II. PHYSICAL DOMAIN

A. Geology

1. Characterization

The Breitenbush drainage is generally oriented east to west. It includes both High Cascades and Western Cascades physiographic provinces with a fairly distinctive transition zone in between. The area has been stratified into three relatively distinct landform blocks (Eastern, Central and Western) that have common geology and geomorphology as described below (see map).

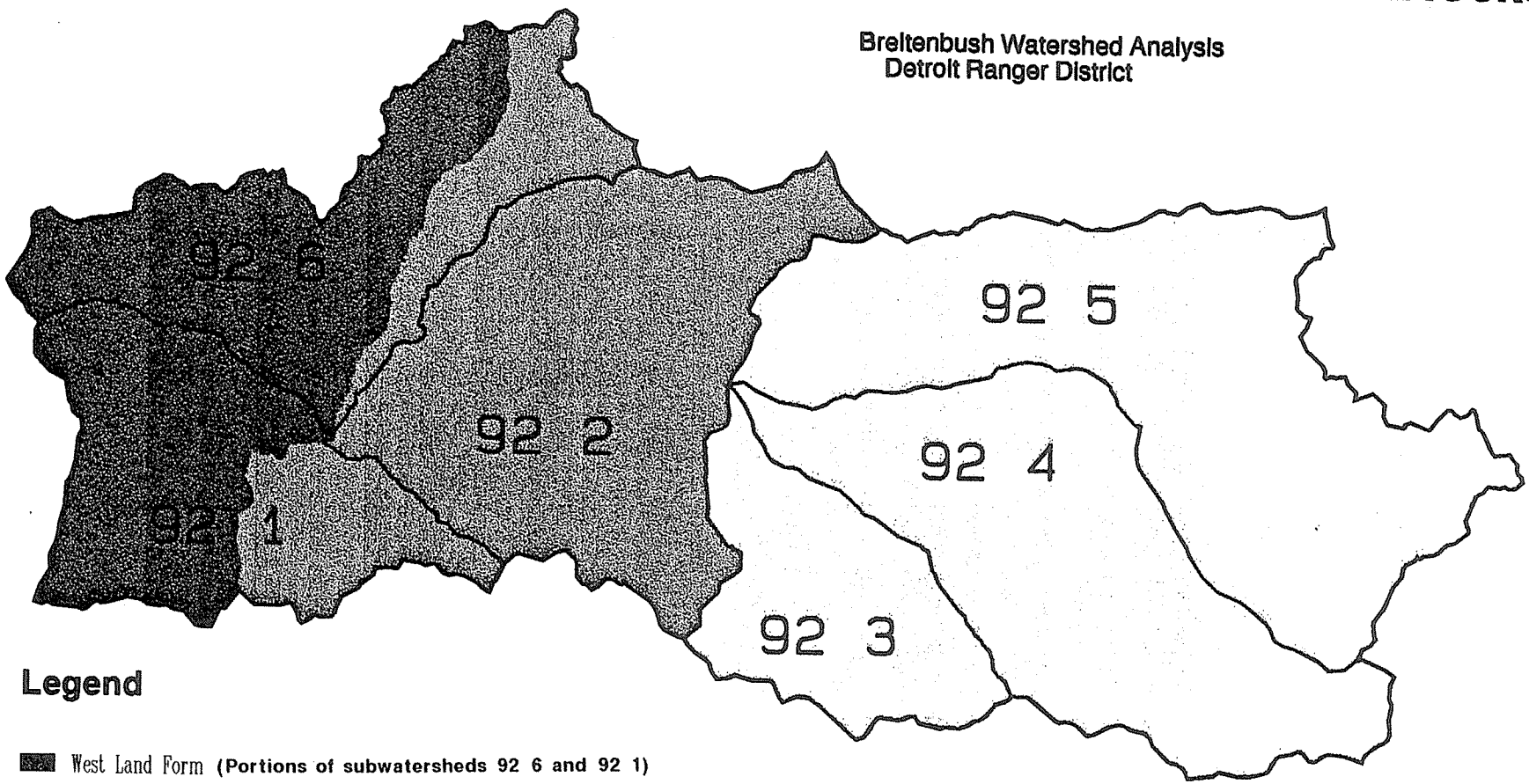
a) Landform Blocks

i) ***Eastern Landform Block - High Cascades***: The drainages of the eastern landform block are typically U-shaped, glaciated valleys with relatively flat bottoms and steep, rocky walls, that abruptly transition to rolling uplands at the higher elevations. The uplands commonly contain broad expanses of uniform, gently sloping topography with numerous lakes. The steep side walls commonly display over 2000 feet of relief, and are extensively dissected, show numerous rock outcrops and cliffs, and often maintain heavily forested side slopes. The gently sloping terrace deposits of the valley bottom are comprised almost entirely of glacial outwash materials. The upland deposits, predominately within the Wilderness, are outwash and ground moraine, with an occasional covering of recent volcanic ash deposits from volcanic venting farther to the east and south.

ii) ***Central Landform Block (transition area) - Western Cascades***: Far and away, the most impressive and imposing structure in this subwatershed is the formidable and protruding rock face at Eagle Rock. Dominating the lower Breitenbush canyon, Eagle Rock remains as an erosional remnant of some long extinct volcanic eruption and lava flow. Second in grandeur, but first in height, is the less awe inspiring form of Short, Mansfield and Collawash Mountains that form the northern skyline of this landform block. These forested peaks look down upon a geomorphically diverse and highly complex landscape that ranges from extensively glaciated upland benches and headwalls at the higher elevations, to large-scale stabilized slump/earthflow complexes, to localized areas of actively unstable landflows, to steep, shallow soiled, highly dissected headlands with rock scarps and bluffs, and finally to extensive areas of lower elevation benches, flats and terraces that formed by fluvio-glacial action. Early to mid Pleistocene glaciation probably carved a broad band of moderate to gently sloping terrain into the underlying Western Cascade volcanic stratigraphy. Subsequent large scale slump / earth flows have relocated much material downslope, and left a jumble of dislocated topography. Later Pleistocene glaciation likely reoccupied this valley at a lower level and deposited extensive moraines in the areas of Hill Creek, Cleator Bend and lower Mansfield Creek.

Subbasins and Landform Blocks

Breitenbush Watershed Analysis
Detroit Ranger District



Legend

- West Land Form **(Portions of subwatersheds 92 6 and 92 1)**
- Central Land Form **(Subwatershed 92 2 and portions of subwatersheds 92 6 and 92 1)**
- East Land Form **(Subwatersheds 92 3, 92 4, and 92 5)**

N

Scale 1:140000
05/08/96

Request R1082

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iii) *Western Landform Block - Western Cascades*: The most distinguishing features of this, the smallest of the landform blocks, are the stunning relief of over 3500 feet and the classic V-shaped, erosional valleys. In this light the rough and rocky headlands of Byars Peak plunge headlong down Byars and Canyon Creeks to ease at the terraces along the Breitenbush River. Stream downcutting of the older Western Cascade volcanic materials has been the principal active process for several million years.

b) *Geothermal*

Of some geologic interest, and certainly maintaining considerable social interest, the Breitenbush hot springs is located approximately at the boundary of the Western and High Cascades. It seems likely that geothermal activity which created the hot springs is related to the relatively recent volcanic peaks that form the spine of the Cascade Crest. The locations and characteristics of the Austin, Bagby and Breitenbush Hot Springs within the upper Clackamas and North Santiam River subbasins fall within the north-south trending hot spring zone along the western slope of the Cascade range. These springs contain chiefly sodium chloride waters or largely meteoric origin and are typically of hot-water dominated thermal systems. Structurally, they are likely related to north to northwest trending fault zones (Hammond et. al, 1980)

2. What do humans value that is associated with geology?

a) Natural geologic processes and their influences on the ecosystem are valued (i.e. the natural influence of erosion on species diversity).

b) Geologic resources have utilitarian and economic value (i.e. rocks to surface roads and decorative rocks for landscaping).

c) Landform has aesthetic, spiritual and functional value (i.e. vistas, vision quests, recreation settings, travelways for humans and animals, etc.)

d) Geologic features such as geothermal hotsprings have both economic and recreational value (i.e. bathing and geothermal power).

3. What are the highest priority issues or resource concerns associated with geology?

a) Whether current erosion processes that are dominant in the Breitenbush watershed are within the natural range of variability or whether they have been influenced to such an extent by human activities that they are now outside that range.

b) A more specific subset of the above issue is whether management activities such as timber harvest and road construction were major contributors to the landslides that occurred in

the Breitenbush watershed during the 1996 flood event and whether the number and types of landslides were outside the range of natural conditions that might be expected in such a storm event.

4. What and where are the management direction/activities, human uses, or natural processes that affect the dominant erosion processes?

a) Current Conditions

What erosion processes are dominant within the watershed? *What are the current conditions and trends of the dominant erosion processes prevalent in the watershed? *Where have they occurred or are they likely to occur?

The dominant erosion processes within the Breitenbush watershed vary by landform block as described below:

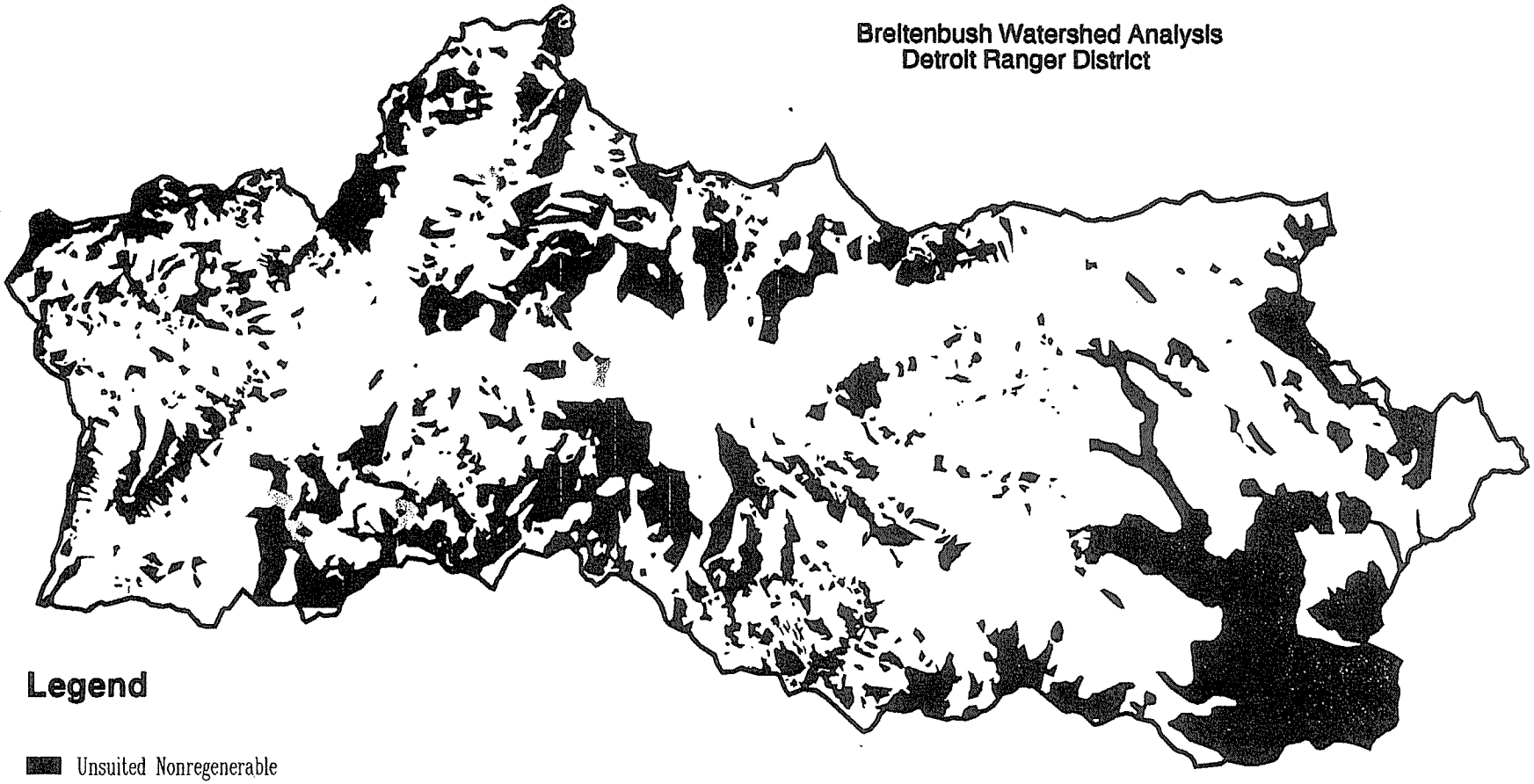
i) ***Eastern Landform Block - High Cascades***: Since deglaciation, the major forces affecting slope morphology have changed considerably. Ice is no longer the dominant player except at the highest elevations. The more traditional geologic forces of wind, rain, freeze/thaw, gravity, and erosion have come into play.

Sediment delivery systems now in operation are related to the more steady-state geologic processes. On the steep, shallow-soiled scarps, creep and slope ravel are most dominant. While on the relatively gently sloping and deep soils of the valley bottoms or the uplands, wind and stream erosion predominate, primarily during those brief periods after catastrophic fires when all vegetation and duff has been stripped away. This landform block has a complex and active fire history dating back several hundred years.

Instablility: Very few actively unstable areas are located in this landform block. However, there are several areas of critical, highly dissected sideslopes with shallow soils and steep-sided draws, which probably support considerable natural, debris-chute-type slope instability, especially after episodic events such as intense stand replacement fires and/or catastrophic floods. It seems likely that the fire/flood events of the last century precipitated a flurry of slope failures; however, little evidence remains to substantiate this. The significance of slope failures to sediment budgets in this landform block is difficult to define because of the time frames involved. For the most part, harvest units have been well located to avoid sensitive areas, and roads have generally been confined to the stable benches or ridges. Except for the abandoned road bed in Skunk Creek, road construction and unit harvest have not resulted in a significant number of additional failures to this point. The recent February 1996 storm appears to have resulted in only one road-related failure in upper Devil's Creek. Consequently, it appears that natural rates of slope instability are currently maintained.

Soils

Breitenbush Watershed Analysis
Detroit Ranger District



Legend

- Unsuited Nonregenerable
- Unsuited Unstable
- Potentially Highly Unstable
- Stable Land Flows

N

Scale 1:140000
05/15/96

Request R1

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Displacement: Little or no evidence can be found to indicate that timber management and slash treatment activities have resulted in detrimental soil displacement or off site soil movement in the uplands. Roads have generally been constructed on stable benches and flats and few sidecast roads were noted. However, there is one example of extensive sidecast on Skunk Creek road (Forest Service road 2231 854). Taking that into account, displacement of soil from timber management and downslope creep from colluvial processes probably are of the same order of magnitude when considered in approximately the same time frames and viewed over the entire study area.

Extensive salvage and cleanout of instream and riparian timber occurred in the North Breitenbush during the 1970's. Millions of board feet of large logs were removed during that period. This large woody material functioned to reduce stream energy and maintain an intact riparian zone in these relatively unconsolidated outwash sediments. With the salvage and subsequent high stream flows, the Breitenbush began to downcut and widen its channel. In the last quarter century, it is estimated that over two million cubic yards of sediment has been eroded away and washed down the Breitenbush River into Detroit Reservoir (modeled by a rectangle that is four miles long, one hundred yards wide and three yards deep). To put this in perspective, this amounts to all the excavated material for almost 200 miles of average road construction or about 80% of the total road mileage in this watershed.

Nutrient loss: Most of these areas were burned, reburned or underburned in stand replacement intensity fires that started approximately two hundred years ago and created a mosaic of stand ages. At some point, these fires consumed much of the existing above ground organic matter, especially on the south aspects. On the other hand, some north aspects had less frequent and lower intensity fire regimes. Consequently a wide range exists in the amount of above ground decomposing organic matter. The older timber harvest plantations display a commensurate removal of above ground nutrient matter similar to intense natural fires. More recent timber harvest has generally been more benign and retained considerably more organic matter than was left by the stand replacement fires and/or underburns.

ii) ***Central Landform Block***: Slope instability by both translational and rotational failures is the dominate *sediment delivery* method in this basin in the near term time frame. Most of the major tributaries of this landform block - Short Creek, Scorpion Creek, Slide Creek, and the eastern face of Humbug Creek - contain potentially highly unstable or actively unstable terrain. All these areas currently display features which indicate that considerable instability has occurred in the last 300 years or so, and more is to follow. These slide zones will continue to supply these tributaries with sediment for decades, and possibly centuries, to come. The Breitenbush was at one time the toe area and collector for the massive amounts of sediment generated by the large, landflows that once occurred around Hill and Leone Creeks as well as Short Lake. It is likely that much of the terrace deposits that surround Detroit Reservoir, found their origins in these landflows. Now, as the landflow activity has

abated, little direct sediment input from slope instability occurs directly into the Breitenbush River. To be sure, as the landslide sediment supplied to the tributaries works its way through the system, this subwatershed becomes one of the principal sediment sources for the Breitenbush River, below this point.

Finally, creep and colluvial deposition from slope ravel and slough certainly play a considerable role in the more steady state, sediment delivery at least on the steep sideslopes. Intensive, often large scale, fire activity and the resulting vegetation removal undoubtedly accelerates these rates. At a much slower rate, stream erosion and deposition have shaped the lower portions of these drainages as major stream terraces have developed at various gradient control points along the main channel of the Breitenbush river.

Instability: Numerous areas of large scale, actively unstable or potentially highly unstable slump/earth flows exist in this landform block. This condition has persisted for at least 300 years or more, and may have been the product of regional tectonic activity. In addition, several zones of critical highly dissected sideslopes with shallow, often debris chute prone soils can also be recorded. These slide zones display considerable natural, translational, slope instability that appears to be related to the stand replacement fire and/ or flood events. High rates of sediment input to some streams are a very natural part of the system. "Natural failures," road sidecast failures and in-unit slope failures all supply necessary sediment and structure to stream channels. Of some importance is the observation that most failures provide streams with necessary structure, either in the form of large woody debris and/or boulders, and sediment for flood plain and terrace development. Stream morphology and function have adjusted to the high rates of sediment input because of the stabilizing influence of adequate structure, primarily large woody debris. It is the removal of this large woody material that may have more adverse effects to stream function than the inputs of sediment.

In conclusion, this section of the Breitenbush is currently a relatively sediment rich system with extensive, nearly continuous input from the numerous tributaries. The failure regimes would indicate that this sediment-rich condition is not likely to change for perhaps many decades or even centuries into the future. From a sediment budget standpoint, the numerous areas of active (or potentially highly active) slope instability are the principal agents affecting change in the channels. The affects from fires on ravel and slough, though extensive, are not as important in the sediment generation race. It is likely that the fires played a greater role in relatively recent stream morphology by creating or consuming considerable woody debris or by changing evapotranspiration rates, than by any direct affects to soil fertility or creep. Finally, in this landform block, human caused sediment to this date are approximately subequal with the colluvial processes. Certainly some roads have been sidecast into streams, and some road sidecast has failed, and some in unit failures may have resulted from timber harvest. However, these events are commensurate with natural sediment input from land flows, fires and floods. A more

likely effect of timber management has been the removal of large woody debris from timber harvest and salvage in riparian areas. In future, harvest activities should be located and scheduled so as to provide a continuous high level of large woody debris to the deficient stream channels.

*Displacement:*The lower elevation, valley bottom zones along the main stem Breitenbush and Humbug Creek were railroad logged in the 1930's. It would seem likely these early entries when few if any standards were in place, produced considerable displacement and erosion of the soil resource. Evidence of this is scant as this area is now heavily covered with advanced regeneration. Timber management activities in the second half of the Twentieth Century have for the most part occurred with the appropriate suspension requirements. Slash treatments have usually maintained some duff retention. Uncontrolled tractor logging and tractor piling occurred on only a few sites, and this practice ceased over a decade ago. Little or no evidence can now be found to indicate that this second generation of timber management activities has resulted in significant detrimental soil displacement or off site soil movement. Finally, most roads have generally been constructed to access stable benches and flats. Some road locations are on steep sideslopes, and some sidecast roads were observed primarily in the area between Hoover Ridge and Eagle Rock. Fortunately, most seriously steep sideslopes have been avoided. Some of the old roads to access parts of the Eagle Rock fire (1967) are a notable exception. Although difficult to equate, displacement of soil from timber management and downslope creep and colluvial processes and slope instability probably are of the same order of magnitude when considered in approximately the same time frames and viewed over the entire study area.

iii) ***Western Landform Block:*** The principal *sediment delivery* systems in operation depend entirely on the slope position that is occupied. On the steep shallow - soiled scarps, slope ravel and slough predominate when vegetation cover has been reduced. The more mundane creep commands the day to day reign in the forested environment. Few areas of active slope instability are present. It seems likely that, given the steep dissected nature of the valley walls, debris chutes would occupy a prominent role in the down slope movement of soil and debris. Since little evidence was found to indicate that this is major source of sediment generation in this century, it would seem that this mechanism is highly episodic in nature. This landform block was likely extensively underburned about one hundred to two hundred years ago. These fires were followed by 100 year storm events in 1861 and 1964. The high number of steep bed rock draws would seem to indicate that debris chutes are a likely failure mechanism although few failures were noted in the recent 1996 flood event.

In*stability:* In stark contrast to the Central landform block, this section, although much steeper and more dissected, is also inherently much more stable. Several areas appear to have the potential for considerable natural debris chute type, slope instability, especially in the high elevation upland meadows and rock cliffs. And, it

seems likely that sustained stretches of substantial slope stability were punctuated by relatively brief periods of intense debris chute activity, usually related to contemporaneous large scale stand replacement conflagrations and/or intensive storm events. Probably the numerous cycles of fires and storms over the millennia have left little material to fail. Harvest units have generally avoided the most sensitive areas, and few in unit slope failures were noted (even in this most recent storm event). However, as was discussed previously, road sidecast failures are likely a principal sediment producer along some stream segments. It is difficult to determine if natural rates of slope instability currently apply, but over the long term it would seem that have been maintained. Certainly, the amount of large woody debris naturally associated with them has not been.

Displacement: Yarding activities in this area have for the most part occurred with the appropriate suspension requirements. Slash treatments have usually maintained adequate duff retention standards. Little or no evidence can be found to indicate that these two timber management activities have resulted in detrimental soil displacement or off site soil movement. Finally, road development is relatively limited and most roads have generally been constructed on stable benches and ridges. For the most part, little sidecast construction was noted, with some roads in Byars and Deadhorse Creeks the notable exceptions. Fortunately, most seriously steep sideslopes have been avoided. Although difficult to equate, displacement of soil from timber management and downslope creep from colluvial processes probably are of the same order of magnitude when considered in approximately the same time frames and viewed over the entire study area.

b) Reference Conditions

What are the historical erosion processes within the watershed (e.g. surface erosion processes, mass wasting)? Where have they occurred?

i) ***Eastern Landform Block:*** Glacial downcutting and scour of the volcanic formations that comprise the High Cascade parent materials has been the principal active process in this area for at least a million years or so. This process was accelerated with the various Pleistocene glaciations, but that record is obscured by the more recent upland ground moraine and lowland terrace deposits. It is likely that glacial ice occupied at least the upper valley segments of much of these drainages in the more recent late Pleistocene glaciation. It seems equally likely that the some of the U-shaped valley construction occurred at some point prior to the last glaciation in this area.

ii) ***Central Landform Block***: Taking a long view of several millions of years, stream downcutting and erosion have been the principal actors to shape the steep sideslopes in earth's evolutionary drama. In the nearer term of several hundreds of thousands of years, Pleistocene glaciation took the main stage as the headline erosion protagonist. As primary evidence, the similar glacial deposits that occur both on the north and south sides of the main stem Breitenbush. Once these surfaces were joined to form the broad base for an extensive valley glacier. This glacier, in its heyday, probably extended well to the west of this particular analysis area, and may have completed its journey near Detroit Dam, much farther down valley. It also seems likely that in the nearer term, late Pleistocene glacial ice actually extended out into this landform block from the valleys of the Eastern Block during the last and most recent Ice Age. Late Pleistocene glaciation may have also developed localized ice fields on the northern aspects of the tallest peaks and ridges, such as at Gale Hill. Finally, in the near term of centuries to millennia, slope instability from landslides, landflows and debris chutes has most acted upon the sideslopes and streams of this subwatershed to create the landscape we now see. Most of this massive slope instability, which resulted in part from the glaciation and part from the downcutting of the Breitenbush River into the weaker Western Cascades volcanic material, has now stabilized (over 25% of the area). However, some localized movement still remains, and active slope instability can be found in Slide Creek (aptly named), Cliffs Creek, and Scorpion Creek as well as others. In fact, the most potentially highly unstable and/or actively unstable terrain in the entire watershed exists within this landform block.

iii) ***Western Landform Block***: Stream downcutting of the volcanic formations that comprise the older Western Cascade parent materials has been the principal active process in this area for several million years. This alluvial erosion process was extensively accelerated with the various Pleistocene glaciations. Ice movement scoured out large quantities of sand and gravel. This sediment, when transported downstream by glacial meltwater, acted like a rasp, to wear down and grind away the underlying volcanic stata. Also, early Pleistocene glaciers likely moved down valley through this landform block. Consequently, glacial ice played a major role in carving and creating the current valley topography. In the most recent Pleistocene glaciations, smaller ice fields occupied only the higher elevation valleys and north aspects, such as in the headwaters of Byars and Humbug Creeks.

c) ***Comparison of Current and Reference Conditions***

i) ***What are the natural and human causes of changes between historical and current erosion processes in the watershed?***

Displacement: Little or no evidence can be found to indicate that timber harvest and slash treatment activities have resulted in detrimental soil displacement or off site soil movement of any significant degree for most harvested units in the analysis area. Forest monitoring concluded, and this analysis has reinforced, that off-site sediment

movement from harvest units where appropriate suspension and duff retention standards have been implemented, has been very low, especially in relation to natural disturbance events such as wildfire.

Of approximately 240 miles of road in the watershed, many miles have been constructed on stable benches and flats, but sidecast road segments are also present. Road construction standards have varied over time as well. With that to consider, within the Central Landform Block, displacement of soil and rock from road construction is not significant when compared to the mass of material displaced by active and semiactive slope instability (landflows and debris chutes) when considered in approximately the same time frames and viewed over the entire study area. When looking at the Western Landform Block, because natural slope instability has been relatively minor, road construction and road sidecast failures appear to be the dominant sediment relocation process for the decades from the late 1950's to the 1980's. This level of industriousness has slowed considerably as this century comes to a close, but many sites still continue to provide sediment to individual stream reaches at rates considerably above more natural mechanisms. In the Eastern Landform Block, roads have generally been well located to avoid most steep sideslopes. With the notable exception of the upper Skunk Creek system, roads in this landform block have not contributed significantly to sediment budgets. This is especially true when one considers the amount of erosion that has occurred along the flood plain of the North Breitenbush in the last two decades.

One conclusion that can be drawn for this watershed, is that sediment from timber management activity is not a significant issue in this basin, with a few notable exceptions, generally associated with sidecast road construction. Some problem sites are present, and require restoration. However, stream channels and riparian areas do not display those features which might indicate problems with excessive off site sediment generation.

The critical factors in this basin are the presence or absence of large structure and the timing of sediment input (see hydrology section), not the amount. The removal of large woody debris and essential stream structure through harvest and stream cleanout appears to have more affected stream channel morphology than sediment inputs from other management activities.

Compaction: Existing compaction, which resulted from unrestricted tractor yarding and tractor piling, is not considered cumulatively significant within the basin, partially because much of the basin is too steep for tractor usage. Some of the flatter areas were likely tractor yarded and piled with minimal control on skid road density. Detrimental compaction, exceeding the 20% Regional Standard level, is probable in some of these units. It is likely that this compaction is starting to ameliorate as root growth and frost action begin to operate to reduce soil density.

Nutrient Loss: Nutrient loss from harvest and slash treatment is not considered

significant in this watershed when compared to historic conditions. Parts of the Breitenbush were burned, reburned, or underburned in large scale, stand replacement type fires than began approximately five hundred years ago. In many areas, these fires consumed most of the above ground organic matter, and extensive acreage now exists that displays very little down woody debris after almost one to two centuries of time. On the other hand, numerous sites, especially on the north aspects and in the deeper draws and sheltered benches avoided the conflagrations, and show little if any effects from the fires that raged around them. Snags and extensive down woody debris can commonly be observed. Consequently, a wide range in the above ground tonnage of decomposing organic matter exists across the subwatersheds. Timber harvest over time has tended to mimic this wide diversity of tonnages. The oldest timber harvest plantations with low utilization standards, resulted in extensive amount of large woody debris and slash retained on the ground. The harvest units of the 1970's and early 1980's, with high utilization standards and fall slash burns, display a commensurate removal of above ground nutrient matter similar to that of severe natural fires. The most recent timber harvest with down woody debris and duff retention standards has generally been more benign and retained about as much organic matter as is displayed in the less intensive fire regimes.

Instability: When the entire basin is taken into account, it appears that natural rates of slope instability are currently maintained. The slope failure record for the Breitenbush is a complex one, and the previous conclusion does require clarification. The Central Landform Block displays features that indicate considerable instability has occurred there in the last 300 years or so to present, and more is to follow (in most areas). Several areas of actively unstable slump/earthflows, massive landslides, and debris chute prone soils can be found in this landform block. Many events are related to the stand replacement fires and/or extensive flooding. Some slope movement may be correlated to regional tectonic activity. Whatever the cause, the cumulative effect of this slope instability is to produce a naturally sediment rich system for the hydrologic regime. Field inventories indicate that road sidecast failures are not significant when compared to the rates of sediment input to streams from the natural system. In unit slope failures replicate conditions similar to natural fire related instability. Consequently, harvest activities are but a distant second in this sediment generation race. It is worth repeating that the removal of large woody debris and essential stream structure through harvest and stream cleanout appears to have more affected stream channel morphology than sediment inputs from management activities.

It would be nice if this was the complete story, but it is not. For the Western and Eastern landform blocks, numerous localized areas of steep dissected sideslopes with potentially unstable draws can be found. Slope instability in these areas may be related to the stand replacement fire and/or flood (or other catastrophic) events over the last 300 to 600 years. Slope instability that is closely linked with longer term episodic catastrophic events will eventually develop somewhat predictable failure rates that are related by frequency, intensity and magnitude of the disturbance.

Unfortunately in the short term, road sidecast, road related drainage, and washout failures have been principal mechanisms for the downslope movement of soil in the last several decades, especially within specific subdrainages in the Eastern and Western landform blocks, as previously discussed. In the near term, forest management related events have outpaced their natural counterparts by a considerable degree, at least in Skunk Creek and Byars Creek (respectively). Consequently, it is difficult to determine if "natural rates" of instability are currently maintained on the landform blocks as a whole, as one has to defind the yardstick for measurement. Whatever the case, increase sediment from these failures is not the principal factor affecting stream integrity at this time. Many affected reaches show limited sediment storage, and appear "sediment deficient." What has changed is the stream's sediment storage capability, often provided by the stabilizing influence of large woody debris.

In conclusion, there seems little doubt that sidecast road construction, poor road maintenance practices, and harvest of highly failure prone soils can increase the incidence of slope failures. On the other hand, natural failures provide sediment to streams, often far in excess of human caused events, and maintain relatively high population levels of aquatic organisms. The concern then is not so much with the amount of sediment as with when and how it reacts in the system. Perhaps the major controlling factor is available stream structure, primarily in the form of large woody debris and boulders. The removal of large organic material in critical locations through harvest, road construction, or stream cleanout can increase the severity of failure impacts by: (1) overloading natural systems with sediment to the point existing features fail, or (2) allowing sediment to be rapidly flushed through the system and thereby robbing the stream of necessary bank building material. The major difference between apparent "natural failures" and road and unit related events is not their point of origin. Either can be detrimental or beneficial. The key factor in evaluating the effects is the amount of large woody debris present down slope of an active failure. Remember, for many subwatersheds in this analysis area, failures provide the stream systems with almost all of the components necessary for proper funtion. However, just because slides can be beneficial to streams, does not mean that we should just let them slip slide away.