. If you are not certain what to look for ask your supervisor or some local watershed professionals. If you cannot see the slide well from the road, carefully climb down to take a closer look. Note any sharp breaks in slope, exposed bedrock, and accumulated debris below the evacuated slide scar. In many instances the slide scar is oval or spoon shaped. Options are **CERTAIN, LIKELY,** and **UNCERTAIN**.
- **CDate** (CDATE)**:** Data collection date automatically assigned in MM/DD/YYYY format.

- **Vehicle ID** (VEHICLE)**:** ID number for the collecting vehicle or crew, automatically assigned.
- **CTime1** (CTIME1)**:** This is the 4-digit number that uniquely ties the landslide point to the contributing drain point. The format is 24 hour time with no colon. This value is the CTime value obtained from the contributing drain point, rounded to the nearest whole minute (30 seconds rounds up, 29 seconds rounds down). If the landslide is not due to road drainage, leave this attribute as the default value (999).
- **CTime2** (CTIME2)**:** The ID for the secondary contributing drain point. In some cases, there will be a secondary drain point on the road that contributes its water to the landslide. The secondary drain point will be assigned a CTime2. If there is no secondary contributing drain point, leave this attribute as the default value (999).

Photo CC-1 and CC-2. These landslides resulted from unstable road fills. Although these are recent events, the gap in vegetation will be notable for many years after the event.

Photo DD. This road related landslide resulted from an over steepened cutslope that failed during an intense rainfall event.

Photo Point (PHOTO)

A photo should be taken to document unusual situations such as all landslides, all gullies, stream flow diversions, road hazards, etc. Additionally, a few photos should be taken that show a typical section of each road, and three or more photos should be taken at each stream crossing (inlet, outlet, road over the crossing). You cannot take too many photos. A **Comment** is used to identify the image, and the GPS location, **CDate** and **CTime** are used to tie the photo to the inventory. Manually enter the time from the camera as the CTime. Please be diligent about collecting these images as it will facilitate the corrective action that must be taken and will help the office staff to understand what is going on in confusing places along the road. It is helpful to include a scale such as a field notebook or measuring tape in each photo. You may include multiple photos in a single photo point, but make sure to list how many photos and their CTimes in the comment field, in addition to the photo descriptions.

Point Generic (Point_generic)

This is used when there is something unusual along the road worth noting, but there is nothing already in the data dictionary to describe it. For example, if the ditch intercepts a stream that has no culvert, a generic point should be used to mark the place where the stream enters the ditch (and the ditch should have **Flow diversion Yes**). Make a **Comment** about what you are documenting and take a photo.

Revisit (REVISIT)

This is used to mark a place where you need to return to collect further data, usually because satellite reception is bad at the time of day you are there. Enter a **Description** of why you need to return to that point. Notice that the **CDate** is automatically assigned.

Road Closed (ROAD_CLSD)

A closed road is a point feature documenting that the road has been closed intentionally by management activity (e.g. log and soil) or by disuse or lack of maintenance (e.g. an overgrown road). The closure is permanent or long-term, as opposed to a gated road which may be open seasonally or to administrative use, and eliminates full-size vehicles from that road permanently or for the long-term. The road line feature may still be hydrologically significant beyond the blockage and will probably need to be inventoried with a backpack GPS. This will typically occur at the beginning of decommissioned roads or old, unused logging roads.

- **Closure Description** (CLOSURE_DESCRIPTION)**:** Options are self-explanatory: **LOG AND SOIL**, **DOWN TREES**, **OVERGROWN**, **PLANTED**, **RIPPED OR SUBSOILED**, **TRENCHED** (generally includes tank traps), **BOULDERS**, **GUARD RAIL**, **CABLE**, or **FENCING**.
- **Closure Efficiency** (CLOSURE_EFFICIENCY)**:** Options are self-explanatory: **Fully effective**, **Driven around**, **Damaged**, or **Missing**.

Road Hazard (ROAD_HZRD)

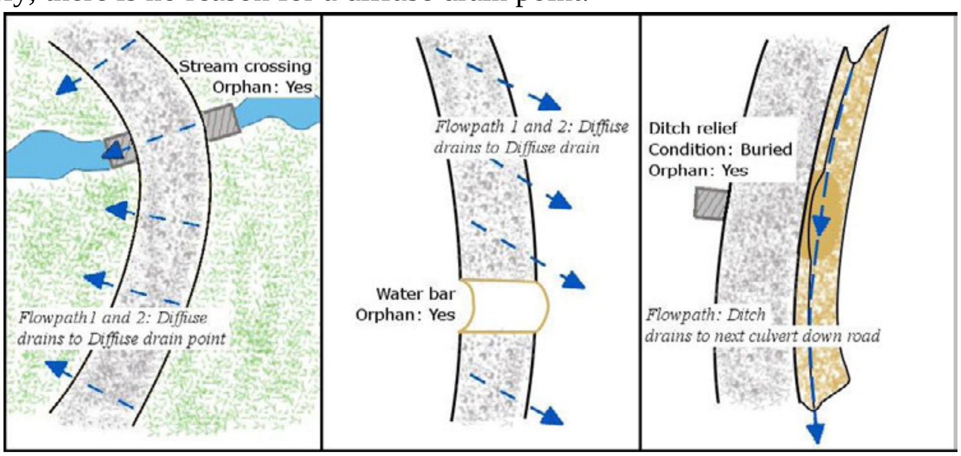
This text field (**Type**) allows a note be made of anything dangerous or seriously wrong that needs to be fixed on the road, such as a downed tree, large boulder, or debris deposit. The hazard poses a risk to public safety on an open road. This point is used by managers to find where there are safety problems so that they can be eliminated.

Appendix A: Frequently Asked Questions About the Features

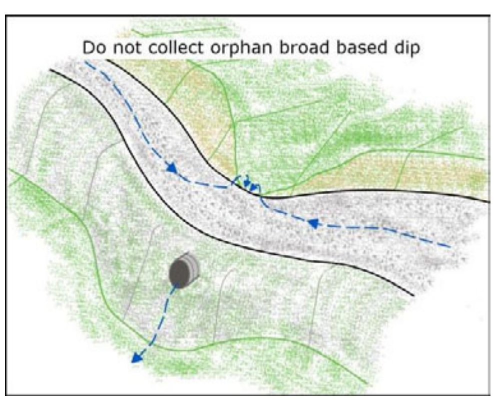
There are a number of areas that frequently cause confusion in the field. This appendix attempts to clarify those confusions so that data can be more consistent between crews and over time. It is a good idea to know what topics are covered in this FAQ, so you can reference them easily in the field if or when you encounter a confusing or unclear situation. If a question remains unanswered or unclear, contact your crew leader and record the answer.

What is an orphan drain point?

An orphan drain point is a drain point that exists in the field, but does not route any water. Examples include crushed, buried or blocked culverts, water bars on diffuse road segments, stream crossings that do not drain any water from the road, etc. When you encounter an orphan drain point, collect and describe it as usual, and select *Yes* in the *ORPHAN* field. Do not use it to route water, or it won't be an orphan. There is an example in Section I, Dry Tutorial, Scenario B. Even though no water drains at orphan drain points, you should still start a new road segment at each orphan. Make sure to collect all orphan drain points. There can never be an orphan diffuse drain point, because these represent a length of road that drains diffusely, and if a road segment does not drain diffusely, there is no reason for a diffuse drain point.



Additionally, you should not collect natural grade reversal broad based dips if they are orphaned. This can happen if you encounter one of these points on a road that drains all water in the ditch, and there is a culvert at the low point in the dip. The dip is not an engineered feature if it is a natural grade reversal, and so should not be included in the inventory, unless it does drain water from the road.



Is there an efficient way to locate ditch relief culverts?

Ditch relief culverts are sometimes hard to spot from the road, because they are buried by sediment or, commonly, obscured by vegetation. Sometimes, they are just low enough in the ditch that they are not obvious. Ditch relief culverts are easy to miss for those reasons. However, in most places, there are tell-tale signs that you are approaching a ditch relief culvert.

- The distance between ditch relief culverts is generally pretty consistent on a road. You can see this on the map after you have collected a few. Typical spacing ranges from 50 to 150 meters on most western forests. When you get close to the spacing you have observed for the road you are on, begin looking more closely.
- There are some visual clues that you can observe from the road.
  - There is often a scalloped cutslope directly above the culvert (Figure 8).
  - Often, there is a sediment pile in the ditch just downhill of the culvert (Figure 9).
  - Ditch relief culverts are often placed below the regular level of the ditch, so the ditch becomes deeper just before a culvert.
- On some roads, all of the culverts have been located by steel posts, wooden stakes, or flagging. These are generally roads where work on the culverts is planned or was performed at some point in the past. However, even if the culverts appear to be marked along the road, you should still look for the other signs, in case some of the culverts were missed, or some of the markers have been removed.
- Wet spots in the ditch and cutslope may indicate a nearby culvert, usually installed to drain that wet spot.

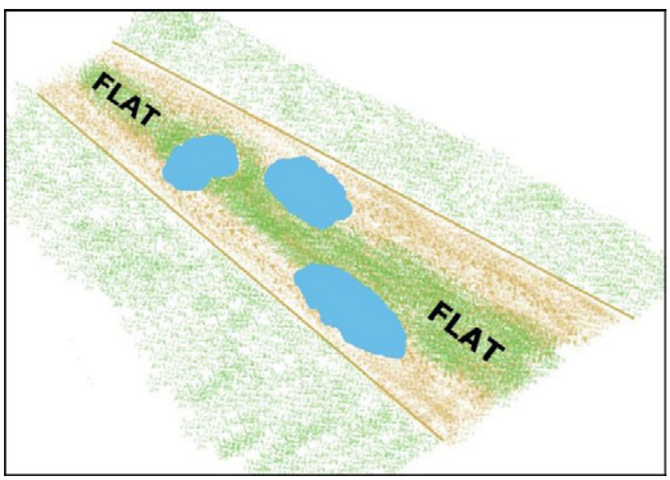
Figure 8. A scalloped cut above a ditch relief culvert.

Figure 9. A sediment pile below a ditch relief culvert.

How is the not constructed sump drain point used, and how does it differ from a broad based dip that does not drain?

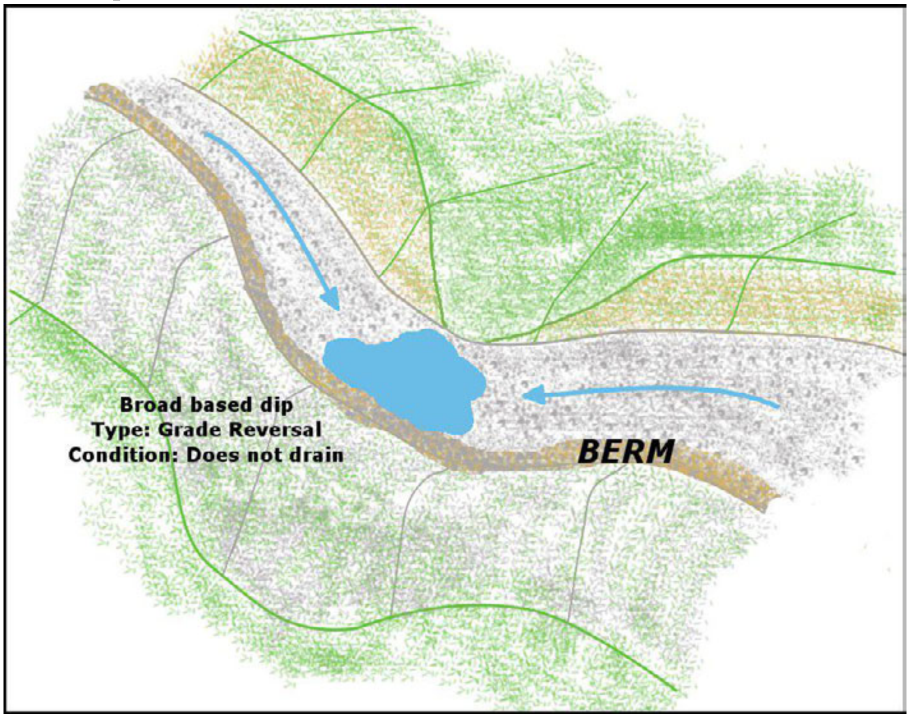
The not constructed sump point is used in places where water infiltrates in a specific area, but there is no specifically designed feature. Some typical cases:

- A flat road that accumulates water, which then infiltrates as opposed to runs off the road. There are usually puddles on the surface of the road. There may or may not be a ditch, and the ditch may or may not drain properly (i.e. it may be part of the sump).



- A flat road that is insloped or has a berm, but is too flat to drain the water. The water accumulates on the inboard side of the road, and infiltrates. There may or may not be a ditch, and the ditch may or may not drain properly (i.e. it may be part of the sump). If the water has broken through the berm and drained off, it is a non-engineered drain point instead of a sump.

A broad based dip that does not drain is usually a natural grade reversal with a berm on the outboard side of the road. Water from both sides of the grade reversal drains into the broad based dip, but the berm prevents the water from running off of the road. The water infiltrates and usually causes the road surface to become muddy (if the road is native surfaced). If this is the case take a broad based dip point and drain all appropriate water to it, even though the water stays on the road. If the water has broken through the berm, then the broad based dip does drain. If this is the case, make sure to check for fill erosion.



When is a stream a stream? That is, when should I take a stream crossing point instead of a ditch relief point?

Large streams (> 6 ft wide) are almost always obvious. However, the smaller the stream, the more it looks like a ditch relief culvert. Small streams may have the same standard size culvert as a ditch relief, and they may occur in what appears to be only a gentle swale. Small streams may not have year-round flow, and they may not get any flow in some dry years. Conversely, sometimes ditch relief culverts occur in a deep swale, which looks like it should get some flow. They may occur directly below a seep in the cutslope, and therefore get flow, but the flow may disappear into the forest floor below the culvert. There may be a gully directly above the culvert, and one below, that may look like a stream bed, but disappear quickly in either direction. The definition of an official stream crossing (for the purposes of GRAIP) is:

- A continuous feature above and below the road that has a defined bed and banks. If you are not sure of continuity, walk up and down the feature from the road until you are sure it is or is not continuous.
- The bed will be armored (transported sand, pebbles, boulders, etc.). Look for armoring above the road, in a location outside of the influence of the road.
- There does not have to be flowing water, but there should be evidence of flow frequently enough to maintain the channel features. This typically means that the stream will get flow for some part of most years.
- The average channel width is greater than 1 foot. Measure this above the road, in a location outside of the influence of the road.

If all of the above qualifications are not met, even if it looks especially stream-like, then do not describe the culvert as a stream crossing, but as a ditch relief culvert. If all of the above qualifications are met, even if it looks like it should be a ditch relief culvert, describe the culvert as a stream crossing.

When is a non-engineered drain point large enough to document?

Non-engineered drain points come in many sizes and types. Any time water leaves the road in a concentrated manner at a location that was not designed to route water off the road, there is a non-engineered drain point. This can happen because there is too much water on the road at one time (often due to too infrequent engineered drain points), the road is outsloped in a spot, potentially unintentionally, a debris torrent from uphill over takes the road and washes some fill away, etc.

- A non-engineered drain point is big enough to document if an estimated 30% or more of the water that runs down the road surface drains at that point, or if there is more than 1 cubic foot of fill erosion.
- It is possible to have an orphan non-engineered drain point, even on a road that has a concentrated flow path.
    - For example, if the concentrated flow path is a secondary flow path, and more water runs past the non-engineered drain point (on the inboard side of the road) than drains through the non-engineered drain point, the non-engineered drain point would be an orphan. If something like that is the case, make a comment in the non-engineered point, as well as select *Yes* in the *ORPHAN*.

– If the non-engineered is an orphan and it does not have more than 1 cubic foot of fill erosion, then do not collect it.

When does a third flow path in the road prism become large enough to become more important than an already existing second flow path?

It is possible to have three clear flow paths on a road segment. For example, the road could be half-outsloped, with one flow path as the ditch, another concentrated, and another diffuse. There may be evidence for all three flow paths. You should always document the ditch and the largest of the other two flow paths, and make a comment in the road line about the remaining flow path. In the above example, if the two road-surface flow paths (concentrated and diffuse) appear to move the same amount of water, document whichever one is more continuous (that is, if the rest of the road is just ditch and diffuse, document the ditch and the diffuse flow paths).

Is there ever a time when a present ditch would not be counted as a flow path?

If there is a ditch present it must be included as one of the flow paths, unless there are two highly eroded concentrated flow paths on the road that drain to different drain points, *and* the ditch is not eroded at all. This is a rare case, and you may never encounter it.

How can I tell if a drain point delivers sediment to a stream channel?

In many places, it is difficult to tell whether or not a drain point connects to the stream network. You should follow any evidence of flow until it terminates to find out if there is a connection. Evidence includes:

- Gullies and rills
- Transported organic matter (e.g. leaves and needles; Figure 10)
- Matted vegetation
- Deposited sediment (Figure 11)
- Distance from drain point to the stream channel

- Steepness of the hillslope (steeper hillslopes are more likely to connect, and flat benches are more likely to allow water to infiltrate).

Figure 10. Transported pine needles that take the shape of a parabola are common flow indicators. These parabolic conifer needle flow forms can point in or against the direction of flow, so look for piled sediment behind the needles. Flow here is to the right.

Figure 11. The light colored sediment has been transported from the road prism to the forest floor, and is a good indicator of flow.

Is there a way to get consistent data about vegetation and surface cover percentages?

This can be the most subjective observation made in the field, and it is also one of the most important. It is often difficult to estimate percentage vegetation and surface cover.

- The estimate should include only and all vegetation that is in direct contact with the ground.
- Dead vegetation counts.

The below diagram of percent cover can help you guide your decision (Figure 12).

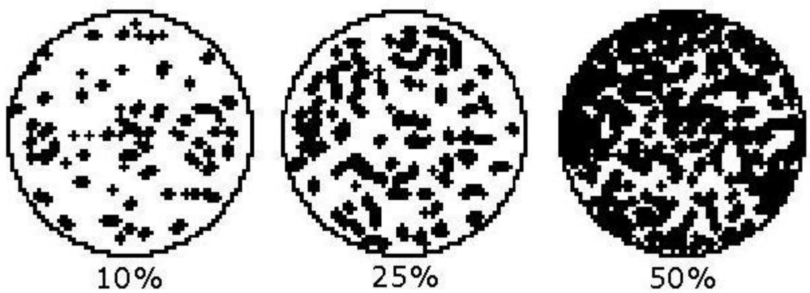


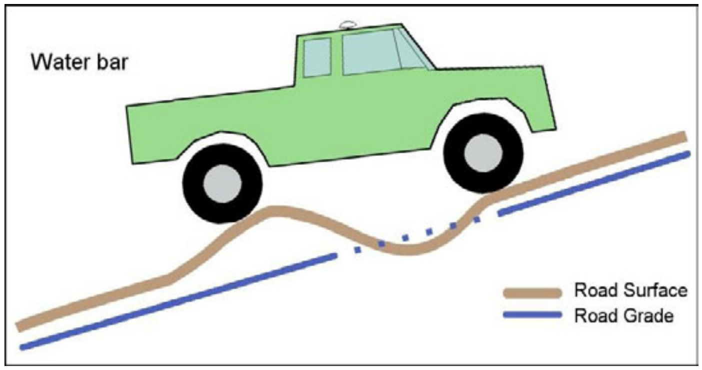
Figure 12. Chart that shows percent cover at some relevant percentages.

In order to establish consistent estimates between crews and individuals, you should implement frequent calibration with measured values. For a given length of road surface, estimate the percentage vegetation cover. Stretch a tape about 100 feet over a flow path (ditch, concentrated). Place the eraser end of a pencil on the left side of the tape at every other foot mark, and record whether the point is vegetation or bare soil. Calculate the percentage of vegetation covered ground, compare that number to your estimate, and adjust your future estimation techniques accordingly. You and your crew mate should do this individually, once every third day or so. Make sure to pick flow paths that are not too easy (0%, 100%), or the calibration is pointless. Crews have tended to underestimate vegetation cover.

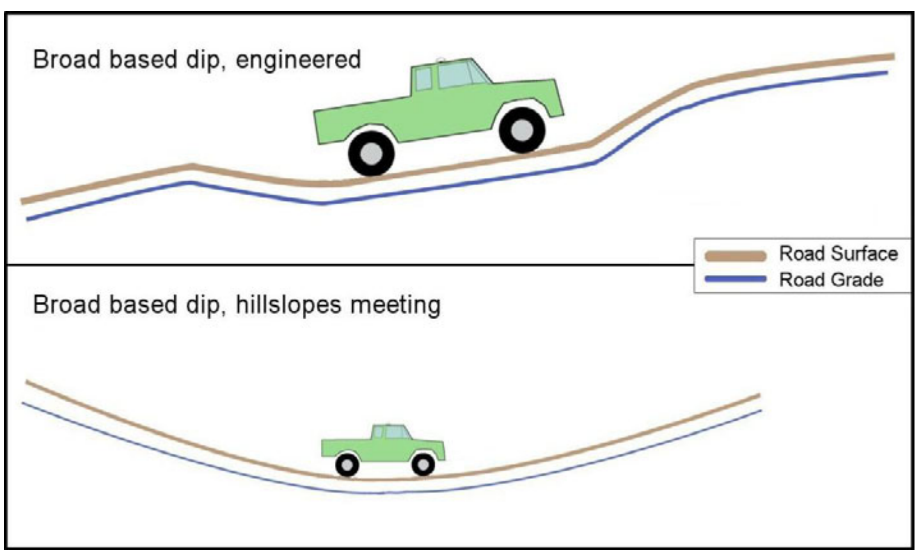
How can I tell a water bar from a broad based dip?

Both of these features are used to drain water from a road surface. Large water bars can be confused with broad based dips. However, the definitions for each are mostly size-independent. Water bars can be very large, and broad based dips are generally larger than water bars. Keep in mind that there are two kinds of broad based dips; they occur both when two opposing hillslopes meet (this is a grade reversal), and as an engineered feature into the road grade.

- A water bar is generally a small feature, which has been cut through the road grade. A vehicle would drive over a water bar. They can be constructed well after the road was built, may not be passable to highway vehicles, and may even be used to close a road (closure berm or tank trap).



- An engineered broad based dip is a larger feature, which is designed and built into the road grade during the initial road construction. A vehicle would drive though a broad based dip. An engineered broad based dip is always easily passable by standard-clearance passenger cars travelling at greater than 15 mph, so long as the road surface condition is good. You do not need to approach an engineered broad based dip at an angle to clear it in any vehicle. A broad based dip must be large enough for you to park your vehicle in completely. These are designed to drain road surface water without impeding the quality of travel and allowing passenger cars and log trucks to pass through.



- If you cannot park the entirety of your vehicle in the low part of the feature, and/or you cannot drive past the feature without effort or without slowing to below 15 mph, then the feature is a water bar.
- If the feature appears to be designed into the road grade, is easily passable, and is large enough for your vehicle to fit, then the feature is a broad based dip.

How can I tell if on-road flow is diffuse or concentrated?

On many roads, especially gravel roads and roads in areas that do not receive a lot of precipitation, it can be difficult to find on-road flow paths. Water on a road can diffuse into the ditch, run down the road, diffuse off the road, or a combination of those. Many times, a road is obviously insloped or outsloped, so it is easy to see that water would leave the road into the ditch or diffusely off the road. Other times, there are obvious concentrated flow paths that run down the road.

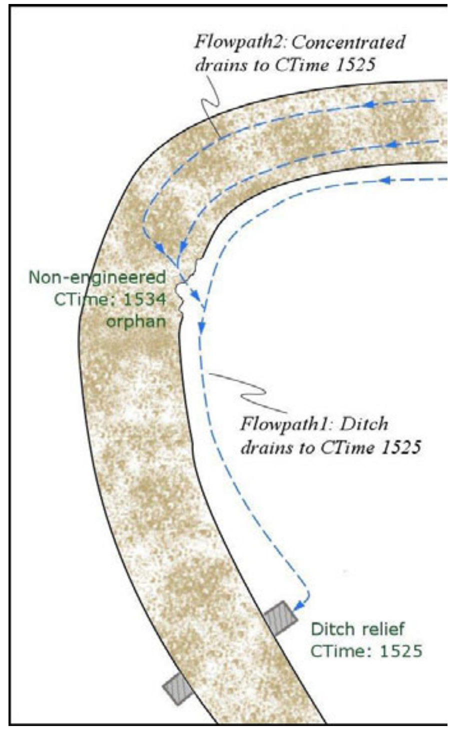
- When water diffuses into a ditch, at least half the road is usually insloped. Many times, that is the only indicator you have that water from the road goes into the ditch. Other times, you will see small rills (< 1 inch wide), or sediment deposits leading to the ditch. Generally, any road that is fully insloped (and therefore the water diffuses into the ditch) is described as having only the ditch flow path.
- When water flows down a road, the road cross-section is usually flat. Often, there will be shallow wheel ruts that gather most of the water from the road. Many times, you will be able to see some sign that water flows down the road, such as small rills (< 1 inch wide), parabolic conifer needle flow forms, etc. When there are wheel ruts and no indicators that water diffuses off the road, the road is generally described as having at least one concentrated flow path. If there is a berm, then there cannot be diffuse flow.
- When water diffuses off the road and out of the road prism, at least half the road is usually outsloped. Many times, the outsloping is the only indicator you have that water diffuses off the road. Small rills, sediment deposition, and parabolic conifer needle flow forms that suggest off-road flow are all indicators of diffuse flow. Generally, any road that is outsloped is described as having at least one diffuse flow path. However, even an outsloped road can have no diffuse flow path. There may be a shallow wheel track (less than ½ inch deep), or a “mini-berm” of fill material or dead and compacted vegetation or

duff on the outside edge (less than ½ in tall) that concentrates water down the road. It does not take very much to concentrate flow.

- Sometimes, a road's cross section looks very flat, and there are no indicators of any kind of flow. If you cannot find any evidence of flow, closely examine the road surface. Try to picture where a bucket of water dumped in the middle of the road would go. These roads are more often concentrated than diffuse.

Which CTime should be used when a flow path moves through an intermediate drain point, like a non-engineered point that goes into the ditch?

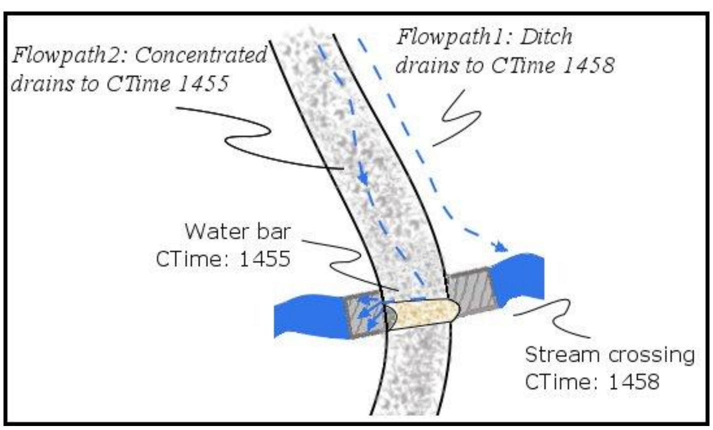
As an example, if a road segment has a concentrated flow path that discharges into the ditch on the inboard side of the road, the water from that concentrated flow path is routed to the same place as the ditch. If there is a significant erosion problem at the place where the water runs into the ditch (more than 1 cubic foot of fill erosion), you should collect a non-engineered point with discharge to ditch. The non-engineered drain point is collected as an orphan, and the CTime that the ditch routes to is used for the wheel tracks flow path. This situation can also occur with water bars that drain to the ditch. Note that you would begin a new road segment at the non-engineered drain point.



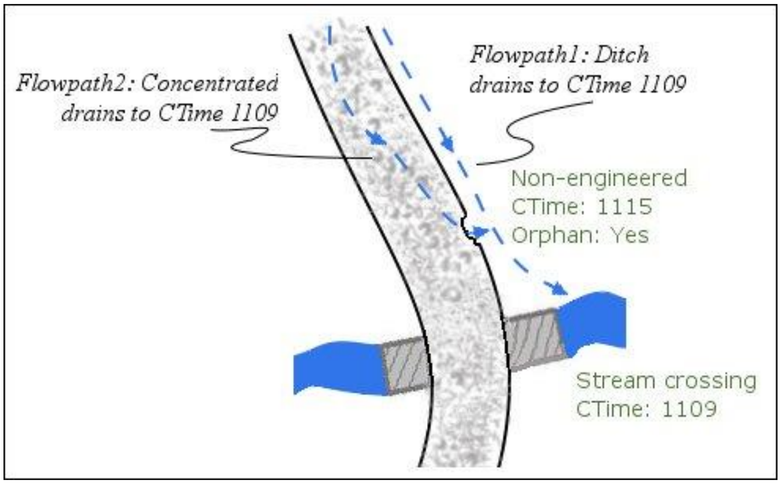
Which CTime should be used when a concentrated flow path drains off the road over a stream crossing?

There are two main scenarios where this is likely:

- The concentrated flow path drains off the road surface and into the stream directly over the stream crossing through a water bar, broad based dip, or non-engineered drain point. In this case, drain the concentrated flow path to the CTime of the other drain point.



- The concentrated flow path runs into the ditch just before the ditch runs into the stream crossing. If this is the case, drain the concentrated flow path to the same CTime as the ditch, which is the stream crossing, as in the previous question.



How are crowned roads described?

A crowned road is a road where the inboard side of the road is insloped (to drain water to the ditch), and the outboard side of the road is outsloped (to drain water off the road prism completely). Unless there is evidence to the contrary, a crowned road is described as having both ditch and diffuse flow paths. Note that it does not take much blockage (wheel track or berm less than ½ in) to keep a road from diffusing water. Many roads are constructed with a crown, but traffic has since flattened or caused shallow ruts in the road profile.

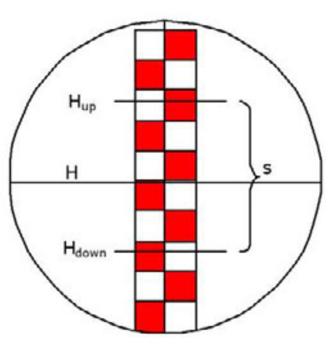
Appendix B: Using the Stadia Rod at Stream Crossings

In order to get accurate data about the length and slope of the culvert (if there is a culvert), and depth of fill over the culvert, a stadia rod paired with a stadia level is used at stream crossings. The numbers generated by the below described process can be easily computed by hand to give the desired length, slope, and fill depth, or they can be entered into a spreadsheet that has been set up to generate the desired numbers automatically. A standard stadia or Philadelphia rod with tenths of feet can be used with a level having stadia crosshairs to measure distance. This process requires both crew members, and cannot be used by only one person. A laser rangefinder may also be used to measure the pipe length, but it will not be able to take the fill depth or accurate pipe slope measurements.

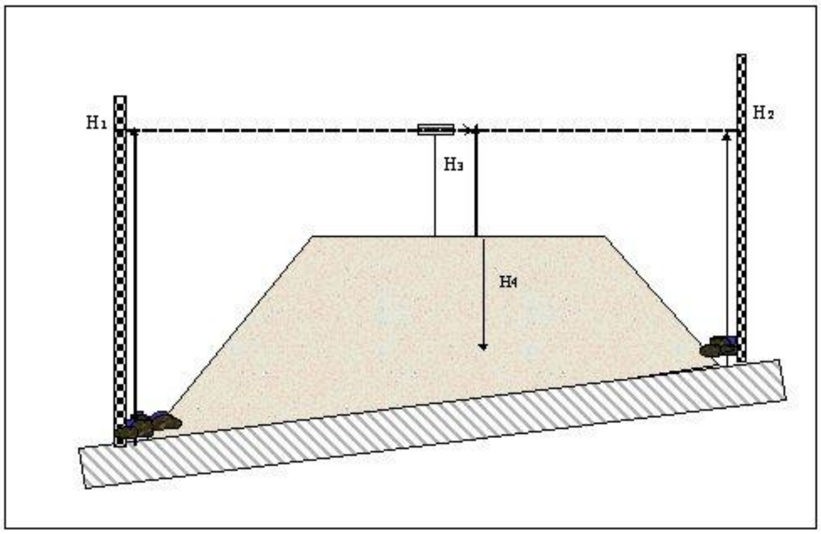
1. One person (the rod holder) takes the stadia rod to the inlet of the stream crossing culvert and places the end of the rod as close to the edge of the culvert as is safe. The other person (the leveler) takes the stadia level and stands in the middle of the road, directly over the culvert.

- **a.** Beforehand, measure the distance from the ground to the eyes of the person operating the stadia level. It is useful to have a support of some kind for the stadia level.

2. The rod holder extends the stadia rod until the leveler's eye is level with the rod. Hold the rod straight up, and extend from the lowest section up.



3. The leveler focuses the telescope in the level on the rod and levels it. The leveler now takes three readings from the stadia rod: $\mathbf{H_{up}}$, $\mathbf{H_{down}}$, and the **H**. These readings are recorded in the field notebook.
4. Now is a good time for the rod holder to take the necessary data from the upstream end of the stream crossing (see the Glossary)
5. Repeat for the other side of the culvert. The uphill side data is referred to as **H2**, and the downhill side data as **H1**.
6. There are nine numbers that you need: $\mathbf{H2_{up}}$, $\mathbf{H2_{down}}$, **H2**, $\mathbf{H1_{up}}$, $\mathbf{H1_{down}}$, **H1**, the eye height of the leveler (**H3**), the pipe diameter, and the stadia interval factor for your level.



a. The typical stadia interval factor is 100, but can be checked by setting up known baseline lengths and taking stadia measurements from the rod in the above way. Use the below equation to find your stadia interval factor.

$$\boldsymbol{D} = (\boldsymbol{F}/\boldsymbol{I}) \times \boldsymbol{S}$$

$\boldsymbol{D}$ is horizontal distance

$\boldsymbol{S}$ is the difference between the elevation readings at the stadia marks ($A - B = S$)

$\boldsymbol{F}/\boldsymbol{I}$ is the stadia interval factor

7. To compute pipe length (feet):

$$\boldsymbol{pipe\ length = stadia\ factor \times (H2_{up} - H2_{down}) + stadia\ factor \times (H1_{up} + H1_{down})}$$

8. To compute fill depth (feet):

$$\boldsymbol{fill\ depth\ H4 = \frac{pipe\ diameter\ in\ inches}{12} + \frac{H2 + H1}{2} - H3}$$

9. To compute pipe slope (%):

$$\boldsymbol{pipe\ slope = \frac{H2 - H1}{pipe\ length} \times 100}$$

Appendix C: Decommissioned Roads for Legacy Roads Monitoring

A decommissioned road is a road that has been permanently closed, with culverts removed, is no longer passable to any vehicle, and typically has a tilled, ripped, or recontoured surface (Figure 13). Legacy Roads crews will be conducting a study that involves inventorying roads before and after decommissioning work is completed on them, and so will probably encounter freshly decommissioned roads. Decommissioned roads pose some extra challenges. The first challenge is safety. Often, inventories of decommissioned roads take place late in the season, after the work has been completed, when there is a greater chance of rain, slippery logs, and deep mud. Be careful in these situations. Decommissioned roads are difficult to navigate, because they are often covered with downed trees, loose surfaces, etc. As such, crews should be aware that transportation for injured persons is much more difficult on decommissioned roads. Always carry a radio linked to the forest network or a satellite phone. Two-way radios are also a good idea.

Figure 13. A decommissioned road in the Olympic National Forest. This road has been recontoured.

The main goal of road decommissioning surface treatment is to increase the infiltration capacity of the road surface so water will no longer run off the road, but will infiltrate in place. The intensity of the surface treatment and type of soil determine how much a treated road will behave like a natural soil instead of a road.

Water has not had a chance to flow over newly decommissioned roads yet, and so there is little evidence to tell if a given drain point is stream connected or not. On-road flow paths may not exist for the same reason. Additionally, on-road flow paths may take a different form than on open roads. Since the surface of decommissioned roads has often been disturbed by tilling, ripping, or recontouring, there is a large amount of relatively loose sediment on the surface. However, generally, the same rules apply. If a tilled road (for example) appears outsloped, water is probably diffusing out of the road prism. Tilled roads are generally diffuse because water infiltrates and does not concentrate and flow down the road surface. If there is still a ditch, then that is one flow path. If there is evidence that water has flowed down the surface of the road, then the other flow path is concentrated. Recontoured roads are always diffuse only, since there is no ditch and surface water would flow off the road without concentrating anyway, due to the outsloping.

There are additional complications presented at stream crossings. On a decommissioned road, the stream crossing culvert will have been removed to facilitate fish passage and to reduce the sediment risks associated with a potential stream crossing failure. Since the culvert is no more, there are no culvert-related measurements to observe. However, there are additional measurements to observe. It is important to know if there are any problems with the crossing, such as incising or lateral erosion. It is important to know roughly how much erosion, if applicable. It may be important to know the distribution of pebble sizes in the new decommissioned stream bed compared to the natural stream bed (upstream of the crossing), and it is important to know the slope of the new channel. Finally, it is important to know the new side slope angle and side slope length (from the old road surface). These goals are accomplished with stadia rod surveys and channel cross-sections.

There is a spreadsheet in which to enter the excavated stream crossing data. When you open the spreadsheet, you will see a place for the stream crossing CTime and the file name, a place for each cross-section (full-crossing, both in-crossing, longitudinal), any side slope erosion, and for the optional Wolman pebble counts. Some of the cells in the cross-section and side erosion section are self-calculated (orange) and some are data entry cells (green). Please use one spreadsheet for each site (e.g. one spreadsheet for the post-decom on the Rogue NF, and another for the post-decom on the Flathead NF). There are a series of worksheets (tabs on the bottom of the window), one for each stream crossing. Please re-name each tab with the CTime of the stream crossing. If you need more worksheets, right click on one, click *Insert…*, click *Worksheet*, click *OK*, then copy and paste (just select all) the data entry cells into the new worksheet(s). As you enter data into the spreadsheet, check the calculated values against visual estimations to ensure that data is entered correctly.

When you come to a decommissioned stream crossing, take the following steps:

1. Collect an excavated stream crossing point as near to the center of the stream as you can get. Satellite reception may be impeded by the new stream banks.

2. Observe and enter relevant data in TerraSync.

   a. Look for evidence of past or present stream flow in the new channel bottom and enter this in the *FLOW* field in TerraSync.

   b. Observe the covering on the side slopes. If there is more than one covering, select *Multiple, comment* in the *SIDE_SLOPE* field, and mention all coverings in the comment for the feature.

- **c.** If there is incision or lateral erosion (see below), or if there are landslides in the side slopes, or if the stream flows under the fill, enter these in the *CONDIT* field.
- **d.** Measure and enter the *CHAN_WIDTH* as usual (upstream of the crossing).
- **e.** If you complete Wolman pebble counts, enter how many data points you were able to collect for the upstream segment in the *UP_WOLMAN* field.
- **f.** Observe the location of the displaced fill material from the stream crossing excavation, and enter it in the *FILL_LOC* field.
  - **i.** If the fill is piled on the side of the road that grades into the crossing, so that any water travelling down the road would hit the fill pile before the stream crossing, enter *Uphill side*. If the fill is piled on the side of the road that grades away from the crossing, enter *Downhill side*. If the fill is distributed along the surface of the road, enter *Along road*, and if there is no evidence of the fill, enter *No pile*.
- **g.** Fill in the *ORPHAN* field as usual.
- **h.** The *STREAM_CON* field has only one option, *Yes*, because the stream crossing is always connected to the stream network.

3. Conduct the stadia rod survey and enter its data into the spreadsheet.

- **a.** Establish a benchmark on the top of the right side slope at a location that corresponds to the middle of the excavated crossing. Use a hammer to pound a rebar stake in far enough that less than four inches are exposed and install a cap. Mark the cap with the unit name (e.g. RMRS GRAIP), date, crew member initials, and BM (for benchmark).
- **b.** Establish a good location to setup the stadia level and read the rod from. It is best to be able to see the whole crossing, as well as the upstream and downstream sections. If there is no location where this is possible, you will have to move instrument setups during the survey.
- **c.** One person will use the stadia level to read the rod (the leveler) and the other will place and hold the stadia rod, read the tape, and enter data into the spreadsheet (the rod holder). If the crew finds it easier, the leveler may be responsible for entering data.
- **d.** Survey and record the full cross-section.

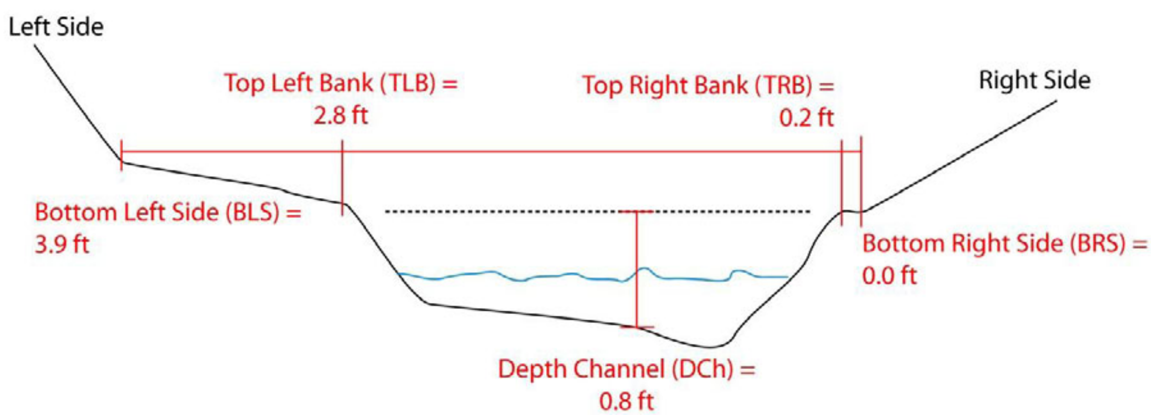
i. Stretch the tape from the benchmark down the right side slope, across the bottom, and then up the left side slope such that the tape traverses the middle of the crossing and is perpendicular to the stream line. You may run out of tape, in which case, bring the zero end of the tape to the run-out end and add distance to the total length of the tape.

ii. The leveler will stand in the same location. The rod holder will place the rod on the benchmark (0.0 ft along the tape) and record the data (tape distance to 0.1 ft and rod reading to 0.01 ft).

iii. Move the rod down the right side to the bottom of the slope (where the slope changes to that of the crossing bottom) and read the tape and rod again. Then repeat for the top of the right bank, the thalweg of the channel (the thalweg is the deepest continuous line with a stream or river—the deep part of the channel with the highest velocity), the top of the left bank, the bottom of the left slope, and the top of the left slope. Also read the tape and rod at any locations on the side slopes where the slope changes significantly (usually this happens only on very long side slopes).

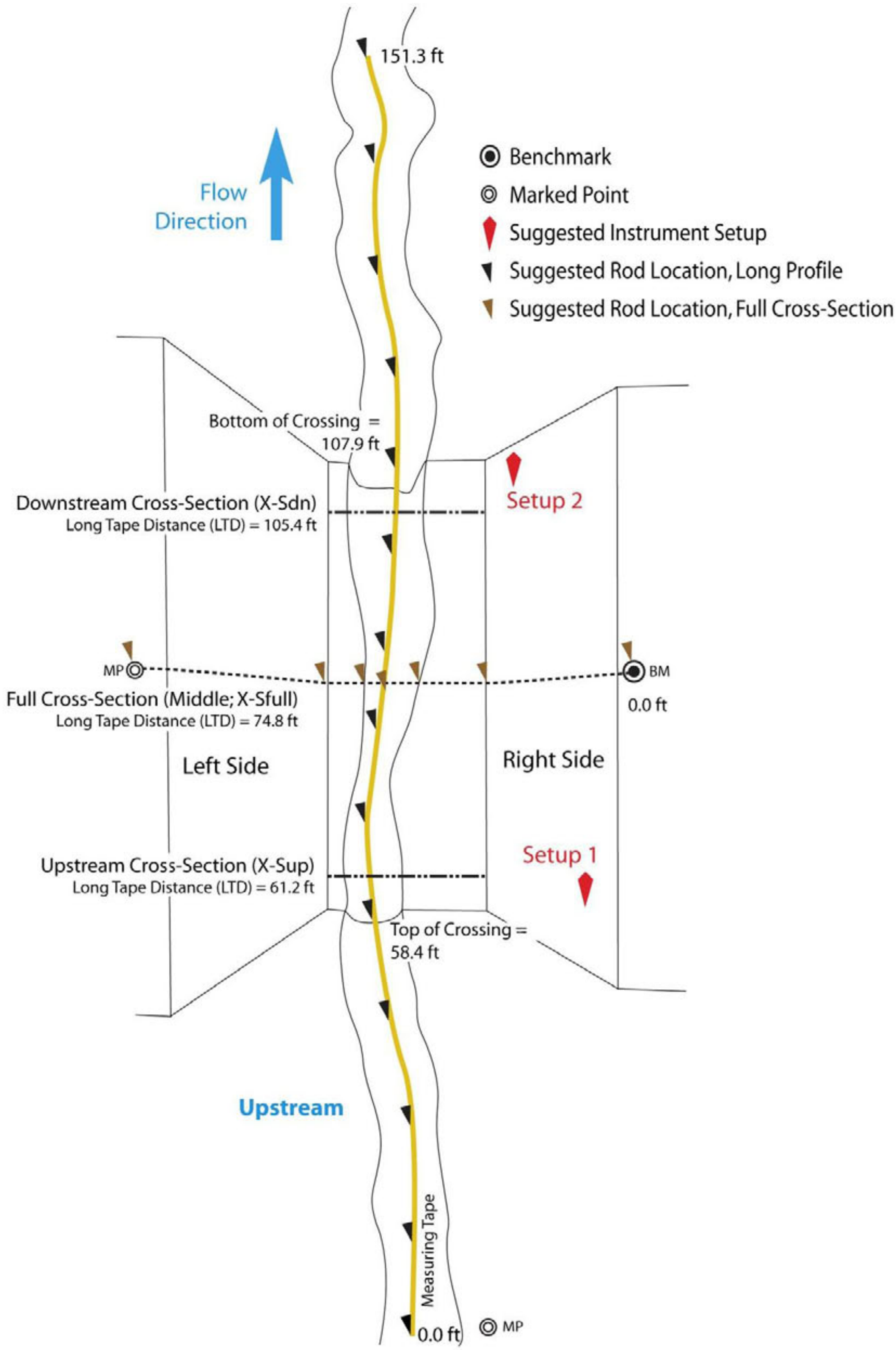
- It is a good idea to mark the location of this cross-section through the channel with temporary rock cairns or sticks stuck in the ground. You will need to know this location later.

iv. Establish a marked point at the top of the left side of the crossing where the cross- section ends with rebar. Mark the cap as with the benchmark, but write MP for marked point instead of BM.



e. Survey and record the longitudinal profile.

i. The goal is to survey through the crossing, as well as upstream and downstream of the crossing. This will allow accurate comparisons to be made (slope, channel character) after a large storm event.



ii. Walk upstream either one crossing-channel length (i.e if the length of the crossing is about 50 ft, walk upstream about 50 ft) or as far as safe or possible, and establish another marked point as before. This point is the zero for the measuring tape.

iii. Stretch the tape from the upstream marked point along the thalweg using rocks to anchor the tape where necessary. Stretch the tape through the crossing and then below the crossing about on crossing-channel length or as far as safe or possible. Again, you may run out of tape, in which case, bring the zero end of the tape to the run-out end and add distance to the total length of the tape.

iv. Start at the upstream end (tape = 0.0 ft). As before, the leveler will remain stationary while the rod holder will move along the tape. For each of the three sections (upstream, in-crossing, and downstream), make four or five measurements along the tape (again, tape distance and rod height). Be sure to always take measurements at the top and bottom of the crossing and *mark which measurements these are in the spreadsheet!* Take a measurement at the location of the full cross-section, and mark it in the spreadsheet. Also take measurements at the top and bottom of any significant steps in the channel, and note this in the spreadsheet.

v. If you must change the location of the instrument setup:

- Take a repeat measurement on a known location from the new location. For example, after the last possible measurement is made from Setup 1, keep the rod in the same location, and then take the measurement again from the new location.
- Record the rod measurements from Setup 1 and Setup 2 in the appropriate cells in the spreadsheet. This allows for office personnel to calculate the elevation difference and correct the subsequent rod readings.
- Only record one of the measurements in the longitudinal cross-section area of the spreadsheet. This will reduce confusion later.
- Record the setup number for each measurement in the longitudinal cross-section area of the spreadsheet.

4. Record the long tape distance at the upstream to in-crossing and in-crossing to downstream transitions in the appropriate cells in the spreadsheet.

5. Measure the upstream and downstream in-crossing cross-sections.

   a. These should both be near to the upstream and downstream ends of the crossing, but should not be at the transitions. If this is a return visit (e.g. post-storm event), measure the cross-sections at the previously recorded distance from the middle (this should be in the spreadsheet from the first visit).

   b. Set a tape (25 ft length is usually fine; leave the long tape in the crossing) so that zero is on the right (looking downstream), against the bottom edge of the right slope, and the other end is against the bottom edge of the left slope.

   c. In the spreadsheet, record the distance to the top of the right bank, the average depth of the channel (from the channel bottom to the top of the bank), the distance to the top of the left bank, and the distance to the bottom edge of the left slope. If there is no channel, just record the distance to the left slope.

   d. You do not have to enter the width of the channel, just the distance of each edge from the right bank, because the width and volume are calculated in the spreadsheet. This method also tells us in the office where in the excavated crossing bottom any future channel incision occurs (left, right, middle).

   e. Record the long tape distance in the spreadsheet.

6. If there is erosion on either of the side slopes greater than 5’ x 5’ x 0.5’, measure its dimensions as you would a landslide and enter the data in the spreadsheet. Leave these Slope Erosion cells blank if there is only minimal side slope erosion.

7. Optionally, take a Wolman pebble count of the channel until you have 100 points, measuring the B-axis particle dimension in millimeters. See below for instructions on taking Wolman pebble counts. Also take a Wolman pebble count of the natural channel upstream of the crossing to gather the same number of points, unless that is unsafe or impossible. Enter each set of numbers in the spreadsheet.

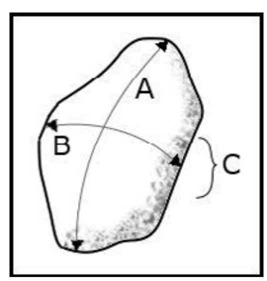
   a. This may be useful if there is something unusual about the particle size distribution in the channel, especially if there is already an existing pebble count for this crossing. As a general guide, if there are existing pebble counts, take one or two pebble counts on small to medium size streams (1-5 ft wide) for every five to ten crossings at a site.

8. Make a drawing of the general shape of the crossing in the field notebook, noting any abnormal pebble size distributions or other unusual features.
9. If there is anything unusual, note it in the excavated stream crossing point comment field.

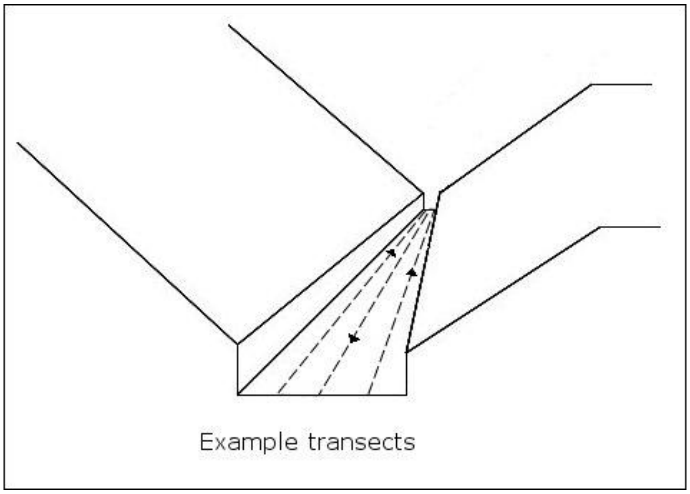
Wolman Pebble Count Procedure

The Wolman (1954) pebble count method has been shown to be the most efficient technique for determining stream particle size ranges. In order for the pebble count to be statistically valid, obtain measurements from 100 particles. This may necessitate walking up and down the stream crossing bed a number of times. The method described here is the step-toe method, but other random sampling techniques can be used. One person should observe the particle sizes and the other should record the sizes as they are called out in a table or tally sheet. The person in the stream will probably want waterproof boots or waders, and a pair of waterproof gloves, such as rubber dish gloves, if the water is cold.

1. Pick a random place on either end of the excavated stream crossing (upstream or downstream) to begin your count.
2. From the selected starting point, take a step while averting your eyes from the ground. It helps to focus on a far point that you intend to move towards for each step.
   - **a.** While still looking away, put your finger on the particle directly beneath your big toe and pick it up.
   - **b.** Measure its B-axis and call the measurement out for the recorder.
     - **i.** The B-axis is the widest portion of the intermediate length of the particle.
     - **ii.** Measure embedded or very large particles (i.e. boulders) in place (measure the shortest visible axis). Any particles under 2 mm are classified as 2 mm.



3. Continue to take steps and measurements in this way until you reach the other end of the excavated stream crossing. Turn around and repeat the process until you have 100 points.



   a. If the first transect is completed in the middle of the channel, complete the second on one side or the other, and then complete the third on the remaining side, etc.

4. If it is safe and possible to do so, also complete a pebble count of the unaffected stream upstream of the excavated crossing in the same manner. Go as far upstream as the excavated channel is long before turning around. Collect 100 measurements.

Appendix D: Additional Stream Crossing Attributes for Watershed-Wide Road Inventories

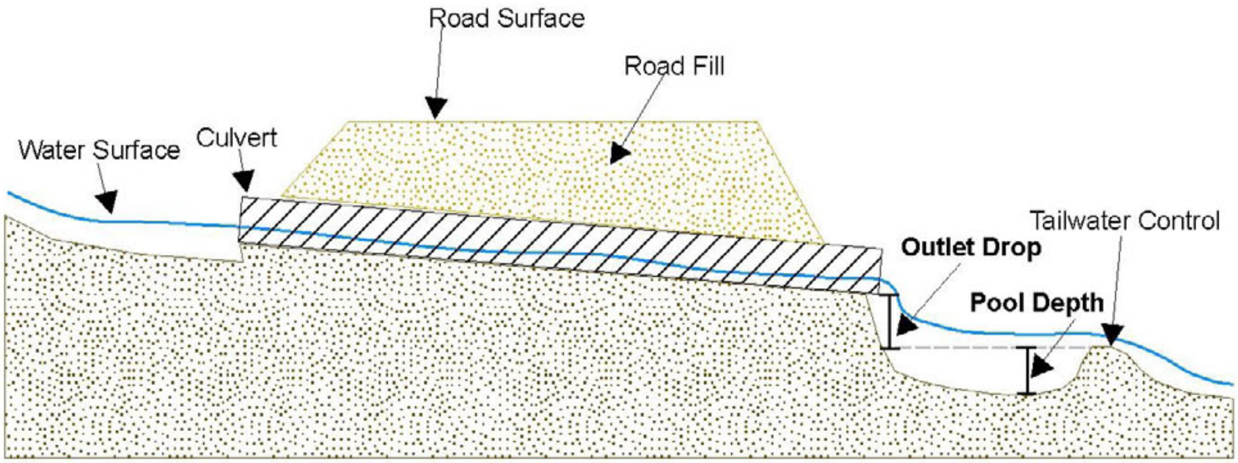
Many forest managers are interested in aquatic organism passage at road-stream intersections. Culverts are the most common type of stream crossing structure found on forest roads; they are also prone to blocking the ability of fish to pass through them. This can segment habitat for certain species or life stages of fish. Two attributes of stream crossing culverts that may create a barrier to aquatic organism passage are the outlet drop and residual pool depth (as defined below).

These attributes may not be necessary to collect for every road inventory using the GRAIP system. The objectives of the study and existing data might determine whether or not to include these measurements during field data collection. For certain road inventories, especially those intended to survey all existing roads within an entire watershed, these data may be valuable. For others, such as small-scale surveys of specific roads or road segments, these data may not be as meaningful in assessing fish habitat segmentation. Forest and project managers will need to decide if this information is a priority. The total added time to take these measurements in the field should be no more than five minutes at each stream crossing. If collecting these data in the field, be sure to use the data dictionary entitled *INVENT5_0_W*, as *INVENT5_0* does not include these attributes (these data dictionary versions were current as of May 17, 2010).

The definitions and background information for these attributes were adapted from the *National Inventory and Assessment Procedure—For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings* (Clarkin et al., 2005).

- **Outlet Drop** (OUTLET_DRP): The outlet drop is the jump at the outlet of the structure that a fish must negotiate to enter the structure. At extreme low flows the outlet drop is controlled by the substrate elevation at the tailwater (waters located immediately downstream) of the outlet pool. The total outlet drop is the elevation difference between the bottom of the culvert at the outlet and the downstream tailwater control (buildup of substrate material at outlet of pool). Tailwater elevations will be higher than the lowest point in the tailwater control, as long as flow continues across the control; the outlet drop measurement represents the highest jump possible (the jump that would be needed at zero flow). Measured in feet and tenths of feet using the end of the stadia rod.
- **Residual Pool Depth** (PL_DEPTH): The residual pool depth is the depth of water in the outlet pool under no or very low flow. Some species, notably salmonids, may be able to negotiate an outlet drop providing a jump pool of sufficient depth is present. The total pool depth is the elevation difference between the downstream tailwater control and the thalweg (deepest point) of the pool. Measured in feet and tenths of feet using the end of the stadia rod.

It is important to note that not all stream crossings will have an outlet drop or a pool at the outlet. Some crossings may have an outlet drop, but no pool or vice versa. If this is the case, enter 0.0 for the corresponding measurement(s). For example, the bottom of the outlet of a culvert is raised two feet above the water surface (creating an outlet drop) where 0.2 feet of flow exits the pipe onto riprap and continues downstream without a pool ever forming. In this case the outlet drop would be 2.2 and the pool depth would be 0.0.



Appendix E: More Details on Field Gear

Below is a typical list of gear needed by a GRAIP crew to complete the field processes. Where applicable, specific products that have been used in the past are listed, but this information is for the convenience of the reader, and in no way constitutes an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Number/crew	Item	Example or Comment
1/each	GPS antenna, receiver and field data recorder	Trimble Pro XH, Pro XR, Geo XT, Geo XM, etc.
1	Trimble TerraSync 4.0	
1	backpack for GPS mounting	Trimble, or constructed from PVC pipes
1	groundplane for antenna	
1	laptop + charger	Panasonic Toughbook, Durabook
1	finger mouse	BXT Finger Trackball Mouse
2	thumb drives	Retractable is best
2 of each	manuals (Vol. 1: Data Collection Method, Data Dictionary)	See GRAIP website (http://www.fs.fed.us/GRAIP/index.shtml)
1 pair	two-way radios + charger	Motorola Talkabout T8500R
1	camera, batteries, charger, data cord	Olympus Stylus 1030SW (ruggedized)
1	stadia level	SOKKIA 5x magnifying hand level
1	stadia rod	SOKKIA 25 ft; tenths; fiberglass; oval
1	stadia level support	Constructed from PVC pipe
1	rangefinder + batteries	Leupold RX-750 (should be able to display angle)
2	measuring tapes, standard, ft, m	25 ft/8 m, should be Hi-Viz orange
2	measuring tape, long ft, (m)	100 ft, fiberglass is best
2	field notebooks	Rite in the Rain
misc	flag tape	Bright colors, not green
misc	extra batteries	
1	power inverter, 120 W or better	
misc	maps	
2 pairs	gloves	Leather work gloves
1	satellite phone or forest radio	
2	safety vests	
2	identifying clothing	In order to identify yourself to other forest users
2	hard hats	May be required in some areas
1	safety beacon + batteries	Powerful enough to see in bright daylight
1	"Survey Crew" road signs and stands	Flexible roll-up are best because they are more compact
1	plastic gear box	Rubbermaid, Action Packer, etc.

Appendix F: The Data Dictionary

This is a text version of the data dictionary document indicating the possible selections under each attribute. The numeric time shown to the right of each feature is the default GPS data collection rate in seconds. For each feature attribute, from left to right next to the feature field name: The first is *Menu*, *Numeric*, or *Text*, which indicates the type of field. If it is a text type field, the next entry is the maximum number of characters allowed. The next entry is the permissions for field entry for initial creation, either *Normal* or *Required*. Next is the description of the feature. The final entry is the permissions for field entry for updating of the feature. The data dictionary is presented in the order it appears by default in TerraSync.

"**INVENT5_0**", Dictionary, "updated 5/5/2010, for Legacy Roads"

```
"ROAD", line, "", 3, seconds, Code
  "ROAD_NUM", text, 20, normal, "USFS road number.", normal
  "SURF_TYPE", menu, required, "Dominant surface type.", normal
    "Crushed rock", default
    "Native"
    "Paved"
  "SURF_COV", menu, normal, "Dominant surface cover.", normal
    "None", default
    "Grass and herbs"
    "Live woody veg"
    "Straw"
    "Organic debris"
  "SURF_COND", menu, normal, "Problems with the road surface.", normal
    "Good", default
    "Rilled/eroded"
    "Washboard"
    "Rutted"
    "Rocky"
    "Ripped"
    "Decom potholed"
    "Recontoured"
    "Tilled"
  "ROAD_TYPE", menu, normal, "Type of road.", normal
    "Passenger car road", default
    "High clearance road"
    "Not trafficable"
    "Decommissioned"
  "RD_EDGE_1", menu, required, "Cut slope height 1 or road edge feature.", normal
    "Fill"
    "0' no ditch"
    "0 - 6'", default
    "> 6'"
  "RD_EDGE_2", menu, normal, "Cut slope height 2 or road edge feature.", normal
    "Fill", default
    "0' no ditch"
    "0 - 6'"
```

"> 6'"
"**EDG_CND_1**", menu, normal, "Primary cut or fill slope condition.", normal
"No problem", default
"Badly rilled"
"Badly ravelling"
"Badly slumping"
"Seep spring"
"Bedrock"
"**FLOW_PATH1**", menu, normal, "Location of flowing water 1.", normal
"Ditch", default
"Concentrated"
"Diffuse"
"**FLOW_PATH2**", menu, normal, "Location of flowing water 2.", normal
"Ditch", default
"Concentrated"
"Diffuse"
"**FLWPTH_VG1**", menu, normal, "Vegetation on flow path 1.", normal
"< 25%", default
">25%"
"**FLWPTH_VG2**", menu, normal, "Vegetation on flow path 2.", normal
"< 25%", default
">25%"
"**FLWPTHCND1**", menu, normal, "Condition of flow path 1.", normal
"No problem", default
"Gullied"
"Buried ditch"
"Stream course"
"Rocked"
"Eroded"
"**FLWPTHCND2**", menu, normal, "Condition of flow path 2.", normal
"No problem", default
"Gullied"
"Buried ditch"
"Stream course"
"Rocked"
"Eroded"
"**FILL_CHAN**", menu, normal, "Dist. fillslpe toe to channel edge (FT).", normal
"0",[1]
"1-20",[20]
"21-50",[50]
"Above 50",[100], default
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME1**", text, 4, required, "Time of primary drain point.", normal, 999, Label1
"**CTIME2**", text, 4, required, "Time of secondary drain point.", normal, 999, Label2

"**DTCH_RELI**", point, "", 1, seconds, 60, Code
"**SIZE**", menu, required, "Pipe diameter, INCHES.", required
"< 15""
"15""
"18"", default
"24""
"30""
">30""

"NA"
"**PIPE_LEN**", numeric, 0, 10, 200, 40, required, "In FEET", required
"**TYPE**", menu, required, "Culvert material.", required
"CMP (Steel)", default
"CON (Concrete)"
"ALM (Aluminum)"
"ABS (Plastic)"
"WDN (LOG)"
"**CONDIT**", menu, required, "Percent sed occlusion or other problem.", required
"0", default
"1-20%"
"20-80%"
"80-100%"
"Buried"
"Partially Crushed"
"Totally Crushed"
"Rusted Significantly"
"Flows around pipe"
"**SLOPE_SHAP**", menu, normal, "Horizontal shape of slope below drain pt", normal
"Concave", default
"Planar"
"Convex"
"**DISCHRG_TO**", menu, required, "Initial destination of discharge.", required
"Forest Floor", default
"Gully"
"Ditch"
"Landslide"
"Wetland"
"Stream"
"**STREAM_CON**", menu, normal, "Hydrologic connection with channel.", normal
"No", default
"Yes"
"**FILL_EROS**", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal, Label2
"**FLOW_DIVER**", menu, normal, "Historic or current flow diversion.", normal
"No", default
"Yes"
"**OBSTRUCT**", menu, normal, "Debris in flow path of drain.", normal
"None"
"Moderate", default
"Abundant"
"**FLOW_DIFFU**", menu, normal, "Is a diffuser present?", normal
"None", default
"Culvert extension"
"Fabric hose"
"Rip rap"
"**ORPHAN**", menu, required, "Is this drain point an orphan?", normal, Label1
"No", default
"Yes"
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME**", time, auto, 24, manual, required, "Time the drain point is opened.", normal

"**STRM_CROSS**", point, "", 1, seconds, 60, Code

"**TYPE**", menu, normal, "Type of crossing.", normal
"Steel culvert round", default
"Steel culvert oval"
"Steel arch bottomles"
"Plastic culvert"
"Baffled culvert"
"Concrete culvert"
"Log culvert"
"Concrete ford"
"Natural Ford"
"Aluminum culvert"
"Bridge"
"**PIPE_DIA**", menu, normal, "Maximum horiz. pipe diameter, INCHES.", normal
"N/A"
"12""
"15""
"18""
"24"", default
"30""
"36""
"48""
"60""
"66""
"72""
"> 72""
"**PIPE_LEN**", numeric, 0, -99, 300, -99, required, "Length of pipe if present, FEET.", normal
"**CHAN_WDTH**", numeric, 0, -99, 100, -99, normal, "Width of channel at greenline, FEET.", normal
"**PIPE_NUM**", menu, normal, "Number of crossing culverts.", normal
"N/A"
"1", default
"2"
"3"
">3"
"**FILL_DEPTH**", numeric, 0, -99, 100, -99, required, "In FEET.", normal
"**CONDIT**", menu, required, "Condition of pipe if present.", required
"Open and Sound", default
"Partially blocked"
"Totally blocked"
"Partially crushed"
"Totally crushed"
"Rusted significantly"
"Flows around pipe"
"**CHAN_ANGL**", menu, normal, "Angle that the channel makes w/ culvert.", normal
"< 25 degrees", default
"25-45 degrees"
"45-75 degrees"
"> 75 degrees"
"**PROB_TYP**", menu, normal, "Problem with the whole crossing.", normal
"No", default
"Sediment Plume"
"Scoured road"
"Washed out road"
"Organic debris pile"
"**PIPE_GRADE**", numeric, 0, -99, 99, -99, required, "In PERCENT.", normal
"**SUBSTRATE**", menu, normal, "What water flows over.", normal

```
    "Culvert Material", default
    "Sand"
    "Gravel"
    "Boulders"
    "Bedrock"
  "DEBRIS_FLW", menu, normal, "Evidence of past debris flows.", normal
    "NO", default
    "YES"
  "DIVERSION", menu, normal, "Stream diversion potential.", normal
    "None", default
    "1 Direction"
    "2 Direction"
  "FILL_EROS", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal
  "ORPHAN", menu, normal, "Is this drain point an orphan?", normal, Label1
    "No", default
    "Yes"
  "CDATE", date, auto, mdy, manual, required, "MM DD YYYY", normal
  "VEHICLE", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
  "COMMENT", text, 100, required, normal
  "CTIME", time, auto, 24, manual, required, "Time the point is opened.", normal


"LEAD_OFF", point, "", 1, seconds, 60, Code
  "SLOPE_SHAP", menu, required, "Horizontal shape of slope below drain pt", required
    "Concave", default
    "Planar"
    "Convex"
  "DISCHRG_TO", menu, required, "Initial destination of discharge.", required
    "Forest Floor", default
    "Gully"
    "Ditch"
    "Landslide"
    "Wetland"
    "Stream"
  "STREAM_CON", menu, required, "Hydrologic connection with channel.", required
    "No", default
    "Yes"
  "CONDIT", menu, normal, "Condition problems with drain point.", normal
    "No problem", default
    "Gullied"
    "Excess deposition"
  "OBSTRUCT", menu, normal, "Debris in flow path of drain.", normal
    "None"
    "Moderate", default
    "Abundant"
  "ORPHAN", menu, normal, "Is this drain point an orphan?", normal, Label1
    "No", default
    "Yes"
  "CDATE", date, auto, mdy, manual, required, "MM DD YYYY", normal
  "VEHICLE", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
  "COMMENT", text, 100, normal, normal
  "CTIME", time, auto, 24, manual, required, "Time the drain point is opened.", normal


"WATER_BAR", point, "", 1, seconds, 60, Code
  "SLOPE_SHAP", menu, required, "Horizontal shape of slope below drain pt", required
```

"Concave", default
"Planar"
"Convex"
"**DISCHRG_TO**", menu, required, "Initial destination of discharge.", required
"Forest Floor", default
"Gully"
"Ditch"
"Landslide"
"Wetland"
"Stream"
"**STREAM_CON**", menu, required, "Hydrologic connection with channel.", required
"No", default
"Yes"
"**TYPE**", menu, required, "Water bar type.", required
"Road material", default
"Fabricated material"
"**FILL_EROS**", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal
"**CONDIT**", menu, required, "Condition problems with drain point.", required
"No problem", default
"Damaged"
"Too small"
"Drains inboard ditch"
"**OBSTRUCT**", menu, normal, "Debris in flow path of drain.", normal
"None"
"Moderate", default
"Abundant"
"**ORPHAN**", menu, normal, "Is this drain point an orphan?", normal, Label1
"No", default
"Yes"
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME**", time, auto, 24, manual, required, "Time the drain point is opened.", normal

"**BBASE_DIP**", point, "", 1, seconds, 60, Code
"**SLOPE_SHAP**", menu, required, "Horizontal shape of slope below drain pt", required
"Concave", default
"Planar"
"Convex"
"**DISCHRG_TO**", menu, required, "Initial destination of discharge.", required
"Forest Floor", default
"Gully"
"Ditch"
"Landslide"
"Wetland"
"Stream"
"**STREAM_CON**", menu, required, "Hydrologic connection with channel.", required
"No", default
"Yes"
"**TYPE**", menu, required, "Broad based dip type.", normal
"Grade Reversal", default
"Constructed"
"**FILL_EROS**", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal
"CONDIT", menu, normal, "Condition problems with drain point.", normal
"No problem", default

```
    "Puddles on road"
    "Wetland in ditch"
    "Saturated fill"
    "Does not drain"
  "MATERIAL", menu, normal, "Material that composes the BBD.", normal
    "Crushed rock", default
    "Native soil"
    "Vegetated"
    "Paved"
    "Cinder"
  "OBSTRUCT", menu, normal, "Debris in flow path of drain.", normal
    "None"
    "Moderate", default
    "Abundant"
  "ORPHAN", menu, normal, "Is this drain point an orphan?", normal, Label1
    "No", default
    "Yes"
  "CDATE", date, auto, mdy, manual, required, "MM DD YYYY", normal
  "VEHICLE", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
  "COMMENT", text, 100, normal, normal
  "CTIME", time, auto, 24, manual, required, "Time the drain point is opened.", normal


"NON_ENGIN", point, "", 1, seconds, 60, Code
  "SLOPE_SHAP", menu, required, "Horizontal shape of slope below drain pt", required
    "Concave", default
    "Planar"
    "Convex"
  "DISCHRG_TO", menu, required, "Initial destination of discharge.", required
    "Forest Floor", default
    "Gully"
    "Ditch"
    "Landslide"
    "Wetland"
    "Stream"
  "STREAM_CON", menu, required, "Hydrologic connection with channel.", required
    "No", default
    "Yes"
  "CONDIT", menu, normal, "Condition problems with drain point.", normal
    "Blocked Ditch", default
    "Diverted flow path"
    "Broken berm"
    "Gully crosses road"
    "Outsloped"
  "FILL_EROS", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal
  "OBSTRUCT", menu, normal, "Debris in flow path of drain.", normal
    "None"
    "Moderate", default
    "Abundant"
  "ORPHAN", menu, normal, "Is this drain point an orphan?", normal, Label1
    "No", default
    "Yes"
  "CDATE", date, auto, mdy, manual, required, "MM DD YYYY", normal
  "VEHICLE", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
  "COMMENT", text, 100, normal, normal
  "CTIME", time, auto, 24, manual, required, "Time the drain point is opened.", normal
```

"**SUMP**", point, "", 1, seconds, 60, Code
"**CONDIT**", menu, normal, "Condition problems with drain point.", normal
"No problem", default
"Fill saturation"
"Puddles on road"
"Flat grade"
"**TYPE**", menu, required, "Is this sump intentional?", normal, Label1
"Constructed", default
"Not constrc, comment"
"**ORPHAN**", menu, normal, "Is this drain point an orphan?", normal, Label2
"No", default
"Yes"
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, required, normal
"**CTIME**", time, auto, 24, manual, required, "Time the drain point is opened.", normal

"**DIFF_DRAIN**", point, "", 1, seconds, 60, Code
"**DISCHRG_TO**", menu, normal, "Initial destination of discharge.", normal
"Forest Floor", default
"Gully"
"Ditch"
"Landslide"
"Wetland"
"Stream"
"**STREAM_CON**", menu, required, "Hydrologic connection with channel.", required
"No", default
"Yes"
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**FILL_EROS**", numeric, 0, 0, 1000000, 0, normal, "What is the eroded volume?", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME**", time, auto, 24, manual, required, "Time the drain point is opened.", normal

"**EXCAV_STRM_CROSS**", point, "On a decom road.", 1, seconds, 60, Code
"**FLOW**", menu, normal, "Is there evidence of past flow?", normal, Label1
"Yes", default
"No"
"**SIDE_SLOPE**", menu, normal, "What is the covering on the side slopes?", normal, Label2
"Straw", default
"None"
"Rip rap"
"Logs"
"Grass"
"Brush or live trees"
"Multiple, comment"
"**CONDIT**", menu, normal, "Are there any problems in the crossing?", normal
"No problem", default
"Erosion"
"Flows under fill"
"Side slope landslide"

"**CHAN_WIDTH**", numeric, 1, -99.0, 100.0, -99.0, required, "Channel width upstream from culvert.", normal
"**UP_WOLMAN**", menu, normal, "Status of the upstream Wolman count.", normal
"100 pts", default
"< 100 pts"
"none"
"**FILL_LOC**", menu, normal, "Where was the xing fill placed?", normal
"Downhill side", default
"Uphill side"
"Along road"
"No pile"
"**ORPHAN**", menu, normal, "Is this drain point an orphan?", normal
"No", default
"Yes"
"**STREAM_CON**", menu, normal, "This drain point always connects.", normal
"Yes", default
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, required, normal
"**CTIME**", time, auto, 24, manual, required, "Time the drain point is opened.", normal

"**PHOTO**", point, "", 1, seconds, 30, Code
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**CTIME**", time, auto, 24, manual, required, "Time the point is opened.", normal
"**COMMENT**", text, 100, required, normal

"**GULLY**", point, "Incised > 6 inches deep, >10 feet length", 1, seconds, 60, Code
"**ROAD_ASSOC**", menu, normal, "Is this gully due to road drainage?", normal, Label2
"YES", default
"NO"
"**ACTIVITY**", menu, normal, "Is the gully still active?", normal
"STILL ERODING", default
"NOT ACTIVE"
"**Wet swale**", menu, normal, "Is the gully located in a wet swale?", normal
"No", default
"Yes"
"**Contributor**", menu, normal, "Non-road contributing factors.", normal
"None", default
"Spring"
"Swale"
"Flow diversion"
"**Terminates**", menu, normal, "Where does the gully end?", normal
"Hillslope", default
"Stream"
"Gully"
"**LOCATION**", menu, normal, "Where is the Gully?", normal
"Hillslope", default
"Fillslope"
"Fill and Hill"
"Above Road"
"**LENGTH**", numeric, 0, 6, 10000, 999, normal, "Length of gully, 10 ft min, FEET.", normal, Label1
"**WIDTH**", numeric, 1, 0.1, 100.0, 99.0, normal, "Average width at surface, FEET.", normal
"**DEPTH**", numeric, 1, 0.1, 100.0, 99.0, normal, "Average depth, FEET.", normal

"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME1**", text, 4, required, "Time of primary drain point.", normal, 999
"**CTIME2**", text, 4, required, "Time of secondary drain point.", normal, 999

"**LANDSLIDE**", point, "", 1, seconds, 60, Code
"**ROAD_RLTD**", menu, normal, "Would the slide be here without a road?", normal, Label1
"NO", default
"YES"
"**LOCATION**", menu, normal, "Location of landslide event.", normal
"HILLSLOPE FAILURE", default
"CUTSLOPE FAILURE"
"FILLSLOPE FAILURE"
"**POSITION**", menu, required, "Location of slide initiation point.", normal
"Below_rd", default
"Above_rd"
"**LENGTH**", numeric, 0, 10, 1000, 999, normal, "Average length of failure zone, FEET.", normal
"**WIDTH**", numeric, 0, 0, 1000, 0, normal, "Average width of failure zone, FEET.", normal
"**DEPTH**", numeric, 0, 1, 100, 99, normal, "Avg depth, surf to failure plane, FEET.", normal
"**AGE**", menu, normal, "Time since initial activity, YEARS.", normal, Label2
"<5 YEARS", default
"<10 YEARS"
"<15 YEARS"
"**CONFIDENCE**", menu, normal, "How certain is this observation?", normal
"CERTAIN", default
"UNCERTAIN"
"LIKELY"
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal
"**VEHICLE**", numeric, 0, 1, 9, 1, required, "Crew ID number.", normal
"**COMMENT**", text, 100, normal, normal
"**CTIME1**", text, 4, required, "Time of primary drain point.", normal, 999
"**CTIME2**", text, 4, required, "Time of secondary drain point.", normal, 999

"**ROAD_CLSD**", point, "", 1, seconds, 60, Code
"**CLOSURE_DESCRIPTION**", menu, normal, "Type of closure.", normal, Label2
"LOG AND SOIL"
"DOWN TREES"
"OVERGROWN"
"PLANTED"
"RIPPED OR SUBSOILED"
"TRENCHED"
"BOULDERS", default
"GUARD RAIL"
"CABLE"
"FENCING"
"**CLOSURE EFFICIENCY**", menu, normal, "Does this feature keep vehicles out?", normal, Label1
"Fully effective", default
"Driven around"
"Damaged"
"Missing"
"**COMMENT**", text, 100, normal, normal

"**GATE**", point, "", 1, seconds, 60, Code
"**Description**", text, 100, normal, normal, Label1
"**CONDITION**", menu, normal, "Does this gate function correctly?", normal, Label2
"DAMAGED"
"FUNCTIONAL", default
"**ACCESS**", menu, normal, "Does this gate require a key?", normal
"LOCKED GATE", default
"UNLOCKED GATE"

"**ROAD_HZRD**", point, "", 1, seconds, 60, Code
"**Type**", text, 100, normal, "Describe what the hazard is here.", normal, Label1

"**END_RD**", point, "", 1, seconds, 60, Code
"**Description**", text, 100, normal, "How does the road end?", normal, Label1

"**REVISIT**", point, "", 1, seconds, 60, Code
"**DESCRIPTION**", text, 100, normal, "Describe why you need to come back here.", normal, Label1
"**CDATE**", date, auto, mdy, manual, required, "MM DD YYYY", normal

References

Bilby, R. E., Sullivan, K., and Duncan, S.H. 1989. The generation and fate of road-surface sediment in forested watersheds in southwestern Washington. Forest Science. Vol. 35, No. 2, pp: 453-468.

Black, T., Luce, C., Staab, B., and Cissel, R. 2009. Legacy Roads and Trails Monitoring Project: Road decommissioning in the Skokomish River watershed, Olympic National Forest. Boise, ID. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Boise Aquatic Science Lab.

Cissel, R., Black, T., Luce, C., and Staab, B. 2011. Legacy Roads and Trails Monitoring Project: Storm damage risk reduction in the Nestucca River watershed, Siuslaw National Forest. Boise, ID. U.S. Department of Agriculture, Forest Service, Forest Service, Rocky Mountain Research Station, Boise Aquatic Science Lab.

Clarkin, K., Connor, A., Furniss, M. J., Gubernick, B., Love, M., Moynan, K., and WilsonMusser, S. 2005. National inventory and assessment procedure for identifying barriers to aquatic organism passage at road-stream crossings. San Dimas, CA. U.S. Department of Agriculture, Forest Service, National Technology and Development Program.

Cline, R., Cole, G., Megahan, W., Patten, R., and Potyondy J. 1984. Guide for predicting sediment yield from forested watersheds. Missoula, MT and Ogden, UT. U.S. Department of Agriculture, Forest Service, Northern Region and Intermountain Region.

Flanagan, S. A., Furniss, M. J., Ledwith, T. S., Thiesen, S., Love, M., Moore, K., and Ory. J. 1998. Methods for inventory and environmental risk assessment of road drainage crossings. Water Road Interaction Technology Series. San Dimas CA. U.S. Department of Agriculture, Forest Service, San Dimas Technology Development Center, July 15, 1999.

Fly, C. M., Grover-Weir, K., Thornton, J., Black, T. A., and Luce, C. M. 2010. Bear Valley road inventory (GRAIP) report; Bear Valley Category 4b assessment, Boise National Forest. Boise, ID. U.S. Department of Agriculture, Forest Service, Boise National Forest.

Furniss, M. J., Love, M., and Flanagan, S. A. 1997. Diversion potential at road-stream crossings. Water Road Interaction Technology Series. San Dimas CA. U.S. Department of Agriculture, Forest Service, San Dimas Technology Development Center, July 15, 1999.

Luce, C. H., and Black, T. A. 1999. Sediment production from forest roads in western Oregon. Water Resources Research, Vol. 35, No. 8, pp: 2561-2570.

Luce, C. H. and Black, T. A. 2001. Effects of traffic and ditch maintenance on forest road sediment production. In Proceedings of the Seventh Federal Interagency Sedimentation Conference, March 25-29, 2001, Reno, NV. pp: V67-V74.

Luce, C. H. and Black, T. A. 2001. Spatial and temporal patterns in erosion from forest roads. In Influence of Urban and Forest Land Uses on the Hydrologic-Geomorphic Responses of Watersheds, M.S. Wigmosta and S.J. Burges, Editors, American Geophysical Union, Washington, D.C. pp: 165-178.

Luce, C. H., Reiman, B. E., Dunham, J. B., Clayton, J. L., King, J. G., and Black, T. A. 2001. Incorporating aquatic ecology into decisions on prioritization of road decommissioning. Water Resources Impact Vol. 3, No. 3, pp: 8-14.

Luce, C. H. and Wemple, B. C. 2001. Introduction to special issue on hydrologic and geomorphic effects of forest roads. Earth Surface Processes and Landforms. Vol. 26. No. 2, pp: 111-113.

Luce, C. H. 2002. Hydrological processes and pathways affected by forest roads: what do we still need to learn? Hydrological Processes. Vol. 16, pp: 2901-2904.

MacDonald, L. H., Anderson, D. M. and Dietrich, W. E. 1997. Paradise threatened: land use and erosion on St. John, US Virgin Islands. Environmental Management, Vol. 21, No. 6, pp: 581-863.

McCammon, B. P., Rector, J. R., and Gebhardt, K. 1998. A framework for analyzing the hydrologic condition of watersheds. Denver, CO. U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management. 40 p.

Megahan, W. F. and Kidd, W. J. 1972. Effect of logging roads on sediment production rates in the Idaho batholith. Research Paper INT-123. Ogden, UT. U.S. Department of Agriculture, Forest Service. Intermountain Forest and Range Experiment Station.

Megahan, W. F. 1974. Erosion over time: a model. Research Paper INT-156. Ogden, UT. U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Megahan, W. F., and Ketcheson, G. L. 1996. Predicting downslope travel of granitic sediments from forest roads in Idaho. Water Resources Bulletin Vol. 32, No. 2, pp: 371-182.

Montgomery, D. R. 1994. Road surface drainage, channel initiation, and slope instability. Water Resources Research. Vol. 30, pp: 1925-1932.

Moore, K., Furniss, M., Firor, S., and Love, M. 1999. Fish passage through culverts: an annotated bibliography. Eureka, CA. U.S. Department of Agriculture, Forest Service, Six Rivers National Forest Watershed Interactions Team, November 1999.

Nelson, N., Clifton, C., Black, T., Luce, C., and McCune, S. 2010. Wall Creek watershed GRAIP roads assessment, North Fork John Day subbasin, Umatilla National Forest. Boise, ID. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Boise Aquatic Science Lab.

Reid, L. M., and Dunne. T. 1984. Sediment production from forest road surfaces. Water Resources Research. Vol. 20, No.11, pp: 1753-1761.

Swift, L. W. 1984. Gravel and grass surfacing reduces soil loss from mountain roads. Forest Science. Vol. 30, No. 3, pp: 657-670.

USDA Forest Service. 1999. Roads analysis: informing decisions about managing the national forest transportation system. Misc. Rep. FS-643. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 222 p.

Washington Forest Practices Board. 1995. Standard methodology for conducting watershed analysis. Version 3.0, November 1995. Washington State Department of Natural Resources, Olympia, WA. pp. B1-B52.

Wemple, B. C., Jones, J. A., and Grant, G. E. 1996. Channel network extension by logging roads in two basins, western Cascades, Oregon. Water Resources Bulletin. Vol. 32, pp: 1195-1207.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union. Vol. 35, No. 6, pp: 951–956.

Ziegler, A. D., Sutherland, R. A. and Giambelluca, T. W. 2001. Interstorm surface preparation and sediment detachment by vehicle traffic on unpaved mountain roads. Earth Surface Processes and Landforms. Vol. 26, pp: 235-250.

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of the National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals. Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Station Headquarters
Rocky Mountain Research Station
240 W Prospect Road
Fort Collins, CO 80526
(970) 498-1100

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah

www.fs.fed.us/rmrs