Forest Sciences

Prince Rupert Forest Region

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Tributary Alluvial Fans

Research Issue Groups:

- Forest Biology
- Forest Growth
- Soils
- Wildlife Habitat
- **Silviculture**
- Timber Harvesting
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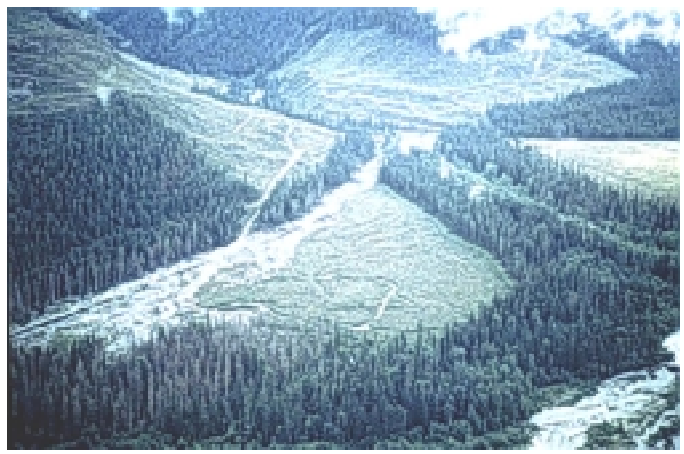

Photo 1. Hunter Creek, a tributary of the Kitimat River, moved out of its channel at the apex of the alluvial fan. The result was a riparian reserve that is high and dry and a stream running down the old road. Significant impacts have occurred to regeneration in the harvested area. The channel migration factors include the forest road and high levels of mass wasting in the watershed.

Tributary alluvial fans are the moderately low-gradient, conical-shaped landscape features formed by the deposition of sands, gravels and cobbles, when confined streams enter a larger valley. Fans are of interest for many reasons:

- usually very productive sites, and hence large trees;
- usually very high fisheries values;
- a source of gravels for road building;
- due to the shifting dynamics of the stream, they are a challenge to cross with roads, are moving targets for riparian reserves, and create havoc for silvicultural investments.

In short, fans are a challenge for forestry managers. There are numerous fans throughout the Prince Rupert Forest Region with ample evidence of washed-out roads, plantations covered in fresh sediments or dissected by new channels, and riparian reserves that are some distance from the current channel.

This Extension Note provides some insight into the basic nature of fans and offers suggestions for conducting forestry activities on them.

The nature of fans

Alluvial fans are sites of constant interplay between supply of water and sediments. The equilibrium shifts to *aggradation* if the supply of sediments increases (either naturally or due to land use). This can be rapid in the case of mass wasting or gradual in the case of fluvial action. The equilibrium shifts to *degradation* if the supply of sediments decreases (the constant removal of materials from the fan by the stream exceeds their recruitment, hence the channel becomes incised). Debris such as downed trees can play an important role by creating structure in the streams (steps) and dissipating energy on the fan. A fan can have a range of gradients from less than 1 percent to as high as 15 percent from the toe to the apex. At the higher gradients, running water has considerable power to erode the fine textured soils, and without replacement of sediments or hydraulic controls, significant stream downcutting results.

Tributary alluvial fans are similar to the fans of gully systems. They both result from the deposition of material carried through a transport zone

Photo 2. A coalescing fan formed by two tributary creeks of the Wedeene River. The creek on the right is stable and the narrow riparian reserve is intact. The creek on the left is actively moving across the fan, impacting the road system and regeneration. Natural differences in the two watersheds, primarily mass wasting, are keys to the different levels of channel activity.

(confined channel segment) from higher in a watershed. The FPC Gully Assessment Procedure (GAP) is appropriate for coastal gullies and the basic concepts are applicable to both interior gullies and tributary fans (see Extension Note 19). It is appropriate to use GAP for coastal tributaries in situations where the Forest Practices Code gully criteria are met.

A basic concept in GAP is to consider gullies as systems - not just the point where you want to build a road or to log. This is an essential concept for alluvial fans also. Fans are the product of a tributary system - the watershed and transport zone.

The watershed of a tributary is responsible for the collection and delivery of water and sediments to a fan. Key factors that influence the delivery of water are presented in Table 1. In essence, the greater the power and volume of water, the greater the watershed's ability to build or erode a fan. Key factors that influence the supply and delivery of sediments are presented in Table 2. In essence, the greater the supply and delivery of sediments, the larger and potentially more active the fan. Sediments are delivered both by water transport (ranging from suspended sediments to bedload) or by mass wasting events (debris flows and debris floods, defined in the GAP Guidebook).

Tables 1 and 2 provide indications as to the potential for fan instability. Features on the fan itself are also helpful when developing forestry prescriptions (Table 3.).

TABLE 1. Key factors that influence the delivery of water to an alluvial fan.

Natural Factors	
Aspect	Influences snowmelt and exposure to storm systems
Size of watershed	Directly relates to potential maximum stream volumes
Gradient/elevational range	Stream power
Hydrologic properties of the soil and bedrock	Speed of soil water movement
Presence of lakes and wetlands	Can retard speed and power of the water
Watershed shape and architecture of the stream channel network	Influences nature of peakflows (long and narrow vs. wide)
Weather	Unusually large precipitation or snowmelt events
Forestry Factors	
Past forest harvesting	Influences snow accumulation and melt
Road networks	Influences water movement

TABLE 2. Key factors that influence the supply and delivery of sediments to an alluvial fan.

Natural Factors	
Nature of the channel network	Confined vs. unconfined channels; influence stream carrying capacity and probability of debris flows
Sediments stored in "wedges" in the channel	Behind debris jams or as mobile features in the channel. Sediment wedges that move onto the fan can result in significant channel changes.
Streambank materials	Bedrock vs. fine textured soil
Connectivity of eroding terrain	Class V terrain (connectivity on the Terrain Map polygons may refer to connectivity to the main valley stream, not the fan - unstable terrain in a tributary stream that is disconnected to the main valley stream by a wetland would not be "connected" even though it is directly connected to its own fan)
Lakes and wetlands	Can act as permanent or temporary sediment traps, effectively disconnecting upstream sediment sources from the fan
Bedrock geology	Influences the amount of material available in the channel (granite vs. sedimentary rock)
Weather	Unusually large precipitation or snowmelt events
Forestry Factors	
Past forest harvesting	Influences erosion potential
Road networks	Influences sediment movement

TABLE 3. Important features on fans.

Stream Channel	
Multiple vs. single channels	Multiple channels represent a higher hazard for channel migration
Location of channel	Relative to the highest lateral cross-sectional locations on the fan (e.g., is the channel in a lower position (moderately stable channel) or a higher position (moderately high risk of channel movement)
Depth of channel	Incised channels indicate a limited supply of sediment, which can be a more stable situation than shallow channels.
Natural levees (elevated ridges next to the channel)	Indicate overbank deposition during debris flows or high streamflows. Can indicate a moderately stable channel situation (but this should be corroborated by other fan features).
Debris in channels	Scattered debris are important as hydraulic structures, but debris jams pose a hazard for channel movement
Abrupt angles in the stream channel (usually from debris jams)	The potential for the debris to move or be bypassed can be high. Usually indicates a high potential for channel movement.
Old channels	Degree of revegetation - bare sediments indicate recent water movement.
Fan Surface	
Old channels	Note depth relative to the current channel. Frequency of channels are important to note for later forestry interpretations (e.g., roads).
Fresh sediments	Either broadcast or in recent channels; indicate active sediment movement - high hazard.
Debris	Piles of tree stems (indicate debris flows) vs. scattered individual trees (blowdown)
Terracettes (small terraces)	A buildup of sediments on the upslope side of stumps and downed trees - indicates broadcast sediment movement
Vegetation	
Deciduous trees	In strips or scattered throughout the fan; indicate localized vs. broadcast disturbance
Strips of conifers	Indicate long-term channel movement
Soils (requires a soil pit at least 1 meter deep)	
Degree of soil profile development	Very little vs. well developed - indicate a general level of activity
Textural profile	Interbedded sands, silts and gravels - rounded rocks - indicates fluvial transport (gradual aggradation on the fan) - undifferentiated textural profile with angular coarse fragments indicates debris flows (rapid major aggradation on the fan; this should tie back to evidence of mass wasting in the watershed).
Soil water	Seepage can be seasonally variable, but indicates hazards for road construction and inferences on site productivity (hydroponics). Note mottles if no seepage is present

Suggestions for forestry activities on fans

Consider three aspects of forestry: planning, roads and harvesting options and issues.

1. Planning - Assessing the hazards

Consider the factors noted above regarding the nature of fans.
Key questions to ask:

- Are sediments being delivered to the stream system?
- Are there indicators of instability on the fan?
- Are there existing roads or harvested areas that now or have the potential to impact the fan?
- Is future harvesting or road construction planned in the watershed above the fan? How could these activities change water and sediment delivery to the fan?

2. Roads

Location

In a perfect world, a road should traverse the lower slope of the hillside, avoiding the fan, and crossing the channel directly above the fan (preferably bedrock to bedrock with a clear span).
If a road must cross a fan, do so as high as possible (i.e., as close to the apex as possible). This is important even on stable fans due to the influence roads have on subsurface flows and the implications for both accelerated channel movement and impacts to downslope site productivity.

Profile

Roads on fans should have rolling grades, tied in with old channels, to ensure that if the channel does change, water will not be diverted to any great extent down the road (this also reduces deactivation costs).

Drainage structures

Drainage structures must accommodate debris and bedload that are transported during high flows. This includes both active channels and old channels where hazards exist.

- Structures should maintain the stream bottom and never increase or decrease velocity through the structure. Bedload constantly moves down channels on alluvial fans, and structures that either constrict flow or act as a dam to the bedload lead to both maintenance challenges and alterations to the stream channel. Open-bottomed structures best meet the need to maintain channel hydraulics.
- Depending on the hazards of channel migration, drainage structures should be removable (e.g., railway car decks), particularly in lower fan locations, and fords (squamish culverts) should be designed into the road.
- "Training" stream channels to stay in place for any distance above a drainage structure is usually too costly to be done effectively. Armouring disturbed stream banks within the cleared area is however an effective practice to help minimize erosion, especially immediately adjacent to the structure.
- Drainage structure design should include capacity for debris and bedload. Debris catchers (grizzlies) require high maintenance, and usually need attention during high flows (safety hazards).

Ditches

Ditches are designed to intercept subsurface flows – something that is common on fans. Erosion can result once this water becomes surface flow. Armouring the ditch has been effective for reducing erosion and is a good precautionary practice in low portions of rolling grades.

In addition, intercepting subsurface flows can have negative implications for downslope site productivity on the fan by dropping the water table and interfering with occasional overland flow (gentle depositional events). Fords can be used to reduce both maintenance and downslope site impacts.

Ditches should be minimized (both extent and depth) and consideration should be given to overlanding roads on fans.

Deactivation

Roads on most fans should be considered as temporary and plans should be made for early deactivation. The plans should call for removing all obstructions in old and current channels and ensuring that water will not be diverted down ditchlines (re-establish the original ground profile). Rolling grades and fords at low points will reduce both maintenance and deactivation costs.

3. Harvesting options and issues
Choosing a silvicultural system requires considerable thought due to several factors:

- alluvial fans generally have rich ecosystems, which translates into vigorous vegetation competition with opening or removal of the canopy.
- given the proximity to both surface and subsurface water, herbicides and mechanical site preparation are most likely not viable options.
- free growing obligations require a specific stocking level, which may not be achievable if the channel is migrating.
- alluvial fans represent opportunities for partial cutting. The goal would be to maintain rooting, a range of tree sizes including recruitment for large woody debris, effective canopy closure to limit understory shrub species, and wind firmness. Partial cutting could focus on frequent, light entries.
- species shifts from conifers to deciduous can attract beavers, and lead to major hydrologic challenges on fans.

Ground disturbance
Ground disturbance should be absolutely minimized because routing of surface and subsurface water flows can lead to erosion on the fan, and in situations with a mobile channel, can lead to complete diversions.

Photos 3 and 4. A steep gradient tributary in the Upper Kitimat. The watershed has high levels of mass wasting, but the fan was able to transfer the materials in the stream channel effectively. However, the narrow reserve left along the channel following logging blew down, obstructing bedload movement. The result was water moving out of the channel and serious maintenance challenges on the mainline road. Note that the blowdown occurred primarily on one side of the stream (down-valley winds).

Logging debris
Logging debris can become mobile leading to debris jams and erosion on the fan. It is important to avoid leaving debris in lower landscape positions (old channels)

Riparian reserves
Two factors must be carefully assessed: windthrow and channel stability.

- Windthrow can be a challenge due to the elevated position of the site and generally shallow rooting.

Reserves that blow down can lead to major channel alterations and impacts to the whole fan. History in the area is important to consider. For example, some tributaries are topographically sheltered (e.g., Skeena West as compared to the Skeena East) and some valleys experience stronger winds in one direction than the other (e.g., down-valley winds in the upper Kitimat). In some locations, clearcutting with a riparian reserve is not an option due to windthrow (the reserve plus management zone would be in effect the whole fan).

- Channel stability hazards must be determined because a reserve along the current channel may be high and dry when the channel moves. This requires a careful consideration of the factors in Tables 1, 2, and 3.

Suggestions for restoration activities on fans

Fans are a product of their whole watershed. If restoration activities are being considered for a fan, the following are critical:

- determine the cause of fan destabilization;
- assess current and potential impacts from the whole watershed (use the FPC watershed, gully and channel assessment procedures);
- carefully consider the factors in Tables 1, 2 and 3;
- use a team approach with geoscientists, fisheries biologists, engineers and foresters; and,
- be prepared to recommend no restoration action on the fan until the watershed has stabilized.

Conclusion

Tributary alluvial fans are the product of the hydrology and geomorphology of their watershed. They can be very active and pose long term challenges for forestry activities. Given their location relative to fisheries values and mainline forest road access routes, care must be taken in developing prescriptions. A series of key factors should be considered when considering forestry activities. The extra effort in the planning phase will be time well spent.

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Suggested Reading

Anon. 1995. Gully Assessment Procedures Guidebook. Forest Practices Code. B.C. Min. For. 40p.