

Water Quality Effectiveness Evaluation

Cutblock Inspection Field Manual

Draft (Sept 13, 2005)

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Format developed
for use with Palm Pilot TM
or other hand-held computer

Introduction

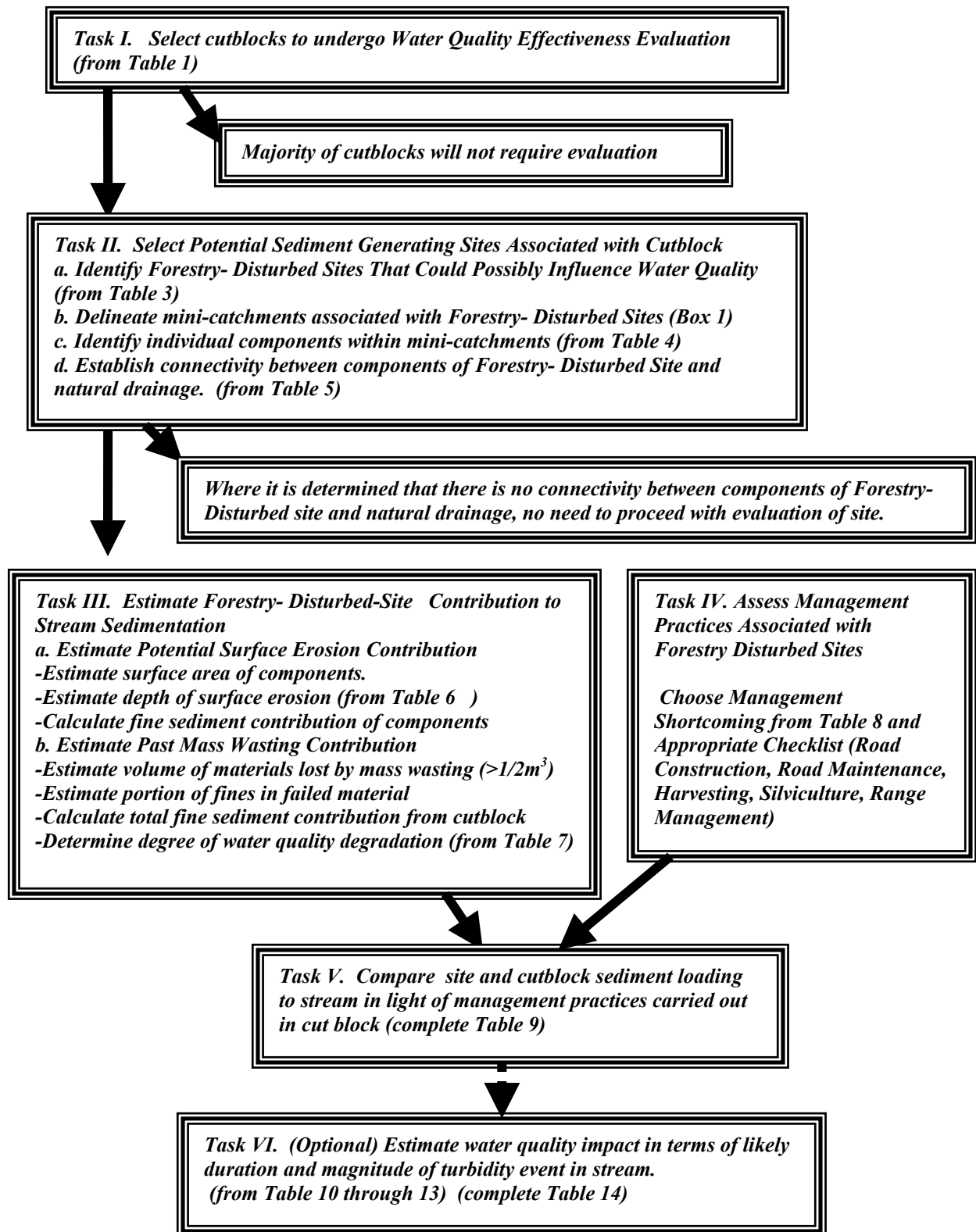
The Forest and Range Practices Act (FRPA) makes provisions for independent assessments of the effectiveness of the Act to meet various environmental objectives. The water quality effectiveness evaluation developed here determines whether cutblocks harvested in the previous year within a Forest District have maintained downstream water quality.

This assessment uses the term “forestry- disturbed site” which is specific to the forestry operations associated with accessing, harvesting and transporting wood from specific cutblocks. The effects of silviculture and livestock management are also considered. Where natural erosion, unrelated to forestry operations, occur in the form of debris torrents, landslides and river bank slumping, they can be ignored or considered separately.

For the purpose of water quality effectiveness evaluation, the primary water quality characteristic of interest is turbidity, which is a measure of the cloudiness of water. When forestry related disturbances generate sediment that is then transported to a stream, turbidity pulses occur which degrade water quality. Field procedures developed here provide a means to quantify forestry related disturbances effect on water quality. The assessment of turbidity will take precedence over other water quality characteristics in this analysis.

With unlimited time and resources, the ideal way to determine whether forestry operations are influencing water quality is to “find the smoking gun”. In other words, if a major turbidity event occurs in the water body of interest, the evaluator immediately travels upstream following the turbidity pulse along the river channel to determine if and exactly where point sources of turbidity are being generated. If it is discovered that turbidity increases along the stream channel, due to road induced landslides, dirty ditch drainage or wind-thrown trees in riparian areas, then one has uncovered a situation where cause and effect is irrefutable. Unfortunately, such a time consuming evaluation is not practical for the volume of cutblocks requiring assessment.

Major tasks with sequential steps and associated reference tables are outlined on Figure 1.



TASK 1. Select Cutblocks to Undergo Water Quality Effectiveness Evaluation

Human resources are not available to evaluate all cutblocks developed within the district in the previous year. Consequently, a subset of those cutblocks is pre-chosen for field evaluation based on a simple rapid appraisal technique. Task 1 provides a means to choose a portion of blocks harvested within the district in the previous year for water quality effectiveness evaluation. This process stratifies all of the cutblocks developed in the previous year into interest in controlling sediment based on hazards associated with the cutblock and consequences of any water quality degradation. A review of available 1:20,000 trim maps, 1:20,000 five year plans, 1:5,000 operational plans, aerial photographs etc is made. The evaluator chooses the appropriate column for each of the stratification criteria listed in Table 1, determines the point rating associated with that criteria answer and adds up the points to determine the predicted level of interest that might be associated with any given cutblock.

A comparison of cumulative ratings for all cutblocks developed within the last year provides the means to select a sub-sample of all the cutblocks for further inspection. The proportion of blocks chosen to undergo the water quality effectiveness evaluation will depend on district resources and perceived water quality problems faced by the district. Of the subset of cutblocks chosen for evaluation, the greater portion will be from the high interest/ concern cutblocks, a smaller portion from lower interest/ concern cutblocks.

Table 1. Criteria used to assign concern or interest associated with a particular cutblock

Stratification criteria	5 points (High risk or consequence)	3 points (Moderate risk or consequence)	1 point (Low risk or consequence)	Point Rating
1. Use for drinking water	Cutblock in community watershed	Cutblock with known water licenses downstream	Cutblock in watershed with no known water licenses	
2. Value of aquatic resources downstream	Cutblock with high value fisheries resources downstream,	Cutblock with moderate or low value aquatic resources downstream	Cutblock with no known aquatic resources downstream	
3. Number of new stream crossings (from TRIM maps) within or along access to block	More than 1 new stream crossing within or along access to cutblock	1 new stream crossing within, or along access to cutblock	No new stream crossing within or along access to cutblock	
4. Length of new road located within 20 m of stream	>500 m	1 m – 500 m	none	
5. Presence of unstable terrain along road alignment or within block	yes	uncertain	no	
6. Presence of sensitive soils (such as lacustrine) within block or along road alignment	yes	uncertain	no	
7. Logging contractor's past performance (if available)	Contractor is unknown or has poor compliance record	Contractor is known and has reasonable compliance record	Contractor is well known and has good compliance record	
Total	Add up points awarded to each stratification criteria for cutblock to calculate Cumulative Risk Rating.			

From the last column in Table 1 we get the Cumulative Risk Rating for a single cutblock.

A **low concern or interest** is assigned where a cutblock receives **<15 points**, a **medium concern or interest** is assigned where a cutblock receives **15- 24 points** and a **high concern or interest** is assigned when the cutblock receives **> 24 points**.

Table 2. Summary Table: Sediment Contribution from Cutblock

Cutblock Identification _____ **Date** _____ **Evaluator** _____

Task II. Select Potential Sediment Generating Sites Associated With Cutblock			Task III. Estimate Forestry-Disturbed-Site Contribution to Stream Sedimentation							Task IV. Assess Management Practices Associated With Forestry Disturbed Sites
			a. Estimate Potential Surface Erosion Contribution			b. Estimate Past Mass Wasting Contribution (must be >1/2 m³ per component)			Total Sediment Generated	
C1 Identify Forestry Disturbed Sites that could possibly influence water quality <i>Choose type of disturbance from Table 3</i>	C2 Identify individual components of Forestry Disturbed Sites within mini-catchment(s) <i>Choose description of component from Table 4</i>	C3 Establish connectivity (Portion of artificial drainage generated by component reaching stream) <i>Choose from one of 0, 0.5 or 1 based on descriptions presented in Table 5. If .5 or 1, proceed to C 4</i>	C4 Estimate surface area of identified components within mini catchment L x W <i>Rough estimation by eye only</i> (m²)	C5 Estimate Depth of Erosion Expected For Surface of Each Component <i>Choose closest fit to describe surface from Table 6</i> (m)	C6 Calculate Estimated Fine Sediment Contribution From Surface Erosion Component C3 x C4 x C5 (m³)	C7 Estimate Volume of Surficial Material Lost by Mass Wasting and Gully Processes (if visually apparent) L x W x D of failure(s) <i>(Rough estimate by eye only)</i> (m³)	C8 Estimate Portion of Fines (Sand, Silt, Clay) in Original Soil or Fill <i>(Rough estimation by eye only) 0, 0 .1, 0.5 and 1)</i>	C9 Calculate Estimated Fine Sediment Contribution form Mass Wasting Component C3 x C7 x C8 (m³)	C10 Calculate Total Sediment Contribution from Component and Forestry Disturbed Site C6 + C9 (m³)	C11 Assess Management Practices Associated with Forestry-Disturbed Site <i>Choose from appropriate Management Checklist)</i>
1. Culverted stream crossing	a. Road surface	1	250	.01	2.5	-			2.5	RC#11 failed
	b. Road ditch	1	20	.001	0.2				0.2	RC#7 failed
	c. Cutbank slump	.5	10	.02	.1	2	.6	0.6	0.7	RC#5 failed
Site 1 Total					2.8			0.6	3.4	
2. Landslide	a. Other disturbed Surface	1	1000	.01	10	10000	.2	2000	2010	
Site 2 Total					10			2000	2010	RC# 3 failed
Cutblock Total									2013.4	

1. Estimation of total fine sediment generation from cutblock (calculated, sum of Column C11.

2013.4 m³

2. Rating of Sediment Volume Loading from Cutblock on natural drainage (from Table 6)

Extreme

TASK II. Select Potential Sediment Generating Sites Associated with Cutblock

To develop and harvest a cutblock, a wide range of forestry activities are required including right of way clearing, borrow pit development, road and bridge construction, culvert placement, felling, yarding, log transport and post harvest silviculture. Task II focuses the evaluator on those forestry-disturbed sites both within and associated with a cutblock where there is a possibility of generating sediment that can reach a natural water body of concern.

Column 1 Description

Identify Forestry-Disturbed Sites That Could Possibly Influence Water Quality

Column 1 focuses the analysis on the most likely sediment-contributing sites within or associated with a cutblock. This follows the logic of Beaudry (2004) with the Stream Crossing Quality Index (SCQI) which was developed for the central interior of British Columbia. The SCQI evaluation system focuses on stream crossings and the quantity of sediment delivered to streams from road ditches, road surface and cutbanks as these features are found to be the major sediment source within this region. Real time water quality monitoring by Beaudry at stream crossings has validated predicted water quality effects.

For the purposes of developing a Water Quality Effectiveness Evaluation relevant to all watersheds in all regions of B.C., an evaluation of a more diverse range of potential forestry-disturbed site is required. This evaluation must include not only stream crossings, but also unstable terrain, extensive skid trail systems, concentrated runoff diverted onto steep slopes, sensitive riparian zones and, in some cases, range that might be overgrazed.

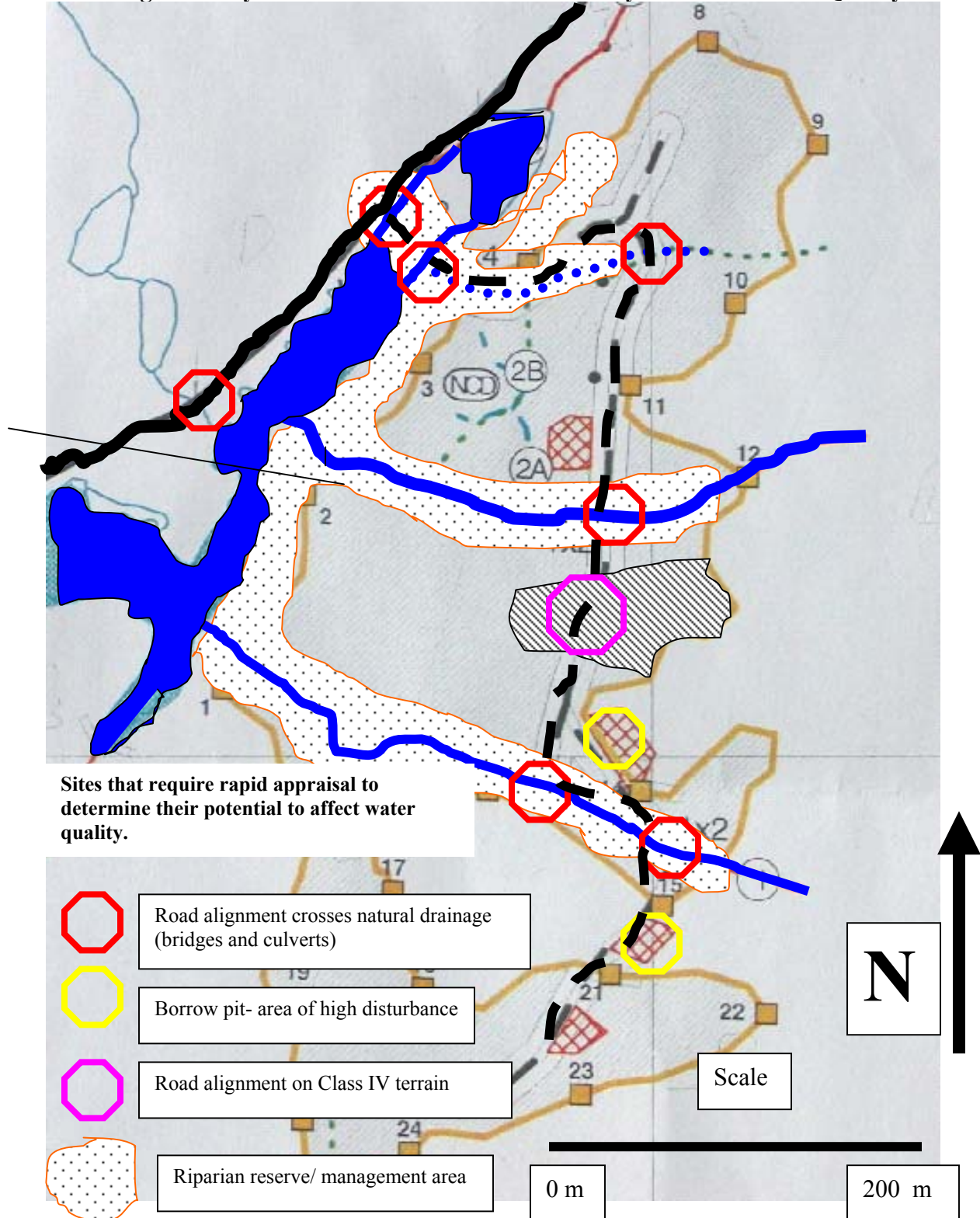
With no means to transport eroded material from a disturbed site to the stream, there will be no water quality effect. If no connectivity is found, further evaluation of a site is unnecessary regardless of the magnitude of potential or actual erosion observed. Distance between the disturbed area and the stream is the single most important criteria for assessing connectivity. Generally, the shorter the distance between sediment source and the stream, the greater the likelihood that generated sediment will be transported to the stream. The more storm water generated by a Forestry Disturbed Site, the farther will be the sediment carrying capacity of the drainage towards the stream. The evaluator is to be cautioned when assuming how far drainage water can and cannot travel. Peak storm discharges from disturbed drainages can travel surprisingly long distances. The greater the intensity and duration of a rain storm event, the more likely that artificial drainage will reach a stream and thus affect water quality. When there is doubt about the connectivity of any forest disturbed site, assume that there is connectivity and proceed with the evaluation.

Forestry disturbed sites to be considered in this evaluation are presented on Table 3.

Table 3. Forestry (and Livestock) Disturbed Sites Associated with Cutblock
Identify Forestry Disturbed Sites That Could Possibly Influence Water Quality

	Road Related
1.	Road stream crossing (bridge and culvert)
2.	Artificial road drainage generation (road intercepting surface or subsurface water from upslope in proximity of stream)
3.	Loose road fill (road prism, bridge, culvert)
4.	Road generated slope failure. (Failure immediately above or below road).
5.	Borrow pits, spoil dumps
6.	Other road related site disturbances
	Harvesting Related
7.	Harvesting /yarding within or adjacent to riparian zone
8.	Skidder/ mechanized harvester trails
9.	Harvesting generated slope failure (failure within or below cutblock)
10.	Landings
11.	Other forestry harvesting disturbances resulting in bare, unvegetated soil
	Silviculture Related
12.	Silvicultural- related- activities leading to water quality degradation
	Livestock Related
13.	Excessive cattle presence within riparian zone and stream channel

Figure 2. Example of cutblock with 1:5,000 Forestry Development Plan indicating Forestry Disturbed Sites that Could Possibly Influence Water Quality



BOX 1

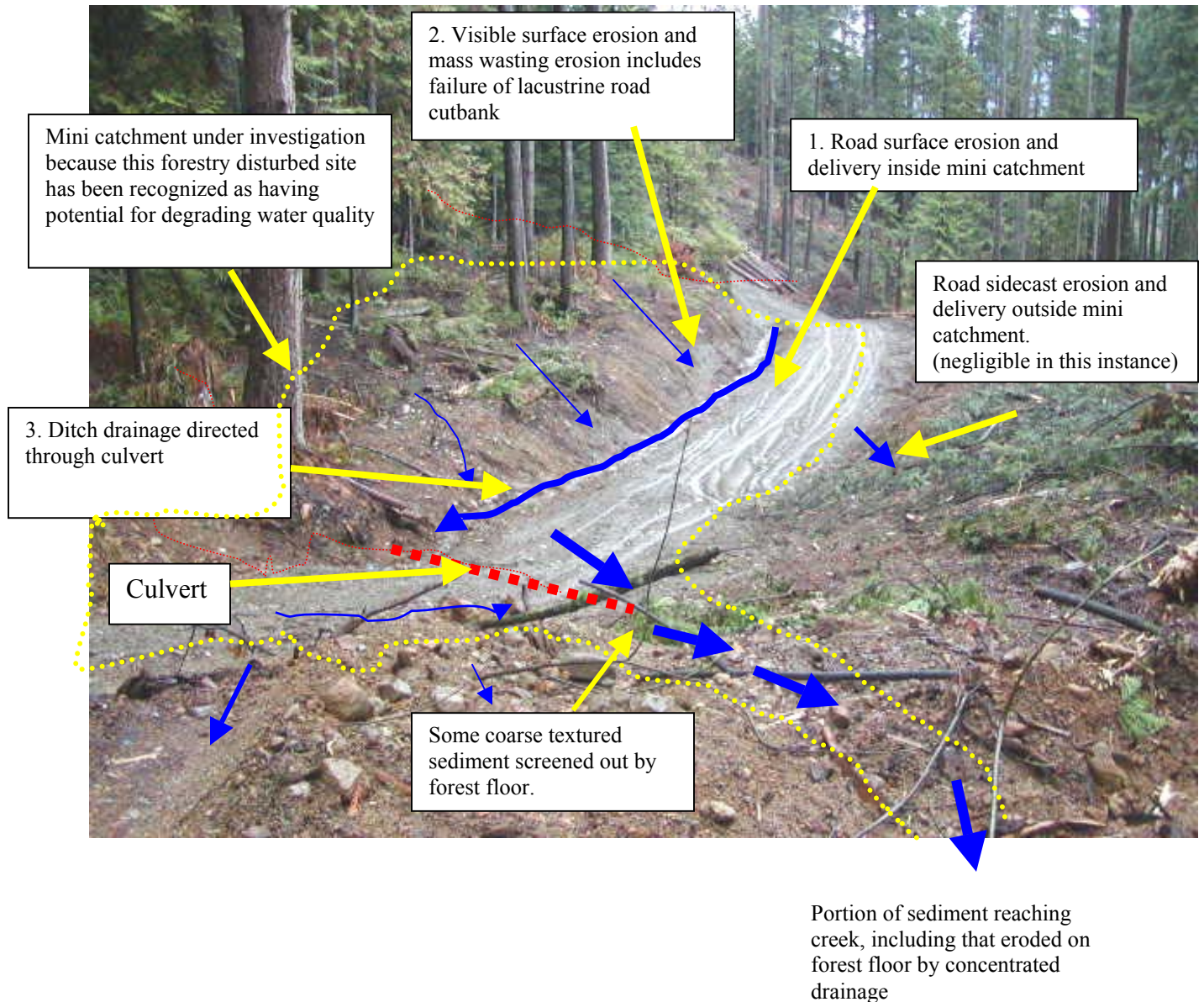
Delineate Mini-catchments Associated with Forestry Disturbed Sites.

Once a Forestry Disturbed Site is selected that has a possibility that soil or water- generated from the site might reach a stream, the evaluator must then delineate the boundaries of the mini-catchment within which all sediment is generated and all drainage water is transported.

The mini-catchment includes the whole drainage area upslope from the specific point of entry of artificial drainage (for example, ditch outflow) into the natural drainage (stream). As an example, a mini catchment might include a portion of forest road drained by a particular culvert, cutbank faces along the road and the pathway of any concentrated water as it flows away from a disturbed site towards adjacent stream. A catchment boundary could be natural such as caused by a local swale in the topography or artificial, where an existing road water bar directs water towards an adjacent mini-catchment that may or may not be under investigation. Mini- catchments are usually small with dimensions rarely greater than 200 m x 10 m. Obviously, standard topographic maps available with, at best, 10 m contours are of little use in delineating mini-catchments. The difference in topography and resulting drainage resulting from a 10 cm deep water bar, which appears on no topographic map, may drastically alter surface drainage and consequences of any erosion.

In the simplest case of defining a mini-catchment boundary, the evaluator might encounter a yarding- induced stream bank slump that has failed directly into a stream. Here, the components of the mini catchment are made up of the slump face and any upslope area generating storm drainage through the disturbed slump face. Mini catchments along road alignments are likely to include a number of components (different types of disturbed surfaces) including culverts, feeding ditches, adjacent road surfaces, cutbanks and the drainage channel below the culvert outfall carrying the water to the stream. An example of a typical mini catchment is shown on Figure 3, which indicates surface erosion and mass wasting features of interest including slumps, road surfaces, ditches, cut banks, side cast material etc.

Figure 3. Delineation of mini-catchment boundary and components



Column 2 Description

Once the boundaries of the mini-catchment have been defined, individual components within those boundaries (having differing actual or potential erosion) are delineated as per Figure 3. Typical components to be considered are listed on Table 4.

Table 4. Individual Components Identified within Mini-catchment of Forestry Disturbed Site

Identify individual components within mini-catchment

a	Road surface
b	Road ditches
c	Road cutbank
d	Road sidecast
e	Fill over culvert or bridge
f	Culvert outflow
g	Heavy machine tracks: compacted, gouged or incised forest floor
h.	Rills or gullies generated by artificially concentrated storm flow
i.	Mass failure scar generated by forest harvesting and road related activities.
j	Other disturbed surfaces

3 Description.

Establish Connectivity. (Portion of Artificial Drainage Generated by Component That Reaches Stream)

In many cases, connectivity can only be established conclusively by inspecting the discharge pathway between the forestry-disturbed site and the receiving waters. If a recognizable continuous or discontinuous sediment trail is observed issuing from the site and reaching the stream, it is obvious that concentrated water has traveled that far during past storm events. In such cases, connectivity is established. Obviously, if the site visit actually occurs during a peak storm flow event, and storm drainage is observed to flow into a natural drainage, connectivity is also established conclusively.

However, connectivity is sometimes difficult to confirm, if the pathway downslope from the disturbed site is irregular and the disturbance is so recent that heavy rainstorms or snowmelt has not had a chance to transport sediment from the site.

Table 5 provides some indicators that can help estimate connectivity. The observations of whether a site is, or is not connected to a natural drainage is usually straightforward. However where drainages down slope are complex (for anything in between 0 and 1), any derived value for connectivity will be somewhat subjective. For the sake of convenience of evaluators and uniformity of results, the intermediate value 0.5 is chosen to provide a reasonable estimate for values other than 0 or 1.

Table 5. Appraisal of connectivity between disturbed site and receiving waters

Connectivity Classes used in this Evaluation	No Possible Connection between Disturbed Site and Natural Drainage	Partial Connectivity between Disturbed Site and Natural Drainage	Direct Connectivity between Disturbed Site and Natural Drainage
Distance between forestry disturbed area and stream	Disturbed areas far removed from natural water body (> 100 m) without source of concentrated storm drainage	Disturbed areas 10-100 metres from water body. Some sign of water concentration at site	Disturbed areas immediately adjacent to water body < 10 metres with obvious concentrated storm drainage through disturbed site.
Infiltration rate at disturbed area	High infiltration rate on disturbed site. Surface around disturbed site able to absorb storm flow discharge	Moderate infiltration on disturbed site. Surface materials capable of absorbing portion of drainage	Slow infiltration rate. Upslope water contributions will likely pass through disturbed area unchecked
Gradient, vegetation and , micro-topography of drainage down-slope of forestry disturbed area	Drainage profile is long, low gradient and broken by numerous depression area, surface is rough and heavily vegetated	Drainage flows onto a moderate gradient and length of rough, vegetated ground before reaching receiving water	Drainage pathway is short, high gradient and smooth with absence of vegetation, or debris along pathway where water will flow.
Estimated Storm Discharge from Forestry Disturbed Area	Estimated storm discharge of inter-drainage culvert < 2 L/s	Estimated storm discharge of inter-drainage culvert 2 to 10 L/s	Estimated storm discharge of inter-drainage culvert >10 L/s
Value to be used for calculations of sediment generation	0	0.5	1.0

TASK III. Estimate Forest Disturbed Site Contributions to Stream Sedimentation

The evaluation is designed to be performed with a single visit to the site where some indication of both potential and actual sediment delivery is estimated. To accomplish this, erosion generated on Forestry Disturbed Sites is divided into two classes, that generated by surface erosion and that generated by mass failures and gullying.

a. Estimate Surface Erosion Contributions

This type of erosion involves finer textured materials dislodged and segregated by the energy of raindrops upon the surface and moved via sheet erosion down slope.

Surface erosion is estimated by assessing the area and erosivity of different types of disturbed surfaces. While the surfaces of slumps and gullies should be inspected for ongoing surface erosion, any observed mass wasting in excess of $\frac{1}{2} \text{ m}^3$ is dealt with in the following section.

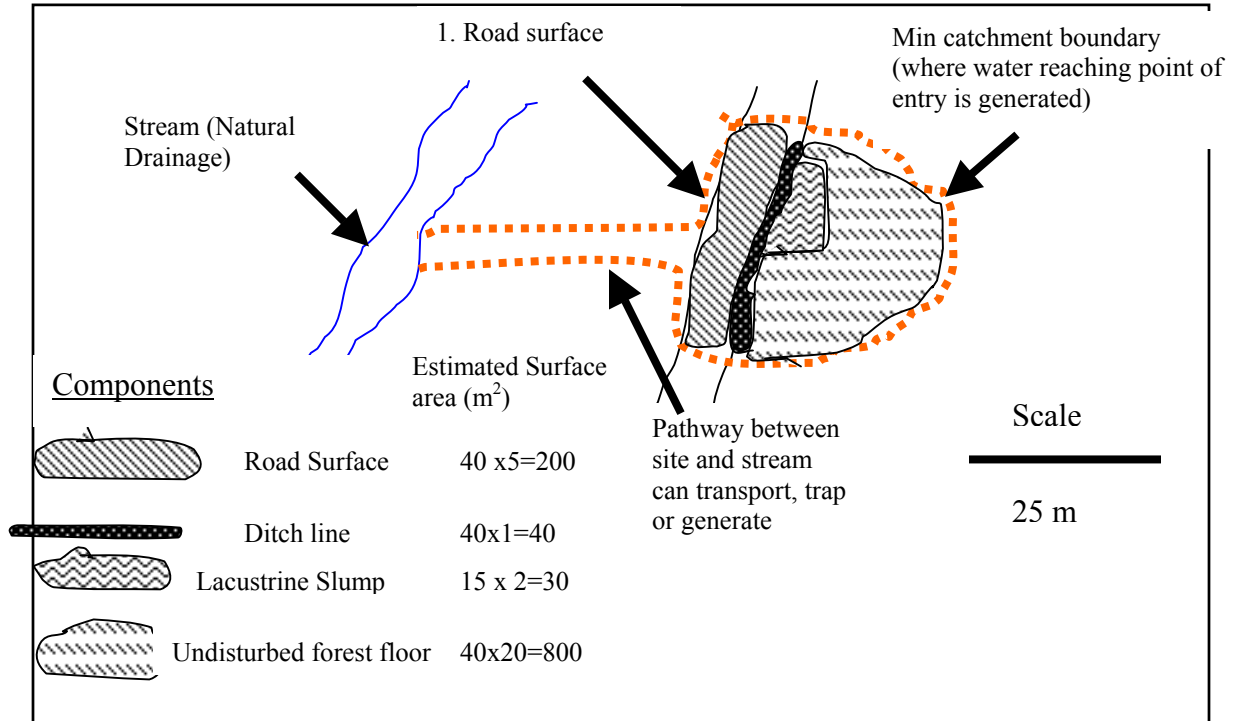
Column 4 Description.

Estimate Surface Area of Identified Components within Mini Catchment

This can be done by simply estimating lengths and widths of potentially eroding surfaces of interest within the mini-catchment.

On Figure 4 an example of surface area determination is provided.

Figure 4. Estimation of Surface Area of Identified Components within Mini-catchments.



The evaluator estimates the surface area of each component identified in Column 3 where at least partial connectivity is established.

Column 5 Description

Estimate Depth of Erosion Expected For Surface of Each Component

Most higher risk sites that are disturbed and improperly managed initially experience high rates of surface erosion that fall off dramatically as the site self-armours or re-vegetates during the growing season. For normal logging operations, the great majority of sediment that a road generates occurs during its first year after road construction and harvesting. Where disturbances are ongoing, such as heavy use of an uncapped dirt road for hauling, or where there is little or no self armouring capability, high rates of erosion can be generated indefinitely with no change in management.

For each component examined, the evaluator must estimate how much erosion can be expected from each surface. If a evaluator is experienced at making such estimates he or she can do so directly, otherwise Table 6 provides ball park rates of expected surface erosion associated with different kinds of surfaces.

Table 6. Estimated annual surface erosion expected on typical forestry-disturbed surfaces

Choose surface erosion rating that provides the best match for condition of surface being evaluated¹.

Surface erosion rating	Typical components of mini-catchments draining forestry-disturbed sites.	Estimated annual depth of surface erosion expected under existing conditions (m)	Comments
Nil	Good vegetation or forest floor cover	0	Forest floor can act as trap for coarser sediment classes
	Bedrock, colluvial rubble, road surface of coarse rock	0	
	Paved road surface	0	
Low	Fair to poor vegetation cover but not otherwise disturbed	.001	
	Road abandoned in previous year, occasional 4 x4 access, with good rock self- armouring and some vegetation growth	.001	Ability to self armour or re-vegetate dramatically reduces erosivity with each rainfall
Moderate	Lightly used gravel road (< 5 times per day in dry weather) with high quality surfacing material, not graded	.002	
	Vegetation removed to expose soil but subsoil is intact	.005	
	Well used gravel road in dry season only with minimal grading	.005	
High	Well used, gravel road, graded, active hauling even during wet weather	.01	
	Exposed road cut in loose disturbed soil material.	.02	
	Well used 4 by 4 dirt road in absence of good quality surfacing material	.02	
Extreme	Bare, disturbed, uncompacted, stone free lacustrine on sloping road cut	.05	Compacted lacustrine that occasionally occurs in coastal kame terraces can be quite erosion resistant (.001)

¹ *Note: Where gullying/slumping or massive slope failure is noted, any expected ongoing surface erosion is considered, but the actual material loss by mass failure is considered separately.*

Column 6 Description.

Calculate Estimated Fine Sediment Contribution from Surface Erosion Component.

By multiplying the results from Column 3, 4 and 5 together, we can get a value for the volume of sediment contributed to the natural drainage from surface erosion of the component under inspection. Because rainfall erosion only moves the fine particle classes, we can presume that the value chosen for connectivity will provide a reasonable proxy of the amount of fine textured sediment reaching a natural drainage¹. An example of this calculation for a mini-catchment is provided on Figure 5.

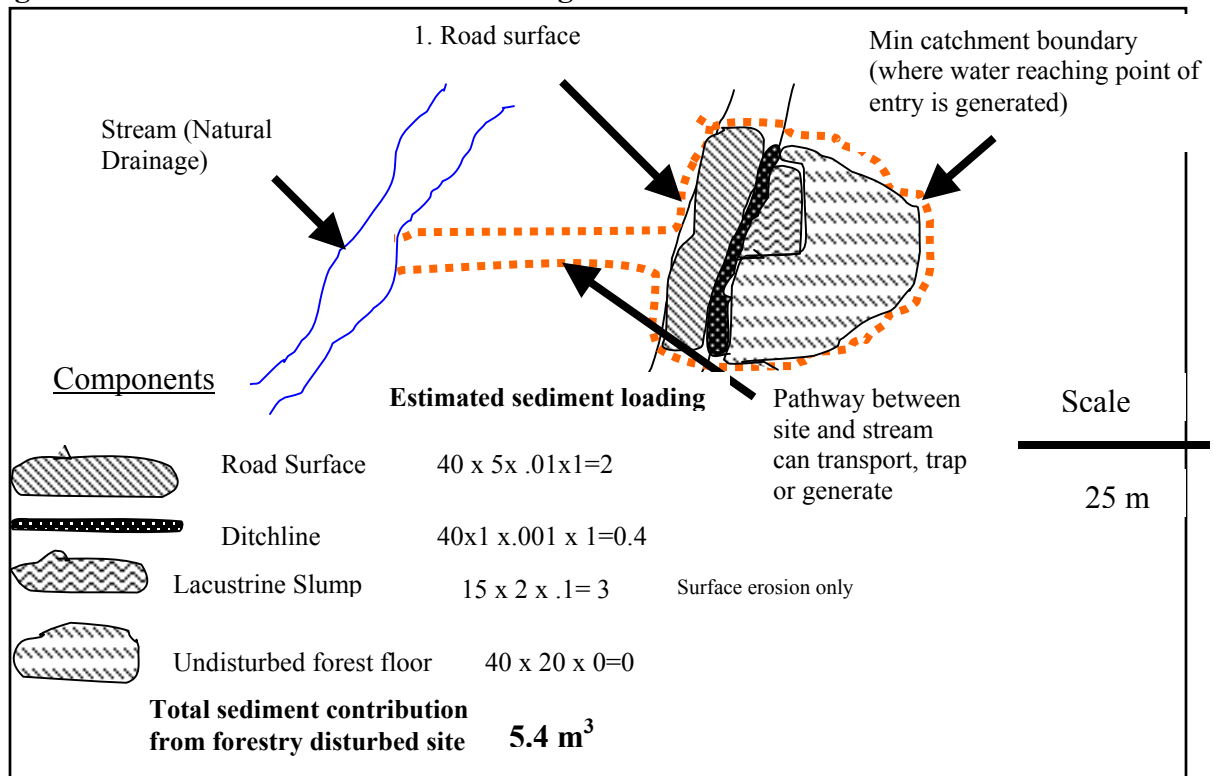
Field Validation of Results

While the evaluation does not require it, field workers should be able to observe signs of erosion and sedimentation that support the volumes of sediment he or she has calculated to have occurred. Again, we are looking for order of magnitude agreements. Does a specific mini catchment contribute 1, 10, or 100 m³ over the period for which the inspection is being conducted?

Sediment deposits are most easily recognized in the first season after the erosion has occurred. By observing the amount and particle size of sediment in road puddles, ditches, sediment traps and culvert outfalls and on the forest floor itself, the evaluator can estimate the magnitude and competence of storm discharge from a particular site. By denoting the presence or absence of certain particle size classes within sediment wedges and characterizing their source, the evaluator is in a good position to determine what sediments might have been transported to the stream and what has remained on site.

All evaluators should, as part of their training, spend some time in the field during the season when erosion is actually occurring so that they can understand the processes that act on forestry-disturbed sites within their region. In this way, experience gained in one type of terrain can be transferred to newly opened areas.

Figure 5. Estimation of sediment loading to stream as a result of surface erosion.



b. Estimate Mass Wasting Contribution

In addition to surface erosion that affects all disturbed surface areas, mass wasting erosion is also considered because of its occasional overwhelming contribution to sedimentation. In this methodology we are considering only that portion of mass wasting that has already occurred and, unlike the estimates for surface erosion contribution, we are not trying to predict mass failures that may happen in the future. Only individual mass wasting features in excess of $\frac{1}{2} \text{ m}^3$ of material are considered.

Column 7 Description.

Estimated Volume of Surficial Material Lost by Mass Wasting and Gully Processes

To assess the contribution of mass wasting to water quality degradation, the evaluator must carefully observe whatever evidence is available on the ground. In general, immediate past degradation of sites by slides and gully is easy to recognize. The more recent the mass failure event occurred, the more obvious the remaining evidence. . An estimate of length, width and depth of landslide scar, gully or rill provides the volume of the material eroded from the site.

Column 8 Description.

Estimate Portion of Fines (Sand, Silts and Clay) in Original Soil or Fill.

Unlike, surface erosion, erosion by mass failures is less selective about the particle size class that can be transported. Large rocks, stones, gravel as well as finer textures are transported down slope with landslides. Gullies incise downward until the base of the gully becomes armoured or a sufficiently low gradient is achieved to reduce discharge velocities. The degree of gully incision depends on the competence of the storm drainage waters. In many cases, larger size particle classes (boulders, cobbles, gravel) may be re-deposited before reaching the stream and, should they reach a stream, they do not directly result in degradation of water quality. Consequently, it is necessary to estimate the portion of fines in relation to the coarser material involved in the initial mass failure or gully incision. This is done by observing newly incised incisions or headwall and sidewall faces and estimating the volume of fines making up the profile.

For this analysis, the values 0, 0.1, 0.5, and 1.0 are to be chosen

Column 9 Description.

Calculate Estimated Fine Sediment Contribution from Mass Wasting

By multiplying the results from Columns 3, 7 and 8 one is has an estimate of sediment contribution from mass wasting on the selected forest disturbed area. This is expressed in m³ of fine textured sediment.

Column 10 Description.

Calculate Total Sediment Contribution from Component.

By adding Columns 6 and 9, one gets an estimate of potential sedimentation resulting from surface erosion and actual sedimentation resulting from mass wasting for a selected component. While they represent different erosion processes occurring over a differing time frame, the value does give a reasonable assessment of possible degradation of water quality resulting from that component.

The total sediment generated from all Forestry Disturbed Sites within the cutblock provides a measure of the effect of the cutblock on water quality.

This total sediment volume is then rated using Table 7 as Low, Moderate, High or Very High or Extreme sediment contribution to water.

Table 7. Degree of Water Quality Degradation Based on Volume of Sediment generated in and around cutblock

Estimated Volume of Sediment (potentially) reaching stream as a result of all Forestry Disturbed Sites associated with cutblock (Total from C10)	<1 m³	1-10 m³	10-100 m³	100-1000 m³	>1000m³
Degree of Water Quality Degradation	Low	Moderate	High	Very High	Extreme

TASK IV. Assess Management Practices Associated with Forestry Disturbed Sites

Management practices associated with forestry operations on higher risk terrain strongly influence if, and how much water quality degradation will occur. If contractors have managed the operations well and carried out more intensive management practices where risks are greater, water quality degradation is usually negligible. On the other hand, if operators fail to employ good management techniques on higher risk sites, water quality degradation is almost inevitable. At least we assume this is the case. This methodology allows the evaluator to consider how effective management practices being employed by contractors are (or are not) in maintaining water quality.

In Task IV, the evaluator reviews the nature and quality of management practices that have been employed on a given site and then compares this with the level of sediment generation from the same site. If poor management is mirrored by severe water quality degradation, it is then apparent that the licensee has failed to properly address water quality concerns.

The assessment of water quality effectiveness requires that the evaluator be familiar with forestry operations associated with roads and harvesting. He or She must recognize what sort of practices put water quality at risk and what management opportunities through Best Management Practices (BMPs) are available to minimize that risk. On Table 7, some of the management techniques required to minimize water degradation are listed.

For each major forestry activity, Forest Road Construction, Road Management, Harvesting and Silviculture, "Management Activity Checklists" provide the evaluator with a list of forest management practices that can influence water quality. These checklists are to be used to evaluate the quality of management practices that have been carried out on these sites. If a site is recognized to have been disturbed as a result of harvesting activity, then the Harvesting Checklist 2 would be reviewed, if there is a road construction problem, the road construction checklist, etc. When it is apparent that the contractor has, for instance, not installed appropriate cross ditches, such results are compared with the estimated amount of sediment generated from the site. The evaluator then considers how effective the better management practice would (might) be to reduce the level of sedimentation. This comparison facilitates developing management feedback loops.

As a part of any on site inspection, photographs taken on a digital camera should be used to document forestry-disturbed sites and their associated management practices.

Column 11 Description

Record Management Practices Associated with Forestry Disturbed Sites

Upon inspecting management practices associated with the Forestry Disturbed Site, the evaluator will determine whether the site has been managed with water quality maintenance in mind. (see Table 8 and lists of Management Checklists. Wherever shortcomings in the management of any forestry- disturbed site are observed, they are recorded in Column 11. This management failure, when compared with estimated sediment production (Table 9) provides an excellent means for the evaluation to develop a management feedback loop.

Table 8. Outcome of management practices on moderate and high risk sites

Higher risk sites as determined in Task 2	Management practices that preserve water quality	Management practices that risk degrading water quality
1. Areas of mass instability (Stability Class IV and V Terrain)	Good road engineering techniques, narrow width, full bench, endhauling of excavated material, minimizing concentration and diversion of water onto unstable slopes.	Poor road engineering techniques. Unnecessarily wide road to allow safe and efficient passage of logging trucks, heavy sidecast, concentrated drainage water diverted onto unstable ground
	On deactivation, complete sidecast pull back and safe storage, out-sloping road to minimize road surface concentration, cross ditches with blocks or French drains at all drainage ways. Bare soils re-vegetated	Abandonment of unstable sections of road without treatment.
2. Areas of erosive soil	Complete absence of ground disturbance with forest floor still intact and no upslope change to drainage	Severe ground disturbance resulting from forest floor removal, machine scouring and compaction that collects and channels water towards natural drainage.
	Short, low gradient, heavily cross ditched, ditch blocked and / or water barred, unused or decommissioned roads, in remote location from natural drainages. Stream approaches graveled, geo-textiles employed.	Drainages not culverted and allowed to flow along ditch, More than 10% road gradient, heavily used, with close proximity to natural drainages, gullying, sheet erosion present. Bridge approaches not graveled. Lack of geo-textiles to support bridge fill
	Smallest seepages are culverted or cross ditched, road sloping to outside	Few culverts, larger drainages have been diverted away from their original channel onto road or steeper slope
	Road construction takes place in dry conditions	Road construction takes place in wet conditions
	Hauling done when road frozen or not wet	Hauling carried out when road prism too wet for heavy loads
3. Areas adjacent to natural drainage within or adjacent to block	Un-impacted riparian reserve zone with wide buffer, low terrace with absence of undercutting and heavily vegetated. Cutblock boundary is wind firm. No evidence of excess grazing.	Riparian zone with narrow or no reserve. Scalping from yarding. Land adjacent to stream has been machine harvested, heavy debris load in stream channel. Extensive windthrow apparent. Evidence of overgrazing exist
	No sign of impingement of any forestry activity on stream channel, no new scouring, tree roots not exposed, no change in channel, no recent unusual sedimentation	Signs of serious disturbance evident: Active scouring, exposed tree roots, avulsed channel, recent stream bank collapse or heavy new sediment loading noted
4. Miscellaneous	No sign of fertilizer spill, hydraulic oil leakage or fecal contamination.	Major fertilizer spill, major spray drift noted, Serious hydraulic oil leakage or fecal contamination on stream banks

Road Construction Checklist (RC)

Record failure to meet relevant indicators for each Forestry Disturbed Sites in Column 11

Criterion 1. Does road construction affect water quality?

Indicators		Yes	No	N/A
RC#1	Road construction practices have prevented disturbance of erodible soil materials.			
RC#2	Concentrated flow from road ditches is diverted onto forest floor before reaching streams.			
RC#3	Road alignment is designed so that road surface drainage is intercepted before reaching bridge or culvert crossings.			
RC#4	Sediment wedges from road or road ditch do not occur adjacent to stream?			
RC#5	Ditch lines, bridge fill or side slopes are stable with no sign of slumping or raveling.			
RC#6	Areas of disturbed soil have been reseeded or armoured with rock or logging slash.			
RC# 7	Culverts and bridges were designed and constructed to minimize disturbance to natural drainages.			
RC#8	Culverts are placed on grade and not left hanging.			
RC#9	Culvert outfalls outside natural drainages are rip-rapped when flowing onto erosive soils.			
RC#10	Culverts are placed at regular intervals between natural drainages where discharge can be dispersed and absorbed on stable ground.			
RC#11	Cross ditches, ditch blocks and/or water bars are installed to break up drainage on long slopes.			
RC#12	Upon deactivation, road is cross-ditched at every natural drainage (including seepages) and regularly water barred where road surface water can concentrate.			
RC#13	More intensive engineering techniques have been used on steep, unstable soils. (full bench of road prism, french drains, end hauling to safe location etc)			
RC#14	In the absence of obvious natural drainage, a sufficient number of culverts have been installed in safe locations to ensure no heavy concentration of storm flow (> 5 l/s) onto unstable ground below the road.			
RC#15	If deactivated, sidecast materials on steep terrain have been pulled back and materials safely located.			
RC#16	Other indicators related to road construction			

Road Management Checklist (RM)

Record failure to meet relevant indicators for each Forestry Disturbed Sites in Column 1

Criterion 2. Does road management affect water quality?

Indicators		Yes	No	N/A
RM#1	High quality road capping materials have been used where drainage flows directly into stream.			
RM#2	Road grading has removed ruts and berms that might channel surface drainage towards a stream.			
RM#3	Culverts are cleaned of excess sediment and woody debris.			
RM#4	If it is raining during inspection, ditches are running clean even when there is active hauling.			
RM#5	Dust prone roads paralleling streams are watered, oiled or otherwise treated to reduce dust.			
RM#6	Other indicators related to road use and maintenance.			

Harvesting Checklist. (H)

Record failure to meet relevant indicators for Forestry Disturbed Sites in Column 11 of Summary Table.

Criterion 3. Do harvesting practices affect water quality?

Indicators		Yes	No	N/A
H#1	Streambanks within or adjacent to cutblocks are intact and well vegetated. (ie no sign of scouring from yarding operations)			
H#2	Logging slash has been kept out of the wetted width of stream channel where it might accelerate stream incision and channel alteration.			
H#3	Riparian protection zone is not disturbed.			
H#4	Forest floor within harvested area lack signs of overland flow/ sediment trails flowing towards the streambank			
H#5	Riparian strip leave- trees have remained windfirm			
H#6	Skid trail tracks only lightly incised (<5 cm) over short distances (<10 m) to avoid concentration of storm or melt water run off.			
H#7	Other indicator questions may be required for specialized harvesting operation.			

Silviculture Checklist. (S)

Record failure to meet relevant indicators for each Forestry Disturbed Sites in Column 11

Criterion 4. Do silviculture practices affect water quality?

Indicators		Yes	No	N/A
S#1	Downstream from areas that have been fertilized, stream channel does not have more filamentous algae production than upstream of cutblock.			
S#2	Vegetation within a designated riparian herbicide- free spray zone has not been affected by herbicide spray.			
S#3	Where brushing and thinning operations have been conducted in riparian areas, slash has been removed from wetted width of channel where it might impede flow and erode banks.			
	Other indicators related to silviculture operations.			

Livestock Checklist (L)

Record failure to meet relevant indicators for each Forestry Disturbed Sites in Column 11

Criterion 5. Does use of range for livestock influence water quality?

If vegetation virtually un-grazed with no evidence of livestock within riparian zone, this evaluation need not proceed further

Indicators		Yes	No	N/A
L#1	Cow pies absent or there is less than 1 cow pie within 2 metres of stream bank for every 20 metres of stream length)			
L#2	Cattle tracks along stream bank and trails leading into stream are absent or only lightly used?			
L#3	Stream banks are covered in vegetation with no sign of serious animal disturbance.			
L#4	Farmer has avoided spreading manure within 5 meters of stream.			
	Other indicators related to range management.			

Table 9. Cutblock Routine Evaluation Summary Sheet

Forestry Disturbed Sites within Cutblock	Observed Management Shortcoming of Forestry Disturbed Site	Estimated Sediment Contribution form Forestry Disturbed Site (m³)
1.		
2.		
3.		
4		
Total Sediment Contribution from Cutblock		

TASK V. (Optional). Estimate water quality impact in terms of duration and magnitude of turbidity events in stream

For routine evaluations, the estimation of volume of sediment reaching a stream is adequate for addressing water quality effectiveness evaluations. Assessing downstream water quality effects of forestry operations is rarely done well and then only in research settings. Most often forestry effects on water quality are considered to be “diffuse” sources without clearly defined points of generation. While on a watershed scale, modeling the sources as diffuse might be reasonable, on the cutblock level, this evaluation considers most forestry related water quality effects to be distinct “point” sources draining pre-selected disturbed mini-catchments. By understanding sediment generation at these discrete “points” one can infer the kinds of water quality changes expected in the receiving waters immediately downstream from the cutblock. Should all these discrete sediment- generating sources for all forestry operations be considered together within one watershed, the evaluator would have amassed a reasonable assessment of the cumulative effect of forestry on water quality.

As noted, the amount of sediment transported to receiving waters from forestry disturbed sites provides an indication of the degree with which receiving waters are impacted. Obviously, if sediment reaches a stream, water quality is impacted. Unfortunately, it is not a straightforward procedure to convert an amount of sediment reaching a stream to a measure of water quality degradation of relevance to water purveyors and fishery managers. What if the receiving waters are glacial-fed, with a discharge of 10 m^3 and normal background turbidity of 100 NTU? How significant would sediment contributions be from a disturbed mini-catchment with a discharge of 2 litres per sec and turbidity of 20 NTU? In this case, it would be hard to argue that the water quality had been degraded with a net 0.1% decline in turbidity downstream. On the other hand, if a clear flowing stream of 0.1 m^3 was to receive drainage water of 10 l/sec with a turbidity of 100 the effect on the water quality would be substantial with a 10 NTU increase downstream. Determining whether and how a sediment contribution has degraded water quality of the receiving stream requires more consideration.

To evaluate forestry effects on water quality, the evaluator must consider not only the volume and texture of the material reaching the stream but the duration of sedimentation event(s) and the discharge and turbidity of the receiving waters. On one hand, a river bank slump in a disturbed riparian zone is immediately delivered to the creek and can have substantial water quality effects over a relatively short period. However, sheet erosion on an active forestry road may result in small but discrete pulses of sediment to the stream whenever a logging truck is hauling during rain. Task V is included to address such complexities.

Column 12 Description

Estimate duration of sediment delivery to receiving waters

Making a reasonable estimation of the period of time that a known amount of sediment has been or will be delivered to a stream depends on the nature of the disturbance. For instance, a landslide may travel and come to rest in a river channel. If the slide material is small and easily dispersed, the duration of the turbidity event in the receiving stream could be measured in terms of minutes, or hours. A gully system developed on a road grade may have occurred from snow melt over a period of 10 days. If a forestry-disturbed site exhibits severe sheet erosion, the duration of erosion sedimentation activity may have occurred during all erosive rains since logging was completed.

In general rough estimations of duration such as presented in Table 10 would be considered appropriate for analyzing the effect of individual forestry-disturbed sites.

For the purposes of this routine evaluation, where only a cutblock level evaluation is required, a duration of sediment generation of 10 days will be assumed. This would roughly reflect the duration of turbidity events for normal annual sediment loading.

Table 10. Typical Duration of Sediment Delivery to Stream

Nature of Sediment Delivery Duration	Sediment delivery duration used in Turbidity Estimation Table	Associated with meteorological or geomorphological event	Comments
Instantaneous	<0.1 hour	Debris torrents/ landslides, river bank slumps	Actual incorporation into stream flow dependant size and nature of slide material and discharge and velocity of receiving stream
High Intensity, periodic	1 hour	Thundershower	Occasionally occur in summer
Medium intensity, periodic	10 hours (1 day)	Single day of heavy rain	Most consultancy call outs to eroded sites are associated with the damages from a single heavy rainstorm
Low to moderate intensity, periodic, reflecting annual rates	100 hours (10 days)	10 winter rainstorms, or spring thaw.	Most reflective of the duration of annual erosion/ sedimentation processes
Long term, chronic	Chronic (100 days) or year-round (Active Main line)	Continuous, intermittent,	Low levels of turbidity over long time periods associated with disturbances such as passage of logging truck during rainfall or cattle walking in stream.

Column 13 Description

Estimate discharge of stream during sedimentation events

In the great majority of cases, erosion and sedimentation occurs when the stream is in flood. This would be the amount of water flowing at bank full discharge. Making an estimate of watershed size, and possible capacity stream channel in combination with the actual discharge observed at the time of visit, the evaluator can come up with a reasonable estimate of discharge during normal erosive events.

In some instances it may be possible to collect hydrometric data to fine tune estimates of discharge volumes for various storm events. Regional hydrologists may also be able to suggest a reasonable storm discharge for a given watershed based on its location, size and elevation. Such information would strengthen bank full estimates made by evaluators.

It is relatively simple to estimate discharge volumes to an order of magnitude precision. The most simple and intuitive method used to measure discharge is to imagine how long it will take for the observed discharge in a ditch, culvert or stream channel to fill a familiar but imagined container. An example of this method of estimation is provided on Table 11.

Table 11. Simple field estimation of discharge in ditch or stream

Typical discharge	Imagined Container	Estimated time to fill	Estimated discharge
Seepage out of bank	Beer glass (300mL)	3 seconds	0.1 L/s
50 m road ditch, moderate rainfall	Ice cream bucket (4 L)	4 seconds	1 L/s
400 mm culvert outlet from 1 ha paved parking lot during rain storm	10 gallon aquarium (40L)	4 seconds	10 L/s
800 mm culvert on ephemeral stream	Bathtub (200 L)	2 seconds	100 L/s
Stream draining 200 ha catchment during storm	Hot tub (2000 l) 2 m ³	2 seconds	1000 L/s or 1 m ³ /s
Stream draining 2000 ha catchment during storm	Small backyard swimming pool (100,000 L or 100 m ³)	10 seconds	10 m ³ /s
River in flood draining catchment of 200 sq km	Olympic size pool (50mx20 m x 1.5 m)	15 seconds	100 m ³ /sec

For discharge of streams over 100 L/ s, a secondary check can be made by estimating width and depth of stream and velocity of current. To carry out such estimates it is best to look at a river segment with minimal turbulent flow and a simple cross-section, free of logs and large rocks. Velocity is estimated by throwing a leaf or twig into the stream where the cross section is taken and length of time taken to travel a defined length is measured.

$$\text{Width (m) x depth (m) x velocity (m/s) = discharge (m}^3\text{/s)}$$

By observing the stream you may imagine it will take two seconds for the flow to fill up a hot tub. This would correspond to a discharge of 1 m³/s. The same river section is measured to be 4 metres wide and 25 cm deep with an estimated flow velocity of 1 m/s. This would have an estimated discharge of 4 x 0.25 x 1 = 1 m³/s which acts as a check on the original estimate. The actual discharge may in fact be 0.6 or 1.5 m³/s but we are confident it is not 100 L/s or 10 m³/s. In any case we have made a reasonable estimate of discharge which helps to understand the effect a given volume of dirty water will have on it. Depending on the time of visit, the evaluator will have to adjust the estimated discharge to reflect normal flows during erosive events.

Column 14 Description

Estimate turbidity

Turbidity is a measure of the cloudiness of a liquid. The more suspended sediment or finely divided organic matter in water, the greater the turbidity. Almost all drinking water degradation caused by forestry operations change the fluxes of turbidity in receiving streams.

Turbidity measurements can be made using a portable turbidity meter, a turbidity wedge or estimating the depth one can see clearly into a column of water. For the purposes of these evaluations, a simple visual estimate is provided on Table 12.

Table 12. Simple field estimation of turbidity

Nature of discharge	Estimated depth of visibility of bright object in water	Rough estimate of amount of suspended sediment	Approximate turbidity (NTU)²
Crystal clear	20 metres	Nil	<0.2
Clear water	5 metres	<1 mg fine textured sediment per litre	0.5
Slightly cloudy water, but drinkable	2 metres	2-10 mg/L (depending on portion of organic/inorganic loading)	5
Cloudy water, rejected by humans but suitable for livestock	20 cm	0.1 gram of fine textured material/litre of water	50
Dirty water	5 cm	1 g of fine textured sediment /litre	500
Muddy water, road puddle after truck passing	0.5 cm	10 grams of fine textured sediment in litre of water	5000

² NTU = Nephelometric Turbidity Units. .

Turbidity (Continued)

Should the evaluator be on site during rains that are producing sediment, it is possible to do a quick check on the order of magnitude of erosion expected from the forestry disturbed site. A simple estimate of discharge and turbidity for the outflow from the disturbed mini-catchment and the receiving stream is all that is required. By calculating the dilution factor resulting when the disturbed turbid drainage enters the less turbid receiving stream, the increase in turbidity in the main stream can be calculated. As an example, if the main stream was estimated to be flowing at 100 L/s and had a turbidity of 2 NTU and the contributing drainage from the investigated mini catchment had a discharge of 2 L/s and a turbidity of 100 NTU, the estimated increase in turbidity of the receiving waters would be 2 NTU.

Background turbidity has doubled as a result of the additions of this disturbed drainage. Another way of saying this is turbidity has increased by 100 %. Based on guidelines developed by MWLAP for drinking water, degradation has occurred¹.

However, most evaluations will be made during low flow periods when turbidity events are not happening. Estimating changes in turbidity will rely on estimated volumes of fine sediment reaching the stream as developed in this methodology.

Column 15 Description

Estimated change in receiving water turbidity generated from component of Forestry Disturbed Site

Once the evaluator has estimated the amount of sediment delivered to the stream, the duration of delivery and the discharge of the receiving waters at time of delivery, Table 13 gives probably turbidity increases expected for the water body of interest.

Table 13. Turbidity Estimation Tables

Volume of Fine Textured Sediment Delivered to Stream (m³)	Estimated Duration of Total Erosion Sedimentation Event	Estimated Flow Rate of Receiving Stream or River (m³/s)	Calculated Increase in Turbidity over Background Levels of Receiving Stream Over Time Period Suggested (changing time period changes concentration)
0.01	instantaneous	0.01	2000 ntu over 0.1 hr
0.01	instantaneous	0.1	200 ntu over 0.1 hr
0.01	instantaneous	1	20 ntu over 0.1 hour
0.01	instantaneous	10	20 ntu over 0.1 hour
0.01	instantaneous	100	0.2 ntu over 0.1 hour
0.01	1 hour	0.01	200 ntu over hour
0.01	1 hour	0.1	20 ntu over hour
0.01	1 hour	1	2 ntu over hour
0.01	1 hour	10	0.2 ntu over hour
0.01	1 hour	100	0.02 over hour
0.01	1 day	0.01	10 ntu over day
0.01	1 day	0.1	1 ntu over day
0.01	1 day	1	0.1 ntu over day
0.01	1 day	10	0.01 ntu over day
0.01	1 day	100	Not measurable
0.01	10 days	0.01	1 ntu over 10 days
0.01	10 days	0.1	0.1 ntu over 10 days
0.01	10 days	1	0.01 over 10 days
0.01	10 days	10-100	Not measurable
0.01	10 days	0.01	1 ntu over 10 days
0.01	10 days	0.1	0.1 ntu over 10 days
0.01	10 days	1	0.01 over 10 days
0.01	10 days	10-100	Not measurable
0.1	instantaneous	0.01	20000 ntu over 0.1 hr
0.1	instantaneous	0.1	2000 ntu over 0.1 hr
0.1	instantaneous	1	200 ntu over 0.1 hour
0.1	instantaneous	10	20 ntu over 0.1 hour
0.1	instantaneous	100	2 ntu over 0.1 hour
0.1	1 hour	0.01	2000 ntu over hour
0.1	1 hour	0.1	200 ntu over hour
0.1	1 hour	1	20 ntu over hour
0.1	1 hour	10	2 ntu over hour
0.1	1 hour	100	0.2 ntu over hour
0.1	1 day	0.01	100 ntu over day
0.1	1 day	0.1	10 ntu over day
0.1	1 day	1	10 ntu over day
0.1	1 day	10	1 ntu over day
0.1	10 days	0.01	10 ntu over 10 days
0.1	10 days	0.1	1 ntu over 10 days
0.1	10 days	1	0.1 ntu over 10 days
0.1	10 days	10	0.01 ntu over 10 days
0.1	10 days	100	Not measurable

Continued

Volume of Fine Textured Sediment Delivered to Stream (m ³)	Estimated Duration of Total Erosion Sedimentation Event	Estimated Flow Rate of Receiving Stream or River (m ³ /s)	Calculated Increase in Turbidity over Background Levels of Receiving Stream Over Time Period Suggested (changing time period changes concentration)
1	instantaneous	0.01	mudflow over .1 hr
1	instantaneous	0.1	20,000 ntu over .1 hr
1	instantaneous	1	200 ntu over .1 hour
1	instantaneous	10	20 ntu over .1 hour
1	instantaneous	100	2 ntu over .1 hour
1	1 hour	0.01	20,000 ntu over 1 hour
1	1 hour	0.1	2000 ntu over 1 hour
1	1 hour	1	200 ntu over 1 hour
1	1 hour	10	20 ntu over 1 hour
1	1 hour	100	2 ntu over 1 hour
1	1 day	0.01	1000 ntu over day
1	1 day	0.1	100 ntu over day
1	1 day	1	10 ntu over day
1	1 day	10	1 ntu over day
1	1 day	100	0.1 ntu over day
1	10 days	0.01	100 ntu over 10 days
1	10 days	0.1	10 ntu over 10 days
1	10 days	1	1 ntu over 10 days
1	10 days	10	0.1 net over 10 days
1	10 days	100	0.01 ntu over 10 days
10	instantaneous	0.01	Mudflow
10	instantaneous	0.1	Mudflow
10	instantaneous	1	20,000 over 0.1 hour
10	instantaneous	10	2,000 ntu over 0.1 hour
10	instantaneous	100	200 ntu over 0.1 hour
10	1 hour	0.01	20,000 ntu over 1 hour
10	1 hour	0.1	2000 ntu over 1 hour
10	1 hour	1	200 ntu over 1 hour
10	1 hour	10	20 ntu over 1 hour
10	1 hour	100	2 ntu over 1 hour
10	1 day	0.01	10,000 ntu over day
10	1 day	0.1	1000 ntu over day
10	1 day	1	100 ntu over day
10	1 day	10	10 ntu over day
10	1 day	100	1 ntu over day
10	10 days	0.01	1000 ntu over 10 days
10	10 days	0.1	100 ntu over 10 days
10	10 days	1	10 ntu over 10 days
10	10 days	10	1 ntu over 10 days
10	10 days	100	0.1 ntu over 10 days
10	100 days	0.01	100 ntu over 100 days
10	100 days	0.1	10 ntu over 100 days
10	100 days	1	1 ntu over 100 days
10	100 days	10	0.1 ntu over 100 days
10	100 days	100	0.01 ntu over 100 days
100	1 day	0.01	mudflow
100	1 day	0.1	10,000 ntu over day
100	1 day	1	1000 ntu over day
100	1 day	10	100 ntu over day
100	1 day	100	10 ntu over day
100	10 days	0.01	10,000 ntu
100	10 days	0.1	1,000 ntu
100	10 days	1	100 ntu
100	10 days	10	10 ntu
100	10 days	100	1 ntu

Table 14. (Optional) Summary Table Estimating Effect of Sediment Loading on Water Quality

Cutblock Identification _____ **Date** _____
Evaluator _____

Task V (Optional)				
Total Volume of Sediment Delivered from Cutblock	C12 Estimated Duration of Sediment Delivery <i>(see Table 10)</i>	C13 Estimated Bank full discharge of Receiving Water <i>(see Table 11)</i>	C14 Estimated Turbidity of Receiving Waters <i>(see Table 12) (not required for routine assessment)</i>	C15 Estimated change in receiving water turbidity generated cutblock <i>(From Table 13)</i>
<i>Sum of entries from Column 10</i>	<i>(for routine assessment assume average of 10 days)</i>			
2013.4	10 days	10 m ³	0	200 NTU increase over background for 10 day period