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Curry Report

Redwood National Park

Resource Management Actions Affecting Redwood Creek Corridor--Options Paper

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Redwood Creek WATERSHED

I. Introduction

In 1968, the Congress of the United States, in order "to preserve significant examples of the primeval coastal redwood (Sequoia sempervirens) forests and the streams and seashores with which they are associated for the purpose of public inspiration, enjoyment, and scientific study," enacted Public Law 90-454 establishing Redwood National Park.

The legislative history, the legislation itself, and the subsequent boundaries of the Park reflect the struggle that occurred between conservation-oriented objectives and economic considerations. In an attempt to strike a balance between these competing interests, the Congress not only drew boundaries incorporating magnificent trees of majestic height but also inadvertently produced a resource management problem of monumental proportions. Simply stated, that management problem is protecting the Park resources from natural erosional processes and man-induced acceleration of those processes.

Similarly, the record and the legislation indicate a strong concern for the protection of this "unique vegetation complex" but the ultimate configuration of the Park bears no relationship to this objective. Past experience, such as the lessons we learned too late in the Florida Everglades and the Bull Creek Basin in northern California, indicates that a vital element of resource protection is wise management of entire watersheds. In the absence of strong enforceable local regulations governing land use practices and water quality, some means of Federal control of the watershed is essential for resource protection. However, in the case of Redwood National Park, control by either method is difficult because no meaningful local controls exist or are expected in the foreseeable future and only portions of several critical watersheds are included in the Park and other Federal land under Federal control. Thus, the effectiveness of resource protection is dependent primarily upon the practices of landowners adjacent to the Park.

This management problem is most clearly defined along the worm-like appendage of the Redwood Creek Unit. This segment runs for approximately seven miles along Redwood Creek and extends from the center of the streambed one quarter of a mile upslope on each side. This portion was added in order to include the Emerald Mile and the Tall Trees Grove under the protective custody of the Park. Moreover, this is a valuable recreation corridor in that the presence of Redwood Creek provides unusual water-related access and compatible recreation.

Protection of this corridor is impossible, however, unless the resource manager can exercise some controls which extend beyond the present Park boundary. Some of the taller trees are located adjacent

to the main channel of Redwood Creek in the lower end of the watershed. The watershed is affected by timber harvesting methods that were practiced and are being practiced both upstream and upslope from these trees.

This paper suggests some of the ways that such protection can be attempted, recognizing both the "nature" of the problem and the existing limitations of authority.

II. The Watershed

Redwood Creek drains approximately 180,000 acres or 278 square miles as it flows northward from the Board Camp Mountain Area of Six Rivers National Forest to the Pacific Ocean near Orick, California, a distance of approximately 60 miles. Park holdings encompass less than 10% of the total drainage and over 49 miles of Redwood Creek itself lie upstream of the southern boundary of the Park.

The location of the Park makes it highly vulnerable to damage from stream-borne sediment because it is located in the downstream (receiving) end of the basin and because Redwood Creek transports an exceptionally large amount of sediment. The presence of this sediment reflects an unusual combination of rock and soil types, tectonic setting and climate.

The morphology of the land surface in the area indicates that the area has been actively eroding for thousands of years. Much of the ground surface in the immediate vicinity of the Park consists of soils such as the Atwell soil series which are particularly prone to landsliding. Large areas are also mantled with soils such as the Hugo and Orick soil series which are particularly prone to gully erosion when stripped of their protective vegetation. Land use practices during the post World War II era have clearly accelerated erosion of the Redwood Creek Basin.

Aerial photographs of Redwood Creek document the relentless increase in the number of actively eroding areas and in the width and braiding of the main channel of Redwood Creek. As the channel starts to aggrade and braid it undercuts its own banks and, in many instances, reactivates the stabilized bases of earlier slides. Both bank cutting and land slippage introduce greater volumes of sediment which increase stream instability thus continuing the self-feeding cycle of resource degradation. Quantitative assessment of the role of changed land use in bringing about the observed changes in landscape morphology is difficult. During the last two decades the area has been subjected to an exceptionally large number of large, historically infrequent storms.

The Stone (et al) Report indicates in its examination of soil types along Redwood Creek from the southern boundary of the Park to its origin:

> "Thirty-four percent of the bank consists of highly erosive soils which are /the/ a major source of the sediment load carried by the Creek today. Fifty-two percent of the bank distance consists of moderately stable soils under natural conditions but which could become areas of accelerated erosion if the land surface is disturbed. Poor road location and faulty diversion of surface runoff waters could supply this disturbance. Fourteen percent of the bank distance consists of moderately stable soils provided the grade of the Creek is not drastically altered and bank cutting is held to a minimum. Only two percent of the bank distance can be considered stable but even there bank cutting is a potential source of sediment input." 1/

On-going studies by Dr. Richard Janda and other members of the United States Geological Survey, Menlo Park, California, support the thesis that most of the sediment load of Redwood Creek is eroded from the portion of the drainage basin that is upstream from the southern boundary of the Park.

Field observations and interpretations of aerial photographs allow the entire Redwood Creek drainage basin to be divided into four segments characterized by different types and intensities of erosion. The portion between Bridge Creek and Lacks Creek is a prime source of debris logs, displays the greatest diversity of erosional processes and appears to be the most rapidly eroding portion of the entire basin. It is, therefore, reasonable to assume that this portion also has the highest sediment yield in the entire basin. However, quantitative assessment of the sediment yield, in terms of weight or volume per square mile, for these different portions of the watershed will require the collection of additional stream discharge and sediment concentration data.

That portion of Redwood Creek basin between Highway 299 and the head of the basin is the second most active eroding area and another leading source of stream-borne sediment. In this area actively eroding material is temporarily stored in the stream channels and is subsequently reworked and borne downstream during periods of high water discharge.

The third most active eroding area lies between Bridge Creek and Prairie Creek. The principal sources of sediment are logging-induced erosion and an active landslide area along Bond Creek.

1/ Page 40, Stone and Associates Report, Redwood National Park, 1969.

That portion that includes lower Redwood Creek and Prairie Creek appears to be eroding relatively slowly and to be supplying relatively little sediment to the Redwood Creek System. Exceptions are provided by highly eroded Arcata harvested land in Lost Man and May Creeks.

Therefore positioned as it is with respect to the remainder of the watershed and given the active nature of the ground surface of the basin, it is not surprising that the worm-like corridor is actively being threatened by stream-borne sedimentation which enters the Park at its south boundary.

III. Timber Harvesting

Extensive logging in the Redwood Creek Basin began around 1950 utilizing selective cutting methods until 1964 when even-aged silvicultural management of clearcutting became the dominant harvesting practice. Presently, the landowners adjacent to the Park in Redwood Creek are the Arcata National Corporation, Louisiana-Pacific (formerly Georgia-Pacific) Corporation, and Simpson Timber Company. In addition to clearcutting, the companies utilize bulldozers to skid their logs downslope to yarding areas, construct haul roads, many of them mid-slope, and form lays and landings. The cumulative effect of these actions seriously disrupts the ground surface and vegetative cover of the logged-over areas making them vulnerable to accelerated erosion. The photographic study prepared by the Earth Satellite Corporation documents the effect of these harvesting techniques.

Approximately 90% of the old growth in the watershed has been logged. The largest remaining uncut sections of old growth and mature second growth stands are located on the steep east side of Redwood Creek immediately adjacent to the "worm" segment of the Park, and in the drainage basins of Bridge Creek and Devils Creek. Smaller patches of old growth Redwood forest, that could cause some resource management problems in the future, are located adjacent to the channels of Tom McDonald Creek and Bond Creek. The drainage divides and other gently sloping areas have already been cutover.

A principal source of surface deterioration resulting from logging activities is the road system utilized for removing the felled timber to mill sites. Documentation is abundant on accelerated landsliding and gullying associated with improperly designed roads. At a minimum, roads disrupt natural drainage patterns. Road construction that has an insufficient number of culvert pipes, culvert pipes too small to handle high flows of water and debris or improperly installed culvert pipes creates major disturbances of the ground surface. Road spoil sidecast directly into water courses is another

contributor to excessive sedimentation in the drainage system. In this instance, not only is the stability of the channel diminished by the change in channel configuration and the destruction of bank vegetation, but the aquatic habitat is also threatened or impaired by the added sediment.

The use of tractors for yarding is also highly disruptive of the ground surface and vegetive cover. Each step from felling to hauling contributes to the disturbance. Layouts are created by pushing brush and soil into mounds with a bulldozer to cushion the fall of the tree and reduce the chance of splintering the Redwood's brittle trunk on impact. Skid trails are made by dragging the logs downhill to a yarding area. The skid trails tend to converge at a central point and the subsequent rainwater runoff is concentrated rather than dispersed. Another significant aspect of tractor logging is that the necessity for down hill skidding requires the construction of more mid-slope roads than are required in high lead cable yarding. Mid-slope roads require more cut and fill operations. Initially, more ground surface must be disturbed for construction and perhaps more importantly the fill materials themselves often "plug" the natural drainage channels.

In gently sloping terrain these activities result in intensive local stream aggradation, but their impact may be rapidly attenuated downstream. In contrast, in steeply sloping terrain, like that adjacent to the Redwood Creek corridor, these activities set in motion a series of mechanisms that accelerate the erosion process. In brief, the eroded surface materials run off along the skid trails and/or an alternate channel which is developed around a plugged culvert. This debris charged runoff transports large amounts of coarse sediment and logging debris. When the burdened runoff reaches steep tributaries the introduced materials increase the eroding capabilities of the tributary thereby further threatening the integrity of the tributary channel and downstream areas (including Park areas).

Historic documentation citing various photographic sources, including remote sensing data as well as on-the-ground observations and measurements, indicate specific threats to Redwood National Park which are caused by the interaction of these timber harvesting practices with the geology of the area, climatic conditions, and other natural phenomena such as record rainfalls. The basic fact is that present harvesting techniques--clearcutting with tractor yarding--produce a greater amount of ground surface disturbance and destruction of vegetive cover than any other combination of practices heretofore employed or envisioned.

IV. Threats to Park Resources

Two general categories of Park resources are presently endangered--the Redwoods and associated vegetation, and the water quality and aquatic ecosystem of Park streams and particularly Redwood Creek.

Aquatic Ecosystem

Actually as early as 1966 the main channel of Redwood Creek was considered by the California Department of Fish and Game to have suffered severe damage.[2/] That is, 75-100% of the bottom of the stream is covered with silt, the stream canopy has been eliminated and no fish shelter is available. The same report characterized the damage to Bridge Creek as being light in 1966. "Light damage" was defined as having less than 50% of the bottom covered with silt, shelter and pools partly eliminated, and the presence of some debris. This contrasts with the observations of Dr. Richard Janda, one of the team members who examined Bridge Creek in 1972. He indicates that along that segment of Bridge Creek from the access road to the mouth (the only portion studied) the damage can now be classified as "severe." Photographic documentation in the Earth Satellite Corporation report graphically details the condition of Bridge Creek today which corroborates these findings. The Fish and Game report cites the floods of 1955, 1964, 1965 and the "impact of forestry" as inducers of these changes without attempting to determine the relative importance of each of these variables.

According to California Fish and Game, Redwood Creek historically supported runs of King and Silver salmon, steelhead, rainbow and coastal cutthroat trout. Resident rainbow and cutthroat were found in the upper reaches of the Creek. The King salmon spawns in the mainstream, while all the others spawn in tributaries.

Current observations by California Fish and Game and National Park Service personnel and local residents indicate that there has been a drastic decline in the fish population of the Creek.

Channel Instability

Not only does a change in stream geometry have an impact on aquatic habitat it also represents in this case the greatest threat to the "unique vegetation complex" of Redwood National Park.

2/ Fisk, Leonard, Gerstung, Erick, Hansen, Richard, Thomas, John, 1966, Stream Damage Survey: California Department Fish and Game, Mimeo. Report, 11 p.

Redwood Creek is characterized by two basic occurrences--(1) aggradation or the raising of the stream bed by deposits, and (2) deflection or redirection of the current out of its normal course. Specifically, four events are occurring as follows:

1. The deflection of the thalweg of Redwood Creek by log jams and sidestreams' alluvial fans.

2. Aggradation of Redwood Creek with attendant increased flooding and deposition of floodplain sediments.

3. Incision and/or widening of tributaries downstream from landslides and/or logging areas.

4. Aggradation of Redwood Creek with attendant avulsion of the main channel.

The deflection of the current causes undercutting of banks. This can cause streamside Redwoods to topple and erode the toes of stabilized slides thereby reactivating them and triggering feedback mechanisms that perpetuate the destruction downstream.

A basic concern of the study team is the impact of the alluvial fans of the sidestreams. These deposits appear to have been formed by sudden flushing of debris from tributaries and rapid deposition at their mouths. These deposits impact on the main channel in two ways. First, they cause deflection of the current with the possibility of undercutting the opposite bank. A specific concern is the delta formed at the mouth of Tom McDonald Creek which enters Redwood Creek directly opposite the Tall Trees Grove. The Arcata National Corporation actually dredged gravel from this delta to retard its development in an effort to protect the Tall Trees Grove. In addition, these alluvial fans retard downstream transport of sediment moving along the bed of Redwood Creek and cause accentuated local channel aggradation.

Redwoods survive floodplain deposition of silt and fine sand by sending new roots vertically upward into flood deposits and by establishing new root systems further up the trunk as the base of the tree is gradually buried. In fact, such flood deposits are an important source of essential nutrients. Dr. Stone has observed healthy trees surrounded by deposits as great as seven feet in depth. However, the nature of the deposits is critical. If the deposit is made up entirely of gravel the tree has greater difficulty surviving because the gravel dries out faster and more completely than loam or silt. More significantly, the deposit must not contain large amounts of organic matter which as it decays competes with the

Redwood roots for oxygen. Fine silt deposits offer the most promising chance for the trees and, in fact, the Tall Trees Grove rises from an alluvial flat that developed from periodic flooding, subject to the above conditions. The concern of the study team is that increasing amounts of deleterious materials (gravel and organic matter) are being introduced into the stream and are thus likely to be included in the flood deposits.

Incision and widening of tributaries downstream from landslides and logged areas have destructive local impact and also may set in motion a chain of events that eventually register destructive impacts further down stream. Increased width associated with bank erosion can topple trees adjacent to the channel and introduce large amounts of coarse sediment into the stream. Incision or deepening of a channel may increase the velocity of the water flowing in the channel providing that the roughness and cross-sectional area of the channel are not greatly increased at the same time. This increased velocity in turn increases the stream's ability to erode its bed.

This accelerating flow picks up sediments and in so doing it is able to pick up larger sediments which in turn accelerate the rate of erosion. Or as my geologist colleagues would state it--Increasing the concentration of suspended sediment transported by a stream can increase the density and viscosity of the flowing water-sediment mixture and thereby increase the stream's ability to erode and transport sediment.

If the gravel bed of the main channel of Redwood Creek aggrades to a sufficient height, high velocity flood waters flowing through pre-existing shallow depressions on the floodplain may erode a new stream channel. That channel in turn may divert all or part of the flow from the preexisting channel. The process may be aided or caused by landslide, log jam or sidestream alluvial fan diversions. Such avulsion results in the toppling of many trees and the introduction of large amounts of sediment into the downstream portion of the main channel. Some of the locations along Redwood Creek where this sequence of events may occur include the point bar at the Tall Trees Grove, the point bar opposite the mouth of Elam Creek, and the floodplain between MacArthur Creek and Orick.

A real concern of the study team is that as the slopes above the Park adjacent to the several tributaries feeding into the Park, are harvested the above mechanisms will be triggered. Indeed in some tributaries the process has already begun. There is nothing to

prevent the tributaries in the Park from becoming the nightmarish tangle of debris and downed trees as were observed along some of the tributaries above the Park.

Accelerated Landslide Activity

As has been stated earlier, much of the watershed is susceptible to landslide activity. Many different types and rates of landslide activity are present. For example, most of the natural prairies on the eastern side of Redwood Creek display hummocky ground and tension cracks indicative of active landsliding; these slides, several tens of acres to several hundred acres in area, appear to move slowly over long periods of time, and only indirectly supply sediment to the channel of Redwood Creek. In contrast to these slides, are those mentioned in the Stone Report which notes that "the upper end of Redwood Creek corridor beginning about a half-mile downstream from the mouth of Bridge Creek falls within a highly active land-slip zone which extends up both slopes for distances up to a half-mile." Most of the individual slides in this area occur in dense timber and are from several acres to several tens of acres in area. They move rapidly and supply sediment and logs directly to the channel of Redwood Creek.

Although it is true that landsliding has been actively eroding this area for thousands of years, the study team was concerned with the inception of new slides, more vigorous movement of presently active slides, and reactivation of dormant slides particularly along roads and stream channels. Photographic documentation depicts the preponderant number of slides that are actively supplying coarse sediment to Redwood Creek and its major tributaries which were induced by activities that accompany timber harvesting. These coarse sediments in turn are the major source of channel instability.

Wind

The shallow rootsystems and brittle stems of Redwoods are characteristics that make them especially susceptible to wind-induced structural damage. It should be stated, however, that windfall and stem breakage are natural occurrences in the Redwood ecosystem in the complete absence of man.

According to the Stone Report trees exposed to wind forces apparently are able to adapt but clearcutting suddenly exposes trees that had previously been sheltered. These trees, Stone suggests, are buffeted by new turbulence patterns and their crowns are in a zone of increased wind velocity. This in turn results in severe oscillation which

increases the likelihood of windfall and stem breakage (windfall refers to uprooting and falling whereas stem breakage refers to trunk fracturing at a point often weakened by fire or decay). To date there has been comparatively little wind throw along existing cut lines.

Bulldozer-Moved Dirt

In this instance we are specifically referring to surface materials that have been disturbed by the bulldozers as they build roads, form layouts, and skid logs to the yarding area. The bulldozer spoil, which consists of a mixture of rock, soil and particulate organic debris, is usually shoved directly downslope where it completely destroys the understory vegetation and severely damages some taller trees. Much of this material works its way further downslope and into the tributaries. Moreover, some bulldozer-moved dirt is introduced directly into the tributaries during road construction and yarding operations. This is documented by several photographs showing harvesting right to the banks and channels of tributaries and of Redwood Creek itself. It should further be noted that compaction of the soil by this heavy machinery has a negative impact on regeneration.

Overbank Deposits

The concern registered by the study team regarding overbank deposits was that the increased concentration of suspended sedimentation in the waters of Redwood Creek and/or the increased magnitude of flooding would substantially increase the rate of deposition. In addition, concern was expressed over the higher concentration of organic debris in the overbank deposits. The problems that these occurrences could cause the vegetive complex have already been explained.

Fire

The threat of fire is of minor concern to the study team at this stage. As was pointed out in the Stone Report, "With the exception of local accumulation of heavy fuels around old landings and in gullies, recently cut over lands are less hazardous primarily because less fuel is available and better access for fire control forces is available on the logging road-net." 3/

Slopewash

In this instance the team is referring to soil and debris that is moving across the forest floor rather than down the water courses. The team observed that natural deadfalls and the dense understory

3/ Page 21, Stone and Associates Report, Redwood National Park, 1969.

vegetation would brake the downslope movement of logs, soil, and debris that were eroding from roadbeds, spoil banks and cut-over areas. The maximum penetration of any mud flow observed by the study team was 400 feet.

V. Discretionary Authority Granted to the Secretary of the Interior

Congress recognized when it established the Park that several problems were left unresolved by the legislative process. Accordingly, the language of the Act grants discretionary powers to the Secretary of the Interior to, among other things, buffer the Park and enter into cooperative agreements on watershed management. The pertinent language is found in Section 3(e) of Public Law 90-545.

> "In order to afford as full protection as is reasonably possible to the timber, soil, and streams within the boundaries of the park, the Secretary is authorized, by any of the means set out in subsections (a) and (c) of this section, to acquire interests in land from, and to enter into contracts and cooperative agreements with, the owners of land on the periphery of the park and on watersheds tributary to streams within the park designed to assure that the consequences of forestry management, timbering, land use, and soil conservation practices conducted thereon, or of the lack of such practices, will not adversely affect the timber, soil, and streams within the park as aforesaid. As used in this subsection, the term 'interests in land' does not include fee title unless the Secretary finds that the cost of a necessary less-than-fee interest would be disproportionately high as compared with the estimated cost of the fee. No acquisition other than by donation shall be effectuated and no contract or cooperative agreement shall be executed by the Secretary pursuant to the provisions of this subsection until sixty days after he has notified the President of the Senate and the Speaker of the House of Representatives of his intended action and of the costs and benefits to the United States involved therein."

This section is explained in House Report 1630.

> "The Committee listened with much sympathy to proposals for the inclusion of at least one entire watershed within the park--perhaps Mill Creek, as proposed in the Administration bill, or Redwood Creek, as proposed in the Sierra Club bill, or some other--but found the proposals infeasible because

of the cost involved and because of the severe effects carrying them out would have on the local economy. It recognizes, however, that damage may be caused to the margins of every park, however large or small it may be, by acts performed on land outside those boundaries and that the streams within a park, whatever its boundaries, may likewise be damaged if the land on the watershed above them is permitted to erode. The trees along the margin, for instance, may be subject to blowdown if clear cutting occurs right up to the property line, and the streams within the park may be heavily silted if proper soil conservation practices are not maintained upstream. It is for such reasons as these that the Committee wrote into its amendment a new section authorizing the Secretary of the Interior to negotiate agreements with the owners of adjacent lands and of lands on watersheds tributary to the park and, if necessary, to acquire interests in their lands which, while allowing selective logging, for instance, to go forward will require the land owner to follow practices that will, as far as possible, protect the trees, soil and streams within the park. Because the power conferred by this section of the bill is necessarily very broad and is in a field with which the Committee has had no previous experience, there is provision that no cooperative agreement or contract shall be entered into and no interest in land shall be acquired under its authority until 60 days after the Secretary has reported thereon to the Speaker of the House and the President of the Senate."

These passages not only suggest the exercise of discretionary authority they also indicate limits. It is clear that Congress does not intend that these powers will be employed as a device for simply enlarging the Park. Although the legislation does not place a limit on the amount of land the Secretary might acquire in fee for buffer purposes, it clearly suggests that acquisition as a protective device is to be used sparingly. This is witnessed by the Committe's referenced concern about land costs and the impact of larger land withdrawals on the local economy.

The Department does not feel that Congress intended the acreage acquired for buffer zone purposes should be charged against the 58,000 acre ceiling. However, it does believe that Congress meant to include all acquisition costs (including lands purchased as buffers) within the 92 million dollar authorization ceiling.

Therefore, although there is no apparent acreage restriction on establishing a protective zone around the Park such a limitation is in fact effectuated by dollar restraints. If the courts determine in every instance that the National Park Service appraisal of the lands acquired by legislative taking are fair then the Secretary could spend up to 20 million dollars without exceeding the authorization. This is most unlikely. However, the Secretary can legitimately commit such a sum since the Department is not exceeding its appraised values.

Consequently, what at first glance would appear to be an impressive array of discretionary power which can be exercised without further congressional support, is in fact sharply circumscribed.

VI. Secretarial Options for Reducing the Impact of Man-induced Threats to the Redwood Creek Corridor of Redwood National Park

There are two general sources of threats to the Park resources--upslope and main channel. The worm-like corridor of the Park is in jeopardy because it is located in the lower reaches of an actively eroding watershed that contains numerous, large active slides and that has recently been extensively cutover. It is also imperiled because it lies downslope from current timber harvesting operations being conducted on slide prone soils. On those lands where logging has already occurred remedial measures must be taken. On that property where harvesting is occurring preventive action must be taken to avoid a repetition of massive land disturbance with its attendant impacts on the Park.

Options for Reducing Channel Threats

The greatest danger to the worm-like corridor comes from stream-borne sediments and debris. The failure of landslides and gullied areas on cut-over lands in the watershed to stabilize as typified by the Copper Creek drainage, suggests that a considerable amount of remedial action is necessary. A serious effort in watershed management must be made by the landowners to prevent the introduction of additional coarse sediment and other eroded materials into Redwood Creek. The State has a major responsibility to require that surface stabilization and road maintenance efforts be made by the landowners. These matters fall squarely on the shoulders of those State agencies charged with regulating forest practices and maintaining water quality standards.

Federal efforts along the main channel of Redwood Creek must be directed toward maintenance of the natural channel integrity so as to minimize undercutting of banks and the redirection of flow. This

may include such remedial measures as clearing log jams, redistributing alluvial fans from sidestream tributaries and, as a last resort, stream engineering such as riprapping the banks when necessary to prevent the loss of spectacular groves of streamside Redwoods. Federally-financed maintenance management on the total watershed is absolutely out of the question as a protective measure. The cost exceeds the value of the resource. Moreover, stabilization is clearly the responsibility of the landowner.

Options for Relieving Upslope Impacts

Logging activity carried on directly above the Park endanger both the vegetive and aquatic resources of the corridor. Clearcutting to the boundary would expose trees within the Park to possible wind damage. Road building and tractor yarding would expose the tributary streams which flow into the Park and the understory of the Redwood forest to the effects of slopewash, landsliding and bulldozer-moved dirt. If the forest products industry continues its present mode of operating then it is imperative that a land buffer be placed between the Park and these harvesting operations.

The extent of control that would have to be exercised depends upon the future practices of industry. The upslope lands contain several tributary streams and slide zones. The introduction of sediments and debris into tributary streams above the Park will result in almost certain degradation of aquatic and vegetive resources within the Park. The construction of a road net and the practice of tractor yarding without regard to potential slip zones may activate massive sliding with its attendant consequences for downslope areas.

Reasonable buffer options range from an 800-foot management zone around the corridor to inclusion of all upslope lands.

In addition to deciding which land must be controlled so as to provide the opportunity to protect existing Park resources, one must also decide what is the best way of effectuating that control. In other words, can the desired level of control be achieved only by outright acquisition in fee, or can it be achieved by purchase of less-than-fee rights, or by cooperative agreement.

There are several options available to the Secretary:

1. Establishment of a buffer zone averaging 800 feet around the corridor and acquiring:

(a) less-than-fee interests in this land. This method could be employed to require construction of only carefully designed roads and stream crossings and the use of such logging practices as a more gradual conversion to second growth Redwood by patch cutting and cable yarding in place of tractor yarding, etc.

(b) fee title to allow the National Park Service to perform whatever forestry and engineering practices are required to minimize the effect of upslope harvesting.

2. Extending the 800-foot buffer to also include obvious slide zones and/or tributary streams by acquiring:

(a) less-than-fee interests to require certain practices in road construction and maintenance and limit cutting within 75 feet from the bank of second or higher order stream.

(b) fee title in order to prevent any logging activity in slide prone areas but employing forestry and engineering techniques to stabilize the slopes.

Note: Fee acquisition in this case would create such a confusing pattern of ownership that it would be more economical to purchase all the upslope lands.

3. Control of all the upslope lands to the hydrologic boundary by acquiring:

(a) less-than-fee interests in the land and stipulating certain practices.

(b) fee title to bring under direct management control of harvesting and/or land stabilization programs.

Obviously, the prevention of any further cutting in the Redwood Creek Basin offers the most complete "preventive" protection package. Even in this instance, however, it is imperative to realize that maintenance of existing forest roads would have to be continued or even improved. On the other hand, the study team felt that harvesting could occur on these upslope lands with minimal impacts on Park resources provided that the tributary streams were adequately protected during harvesting operations and that obvious landslide areas were treated with sensitivity and a protective, Park-controlled management buffer was established.