Landscape Function Analysis

Ephemeral Drainage-line Assessments (EDA): Indicators of Stability

Ephemeral drainage-lines are present in almost all landscapes such as those observed on a hillslope in a watershed catchment. We define ephemeral drainage-lines are those where water briefly flows such as after moderate to heavy rains. However, adverse management or rare natural disturbances can result in incision and soil erosion. The health of ephemeral drainage-lines can be assessed by evaluating signs of their stability. For example, on hillslopes in healthy landscapes ephemeral drainage-lines are smoothly concave in cross-section (no sharp edges), receive runoff as diffuse overland flows from surrounding slopes, and gently drain water downslope. In contrast, unhealthy landscapes have ephemeral drainage-lines that are unstable as evident by active channel cutting (sharp edges, large and rapid flows after rainstorms). In such cases, inflow rates into the drainage line may be rapid and highly focused. [A channel deeper than 0.3 meters is defined as a gully, if less than 0.3 meters it is called a rill.] Examples of both healthy and unhealthy ephemeral drainage-lines are illustrated in chapter 15 in Tongway and Ludwig (Restoring Disturbed Landscapes; Island Press, 2011).

In this document we describe eight indicators that provide landscape restoration practitioners (RPs) with information about whether an ephemeral drainage-line in a restored landscapes is becoming stabilized and healthy or is still actively eroding. In addition, the cause of the problem is also addressed: down-channel flow or over-bank flow (or both). Our aim is to present these eight indicators in a logical order. First we describe how to assess two indicators defining the characteristics of the slopes flanking the ephemeral drainage-line. Then we focus on scoring six indicators within the drainage-line itself. These six indicators assess the functional role of vegetation within the drainage-line and evaluate the shape and erodability of the drainage-line channel, including channel walls and floors.

Field Procedures

Start the assessment procedure at the upslope (top) end of an ephemeral drainage-line, such as at the top of a gully on a hillslope. The eight indicators are assessed at this upslope end before proceeding down stream until a change in the indicator set is observed. This point is recorded using a tape or a distance measuring wheel or a GPS to locate it. The observer than proceeds down the drainage-line so as to produce a continuous record along its full length so that the drainage-line is stratified into zones by identifying boundaries reflecting different states of health or stability. Different zones are given names representing their health status, such as “grassy beds” and “dispersive side wall”. Sometimes, zones change frequently over short distances – sometimes there may be little change over long distances. Zone boundaries should be marked onto a topographic map, recognizing that the left and right hand banks may be different. As the health indices can be very quickly calculated, coloured pens may be used to map the zones of different stream health.

The eight indicators are assessed at about the mid-point of each identified zone. Assessing the whole length of the ephemeral drainage-line is important because impressions from one part of the drainage-line, such as at the top of a gully, may not represent the overall state of the entire drainage-line. In some cases, healthy stable zones may alternate with unhealthy eroding zones. This alternating pattern down an ephemeral drainage-line was found in a study by S. Lane (2008; MS thesis; Australian National University, Canberra). We have decided not to calculate an “average” drainage line health index, but to present the assessment as a series of zones.
This approach allows RPs to readily evaluate where restoration needs to be applied, or whether the restoration technologies they have applied are effectively stabilizing the landscape.

The field procedures for assessing ephemeral drainage-line indicators is a modification of a gully assessment procedure specifically addressing problems on rehabilitated mine sites by R. Loch (pers. comm.; Landloch Pty Ltd; Toowoomba, Australia). Our procedure is generalized for ephemeral drainage-lines to enable RPs to assess not only gullies on mine sites, but also healthy or mildly eroded drainage-lines in landscapes on farms or conservation areas.

Because the eight indicators of ephemeral drainage-line stability are also described in chapter 15 in Tongway and Ludwig (2011), here we emphasize how RPs can assess or score these eight indicators in the field using EDA tables, EDA photographs and EDA data sheets.

To keep this document small for easy downloading, here we only provide low-resolution, tonal images to illustrate examples of what indicators may look like in the field, but we have also made high-resolution, color photographs available on the LFA Procedures web page within the EDA-Photos sub-directory. These representative photographs are identified by indicator number and score. For example, a color photograph illustrating what an ephemeral drainage-line with a score of 2 for indicator 1 is identified as EDA_Fig1-2.jpg. Where we provide multiple photographs to illustrate a given score, they are labeled, for example, as EDA_Fig1-2a, EDA_Fig1-2b, etc.

Assessing indicators of potential runoff from slopes adjoining ephemeral drainage-lines

The nature of the slopes above and along the drainage-line can strongly affect the rate and amount of runoff likely to impact the drainage-line by over-bank flow during rainstorm runoff events. To assess these potential impacts of runoff, two indicators are scored: steepness of the slopes, and the amount of surface protection on the slopes.

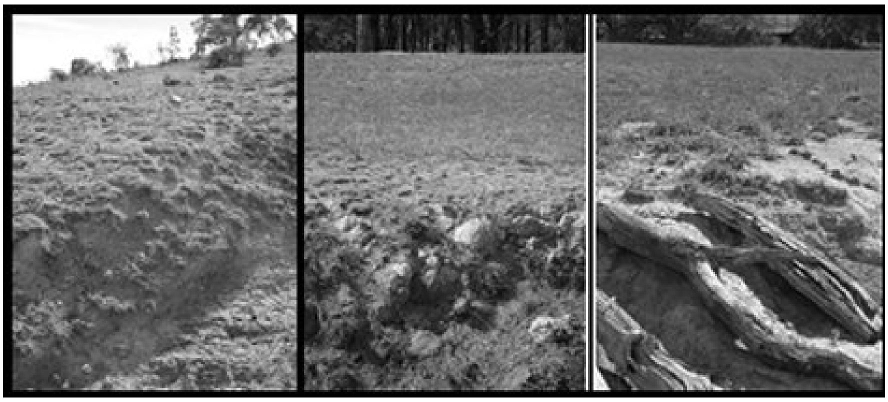
1. Slope steepness indicator

The steepness of the slopes above and bordering the drainage-line affects the potential energy of any runoff flowing into the line during rainstorms. Basically, this indicator assesses the contribution of slope steepness to the potential for high flow rates into the drainage-line and resultant erosion of the drainage-line channel walls and floor. This indicator is scored as being in one of five classes from very steep to flat (Table EDA.1), which reflect the potential for high to low velocity flows of runoff from the bordering hillslope into the drainage-line over its walls.

Table EDA.1. Steepness of slopes above and bordering an ephemeral drainage-line

Score	Description
1	Very steep, > 30 deg. enabling high flow velocities into the drainage-line over walls
2	Steep, 10-30 deg. creating moderate to high velocity flows into the drainage-line
3	Moderately sloped, 5-10 deg., generating moderate flow velocities into the drainage-line
4	Gently sloped, laterally extensive, < 5 deg., generating moderate to low velocity flows into the drainage-line over walls
5	Nearly flat, laterally extensive, generating low velocity flows over drainage-line walls

The following three tonal images illustrate steep (left; score 2), moderate (center; score 3) and nearly flat slopes (right; score 5). On the LFA web site, color photographs illustrating ephemeral drainage-lines with scores 1 to 5 are labeled EDA_Fig1-2 to EDA_Fig1-5.



2. Slope surfaces indicator

The amount and rate of runoff coming from above an ephemeral drainage-line strongly affects its stability. This runoff is regulated by the amount of vegetation, litter and coarse debris on the hillslope. Essentially, this indicator assesses the role that such surface protection materials play in the contribution of overland flows into a drainage-line and potentially eroding it. The slope surfaces indicator is also scored in one of five classes based on the degree of surface protection on slopes above and bordering a drainage-line (Table EDA.2).

Table EDA.2. Surfaces on slopes above and bordering a drainage-line

Score	Description
1	Bare slopes with side-arm channels: very high inflow rates, copious sediment
2	Bare slopes by drainage-line, laterally extensive, high inflow rates, moderate sediment
3	Sparsely covered slopes with bare-soil bank lip: moderate flow rate, some highly focused inflows, low sediment
4	Densely covered slopes: low and diffused inflows, very low sediment visible
5	Very densely covered slopes with litter and coarse woody debris: very low and diffused inflows, no observable sediment movement

The following tonal images illustrate the kinds of slope surfaces that occur above and beside ephemeral drainage-lines. These images include bare slopes well away from the drainage-line, which scores 1 (left); a drainage-line with bare soil just along its borders, which scores 3 (centre); and a drainage-line where bordering slopes are covered with dense grasses, litter and coarse woody debris, which scores 5 (right).

The above two indicators help RPs determine whether any drainage-line erosion is being caused by flows of water from further upstream in the channel or by water cascading over the lip of the drainage-line from areas directly adjacent to it. Identifying the source of excessive overland flows can assist RPs in designing appropriate drainage-line restoration technologies. This restoration design can also be aided by deploying the LFA soil surface condition indicators along gradsects oriented upslope and adjacent to the drainage-line. This approach is particularly valuable when there is a point source of disturbance, such as a track or an incised animal crossing,

Assessing indicators of ephemeral drainage-line vegetation

Vegetation growing within a drainage-line that has, for example, eroded into a gully, provides RPs with an indication of the potential for the gully to erode. Dense perennial vegetation within a drainage-line indicates that it has been stable for a substantial period of time and has resisted erosion during recent runoff events. Annual weedy vegetation growing within the drainage-line provides some resistance to flows, but indicates that stability has been of shorter duration and of lower resistance to erosion during major flows events. Lack of vegetation, or its recent burial by sediments, indicates that erosion and sedimentation processes are active within the ephemeral drainage-line during runoff events.

Two indicators are scored when assessing vegetation within an ephemeral drainage-line: vegetation on side-walls, and vegetation on floors. Typically, this assessment takes just a few seconds.

3. Ephemeral drainage-line wall vegetation indicator

This indicator assesses the amount of vegetation covering and protecting the walls of the ephemeral drainage-line. Walls with a dense covering of vegetation will resist the erosive forces of flows into and along the channel. This indicator is scored as being in one of three classes based on the amount of vegetation covering and protecting the walls of ephemeral drainage-lines at assessment points (Table EDA.3).

Table EDA.3. Vegetation on ephemeral drainage-line walls

Score	Description
1	Little or no vegetation growing on drainage-line walls
2	Vegetation present is mainly ephemeral, allowing sediment to flow past
3	Dense perennial plant covers walls with observable sediment control

Examples of these three classes of drainage-line wall vegetation are illustrated by the following tonal images: walls with no vegetation (left), which scores 1; walls with mostly annual weedy vegetation (center), which scores 2; and walls with dense perennial vegetation (right), which scores 3. High-resolution color photographs are available as EDA_Fig3-1 to EDA_Fig3-3.

4. Ephemeral drainage-line floor vegetation indicator

This indicator evaluates the type and amount of vegetation on the floor, or bed, of the ephemeral drainage-line using similar methods to those employed in the assessment of vegetation along channel walls. Drainage-line floors with little perennial vegetation, or with sparse annual weedy vegetation, provide scant protection from the forces of flows into and down the drainage-line. This indicator is scored into one of three classes by evaluating the type and amount of vegetation on the floor or bed of the drainage-line (Table EDA.4).

Table EDA.4. Vegetation on ephemeral drainage-line floors

Rating	Description
1	Little or no vegetation growing on drainage-line floor; flow rates too high to permit plant growth
2	Any vegetation present is annual or short-lived: partial burial of plants by recently deposited sediment evident
3	Dense perennial plant cover, similar to vegetation on the bank of the drainage-line: or characteristic wetland species composition: no observable plant burial by sediment

An ephemeral drainage-line floor with little vegetation is shown in the left panel below, which scores 1; one with scattered annual vegetation is shown in the center, which scores 2; and one with dense perennial vegetation is shown to the right, which scores 3. High-resolution color photographs of these examples are available as EDA_Fig4-1 to EDA_Fig4-3.

When assessing the above two indicators, no distinction is made between native and exotic vegetation because this assessment is aimed at defining the degree of protection of ephemeral drainage-lines by vegetation. However, weeds within a drainage-line may need control.

Assessing indicators of ephemeral drainage-line shape

The shape of an ephemeral drainage-line provides the observer with information about the concentration, or dispersion, of energy in the water flowing into and down the drainage-line. This in turn affects the extent to which materials are eroded from and deposited along the drainage-line channel. The shape of a channel and its relationship with the wider floodplain also affects floodplain forming processes. These geomorphic processes are complex and beyond the scope of this book, but we refer those interested in these processes to a book by Brierley and Fryirs (2005; Geomorphology and river Management; Blackwell Publishing).

Two indicators are used to assess the vigor of these geomorphic erosion processes at selected points along the ephemeral drainage-line: cross-section shape, and longitudinal profile.

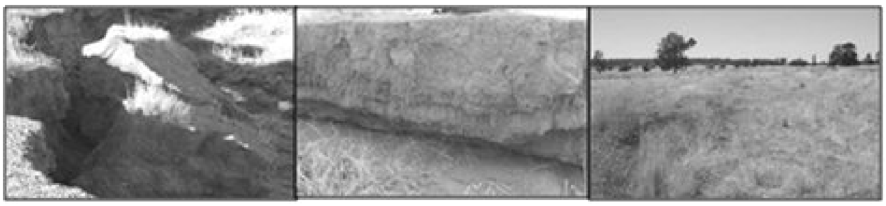
5. Ephemeral drainage-line cross-section indicator

Ephemeral drainage-lines that are still actively eroding typically have channel banks with steep or vertical walls and sharp edges whereas those that are stabilizing tend to have wall angles of less than 65 degrees and more rounded edges. Thus the cross-sectional shape of a drainage-line gives a strong indication of whether it is stabilizing or continuing to erode and produce sediment. The cross-sectional shape indicator is assessed into one of five classes depending on the ephemeral drainage-line's erosion status and its depth versus width (Table EDA.5).

Table EDA.5. Ephemeral drainage-line cross-sectional shape indicator.

Score	Description
1	Drainage-line walls nearly vertical; depth typically greater than width; Signs of active erosion include side-wall caving, mass wasting and tunneling. Fine sediments have been washed away from the base of the walls.
2	Drainage-line walls also near vertical but signs of erosion are less severe; depth about equal to width: slight undercutting of walls, and some sediment deposits are visible along drainage-line walls.
3	Drainage-line wall angles moderate with both bank and bed edges typically rounded and stabilizing: width greater than depth; Some deposits of sediment at base of walls.
4	Drainage-line wall angles low to moderate and clearly stabilizing; width greater than depth. Maybe some low, small sediment deposits at base of side walls.
5	Drainage-line walls gently sloping and strongly vegetated; width typically much greater than depth;; Drainage-line has obviously been stable for a considerable period of time: indications of spontaneous restoration.

Below are tonal image examples of ephemeral drainage-lines with cross-sections that score 1 (left), 2 (center), and 5 (right). Those with score 1 have cross-sectional shapes where walls are vertical with clear current erosion by caving-in or mass-wasting, and with depth greater than width. Those with score 2 have near vertical walls but show less active erosion and have depth about equal to width. Those that score 5 have very subdued wall angles, well rounded walls and bed angles and have width much greater than depth. Color photographs illustrating examples of ephemeral drainage-lines with all five scores are available as EDA_Fig5-1 to EDA_Fig5-5.



6. Ephemeral drainage-line longitudinal-section indicator

The longitudinal profile of an ephemeral drainage-line indicates the pattern and strength of flows along the channel. When evaluating this profile it is important for RPs to be aware of changes in slope. For example, the bed may be observed to have alternating flat and sloping sections, which indicates differences in flow energy. The longitudinal profile also indicates how the drainage-line interacts with the adjacent floodplain by characterizing a continuum that ranges from deeply incised gullies to a chain-of-ponds profile. In a chain-of-ponds profile the drainage-line and floodplain are connected, and flood waters dissipate with low energy onto the bordering floodplain. In deeply incised ephemeral drainage-line profiles the channel bed and floodplain are disconnected and flood waters further incise the channel instead of dissipating over the floodplain.

Based on the characteristics of the longitudinal profile of the ephemeral drainage-line at the point of assessment, this indicator is scored into one of four classes (Table EDA.6). Tonal images illustrating ephemeral drainage-lines these four scores are shown below, with color photographs available as EDA_Fig6-1 to EDA_Fig6-4. Ephemeral drainage-lines scoring 1 have nearly linear actively incising channels with both scour holes and piles of deposition (top-left). Those scoring 2 have less actively incising channels with less obvious signs of active erosion and deposition (top-right). Those scoring 3 have flat channels flat with few recent signs of erosion (bottom-left). Those scoring 4 have vegetation stabilizing their channels and no signs of sediment movement, and they may form a ‘chain’ of disconnected ponds (bottom-right).

Table EDA.6. Ephemeral drainage-line longitudinal profile indicator.

Score	Description
1	Drainage-line currently incised into a drainage-line channel where existing sediments are within scour holes and are deposited along the channel. Flow substantially linear
2	Drainage-line channel flat and continuous with deposits of loose sediment and signs of slow and recent sediment movements along the channel. Flow noticeably sinuous
3	Drainage-line channel flat but with a cohesive, fine textured and “soil-like” floor; no or only a few signs of fine sediment movement evident along the channel. Meandering bed shape, with point bars.
4	Drainage-line channel well vegetated between non-cascading chain of ponds with cohesive fine sediment /organic matter floors; no signs of sediment movement down the channel are evident. Typically, this type of channel is closely connected to its floodplain and gentle over-bank deposition may occur.

Assessing indicators of drainage-line erodability

Many Australian soils slake and disperse when wet. These soils readily erode when exposed to flows of water. When dispersive soils become wet, tunnel erosion may occur, even at low flow velocities. Tunnel erosion may form sink holes on a hillslope. Other signs of erosion include fluting, undercutting and caving along incised drainage-line walls, and mass wasting onto floors. These erosion features have many implications for RPs aiming to restore disturbed landscapes. The kind of questions they need to be addressed are: “How can these types of erosion be reduced?” and “Is the erosion process predominantly due to initial exposure of dispersive materials that have then continued to erode when exposed to low and high flow events?”

To answer such questions, RPs need to evaluate the stability of soils found along ephemeral drainage-lines before assessing indicators. The slake test is a simple but useful way to evaluate the degree to which soil particles disintegrate into smaller particles that settle and readily erode. How to perform the slake test is described as part of the scoring of indicator 10 in the soil surface assessment document (SSA-Field-Procedures.pdf).

Another soil stability test is the ASWAT (aggregate stability in water), which evaluates how readily clay dispersion can occur in those soils with significant amounts of clay. Clay dispersion is a much more serious erosion threat than particles that just disintegrate and settle (slake). RPs will find that restoring drainage-lines with exposed dispersive clays is technically more difficult and expensive than dealing with soil particle slumping or slaking.

Like the slake test, the ASWAT test looks at the response of dry soil fragments when immersed in high quality water, but scores the degree of “milkiness” (amount of clay dispersion) after 10 minutes and then again after 2 hours. Based on the rapidity and degree of milkiness, ASWAT dispersion scores range from zero (no dispersion) to 16 (complete dispersion). Typically, ASWAT index values of 6 or more would signify to RPs a problem urgently needing attention. Theoretical details of the ASWAT soil stability test are available in a research paper by Field et al. (1997; *Australian Journal of Soil Research*, Vol. 35, pgs 843-852). RPs will find instructions on how to perform the ASWAT test in the document LFA-ASWAT.pdf. RPs can conduct both the ASWAT and slake tests in the field or, if a large number of samples need assessment, in the laboratory.

After evaluating the stability of ephemeral drainage-line wall and floor soil materials, RPs can assess two indicators: wall erodability and floor erodability.

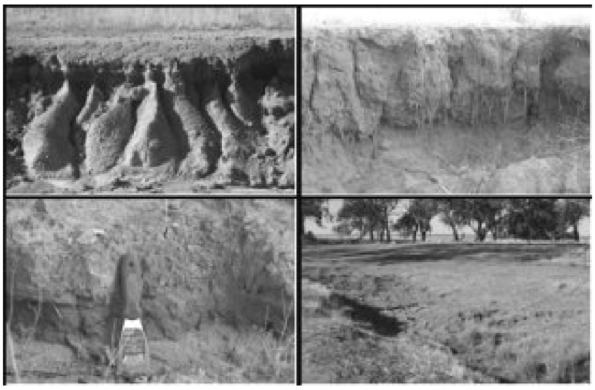
7. Ephemeral drainage-line wall erodability indicator

This indicator reflects the susceptibility of drainage-line walls to erosion by runoff flows, both by overland flows spilling over walls and by energetic flows along channel floors. RPs score this indicator as being in one of four classes based on the degree of exposure of unstable soil materials along the drainage-line wall (Table EDA.7). Sometimes, a number of layers will be exposed with different erodability factors: the least stable example should be recorded.

Table EDA.7. Ephemeral drainage-line wall erodability indicator.

Score	Description
1	Dispersive materials are exposed for greater than 1 m of drainage-line wall height.
2	Materials that readily slake are exposed on greater than 0.3 m but less than 1 m of drainage-line wall height (use the sum of multiple layers if they are present).
3	Materials with noticeable slaking are exposed on less than 0.3 m of drainage-line wall height.
4	No unstable materials are exposed on drainage-line walls.

Tonal images of ephemeral drainage-lines with four different wall exposures, which score 1 to 4, are shown below. Walls with greater than 1 meter of dispersive materials exposed and eroded by ‘fluting’ score 1 (top-left) and those with 0.3 to 1 meters of exposure score 2 (top-right). Drainage-line walls with less than 0.3 meters of exposed dispersive materials score 3 (bottom-left) and those with no exposed unstable materials score 4 (bottom-right). Ephemeral drainage-lines these four scores are available in color as photographs EDA_Fig7-1 to EDA_Fig7-4.



8. Ephemeral drainage-line floor erodability indicator

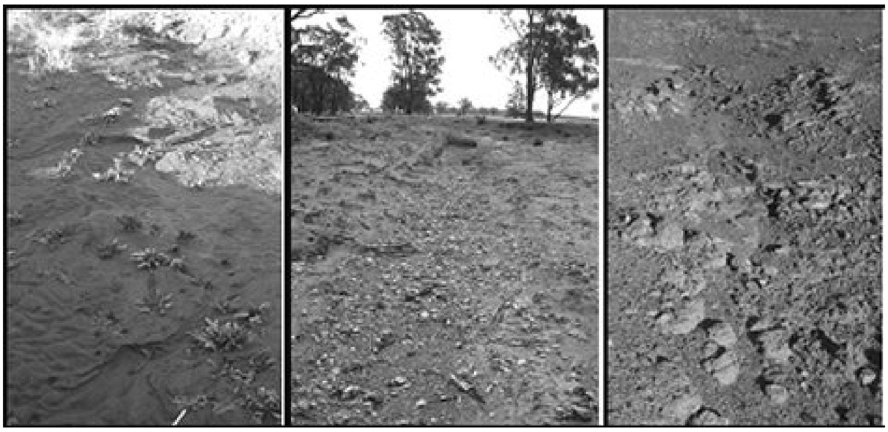
The size and cohesion of the materials on the floor of a drainage-line indicates its potential erodability. RPs use these attributes to score this indicator. For example, large rocks protect drainage-line floors from erosion by slowing and dispersing the energy of flows. Floor materials that are loose and similar in size, or smaller than those on drainage-line walls, require less energetic flows to mobilize them and, hence, indicate to RPs that these drainage-line floors are susceptible to erosion. The one exception to this is the organic matter/clay material found within a “chain of ponds” drainage-line. The floors of these ponds are relatively stable because of the very low flow downstream energy in such locations.

The ephemeral drainage-line floor erodability indicator is assessed as being in one of three classes depending on the nature of materials dominating the channel bed (Table EDA.8).

Table EDA.8. Ephemeral drainage-line floor erodability indicator.

Score	Description
1	Materials on the drainage-line floor have a particle size and density similar to (or smaller than) materials in the walls; For example, fine silt or sand deposits on the floor and coarser materials in the walls.
2	Materials on the drainage-line floor are somewhat larger in particle size and denser (more consolidated) than materials in the walls; For example, gravel deposits on the floor and coarse sands in the walls.
3	Materials on the drainage-line floor are much larger in particle size and denser than materials in the walls: For example, the floor is armored with stones and rocks and the wall has coarse sands.

Tonal images of drainage-line floor materials with these three scores are illustrated below, and high-resolution color photographs are available as EDA_Fig8-1 to EDA_Fig8-3. Ephemeral drainage-lines predominantly covered with sands score 1 (left), those with coarse sands and gravels score 2 (center), and those with stones and rocks score 3 (right).



Recording and using ephemeral drainage-line assessments

As noted earlier in this EDA document, the eight indicators described above assessed at the mid-points of each zone of ephemeral drainage-line health or stability identified down the drainage-line (starting at the top). RPs can readily record their scores onto a field data sheet shown below as Table EDA.9, which is also available as a separate field data sheet file: EDA DataForm.pdf.

The process produces a record of scores reflecting the stability of zones down the entire ephemeral drainage-line. This record can be used to calculate a stability index for each zone, as shown by the formula in the second line from the bottom in Table EDA.9. This equation is applied by adding all the scores in a zone and dividing by 32 (the maximum possible score) and then multiplying by 100. This calculation produces an index value between 25 and 100 (25 is the smallest index value because the minimum raw score is 8, hence, 8/32 times 100 equals 25).

Table EDA.9. An example of a field form for recording eight indicators of stability in eight zones down an ephemeral drainage-line. Zone mid-point distances can be determined by GPS starting at the top of the drainage-line.

Site name: ________________________ Location: ___________________________

Observer(s): ____________________________________ Date: ______________________

Zone: Mid-point distance (m):	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m
Indicator (range)	Score	Score	Score	Score	Score	Score	Score	Score
Slope steepness (1-5)								
Slope surface (1-5)								
Wall vegetation (1-3)								
Floor vegetation (1-3)								
Cross-section shape (1-5)								
Longitudinal profile (1-4)								
Wall erodability (1-4)								
Floor erodability (1-3)								
Sum of scores								
Maximum Possible Score	32	32	32	32	32	32	32	32
Index: (Sum/Max) x 100%								
Stability class (1-5)								

These index values can be used to assign each ephemeral drainage-line zone to one of five stability classes using Table EDA.10 (1, very stable, to 5, very unstable).

Table EDA.10. Five classes of drainage-line stability based on index values computed from scores for eight indicators.

Index	Classification	Interpretation of drainage-line stability
80 +	1. Very Stable	Drainage-line is likely to be in a durable and resilient state and able to withstand major storm events. Only minimal drainage-line monitoring is required, such as after very high flow events to evaluate whether stability has been retained.
70 - 80	2. Stable	Drainage-line is stable, but it is important to closely assess the eight indicators on the “least healthy” zone type, to ascertain whether the drainage-line is trending towards a less stable condition. If drainage-line stability is declining, these indicator assessments will help with selecting appropriate remedial actions.
60 - 69	3. Potentially stabilizing	Drainage-line is potentially stabilizing from an actively eroding and unstable state. Monitoring is required to determine if and what remedial actions may be needed in the future.
50 - 59	4. Unstable	Drainage-line is actively eroding and remedial actions are required. It is important to determine if erosion is caused primarily by upslope or lateral flows into the drainage-line(indicators 1 and 2), or by the presence of dispersive wall materials (indicators 7 and 8).
< 50	5. Very unstable	Drainage-line is very actively eroding and immediate remedial actions are required. An examination of the eight indicators will help determine the causes of erosion and what remedial actions are needed.

Although these stability class values by zone could be used to calculate an overall average for the whole drainage-line, we have found it far more useful to assess the stability information for each zone. There can be quite surprising changes, from very stable to very unstable and the reverse, along ephemeral drainage-lines. We have found that it cannot be assumed that lack of stability in upper reaches of a drainage-line will necessarily transfer right down the drainage-line

– lower reaches may be quite stable. To properly address different problems, RPs may need design and apply different restoration technologies to different locations along a drainage-line. By examining the eight indicator scores in a zone, the RP can usually identify the underlying causes of erosion activity in that zone. For example, these data may indicate whether an actively eroding zone is caused by: (i) high flow rates from upslope, (ii) high lateral flow rates from bordering slopes, or (iii) exposure of unstable (dispersive) side wall material to flows. By assessing ephemeral drainage-line stability in zones, RPs can determine where the most urgent remedial actions are needed, and what technologies to apply.