REHABILITATION of the SELDOM SEEN CATCHMENT JARRAHDALE

A Project 5 Report 1976

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OF THE
SELDOM SEEN CATCHMENT
JARRAHDALE

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1. Introduction

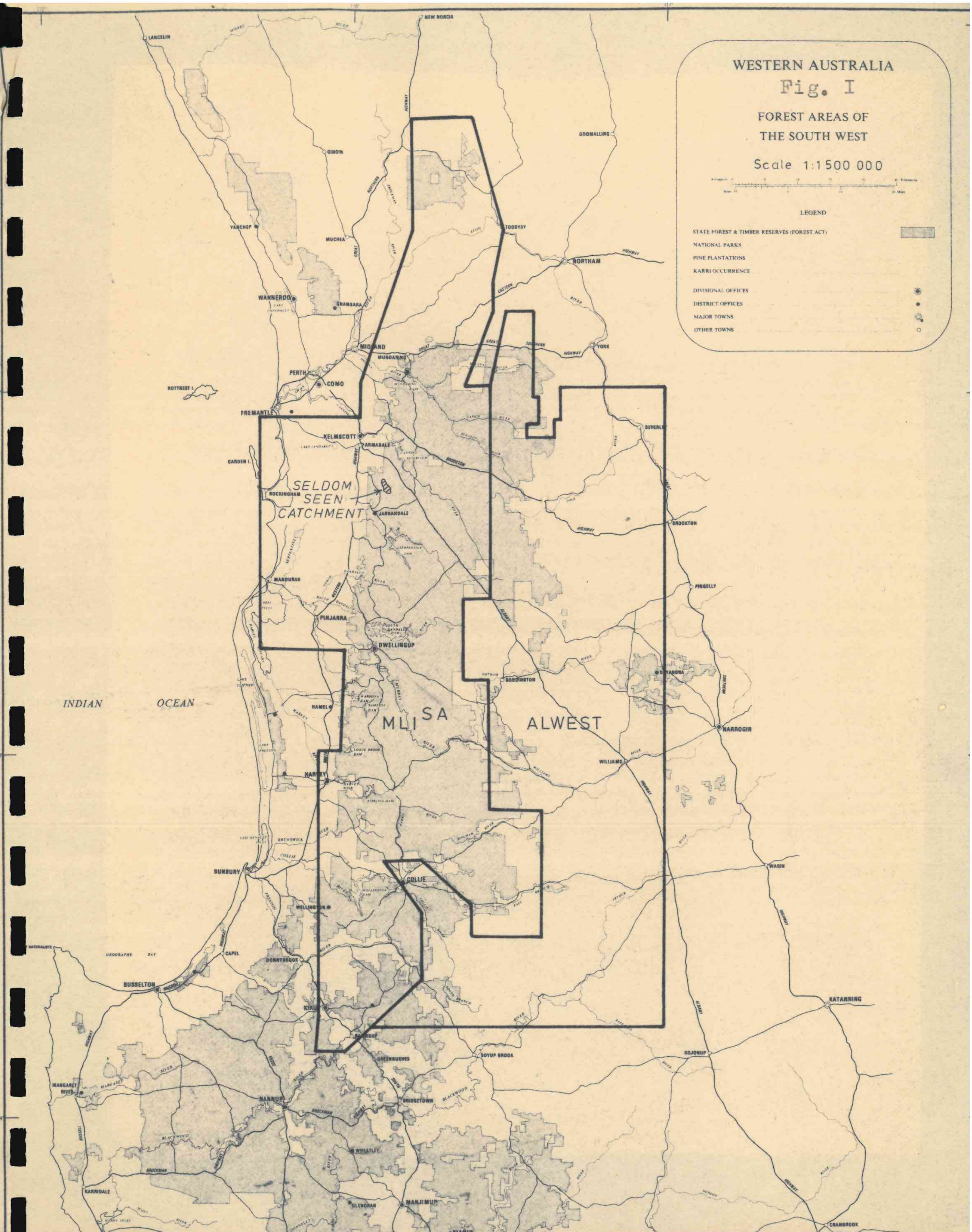
Rehabilitation following bauxite mining operations has been restricted to the surface of the mine pits. However, the effect of bauxite mining extends beyond the pit boundaries. For example, it is inevitable that the mining operations will cause spread and intensification of Jarrah Dieback in the forest surrounding the mine pits; and any effect of mining on the hydrological cycle must be evaluated in the context of the total catchment. In addition, that zone of the Jarrah forest west of the 1100 mm isohyet ("the western scarp zone") where bauxite mining is currently carried out, has already been extensively modified by Jarrah Dieback. It is logical, therefore, to consider rehabilitation following bauxite mining in terms of the total catchment.

The Seldom Seen catchment has been selected as a model to be used as an aid to develop a total catchment rehabilitation policy. This catchment is representative of a large proportion of the western scarp zone of the jarrah forest, between Jarrahdale and Collie. In this preliminary report all available data on the catchment has been collated, areas where further research is required have been defined and management options are outlined and discussed. No conclusions have been drawn as this report is an attempt to provide framework from which rational policy can be developed.

2. Environment

2.1 Location: The Seldom Seen catchment lies 7 km north east of Jarrahdale township and forms portion of the ALCOA No. 2 minesite (Fig. I). The catchment is 694 ha in area. It is approximately 4 km long and 2 km wide with its long axis lying north-south. It drains northwards into the Wungong River 5 km upstream from the Wungong Dam site.

2.2 Physiography and Soils: The Seldom Seen catchment is situated on the Darling Plateau adjacent to the Darling Scarp. The Plateau is an ancient stable shield of low relief, sluggish drainage and extremes of weathering (Mulcahy et al, 1972). Uplift has resulted in rejuvenation of the drainage systems on the western margin of the plateau. Mulcahy and Bettenay (1972) have described the sequence of land forms observed, dropping from the ancient drainage lines of the Plateau, through progressively more rejuvenated forms to the


WESTERN AUSTRALIA
Fig. I
FOREST AREAS OF
THE SOUTH WEST
Scale 1:1 500 000
LEGEND
STATE FOREST & TIMBER RESERVES (FOREST ACT)
NATIONAL PARKS
PINE PLANTATIONS
KARRI OCCURRENCE
DIVISIONAL OFFICES
DISTRICT OFFICES
MAJOR TOWNS
OTHER TOWNS
SELDOM SEEN CATCHMENT
MLI
SA
ALWEST
INDIAN
OCEAN
NEW NORCIA
LANCELIN
GINGIN
GOOMALLING
YANCHEP
MUCHEA
TOODYAY
NORTHAM
WANNEROO
GNANGARA
MIDLAND
MUNDARING
YORK
PERTH
COMO
ROTTNEST I.
FREMANTLE
KELMSCOTT
ARMADALE
BEVERLEY
GARDEN I.
ROCKINGHAM
JARRAHDALE
BROOKTON
MANDURAH
PINGELLY
PINJARRA
DWELLINGUP
BODDINGTON
HAMEL
NARROGIN
WILLIAMS
HARVEY
BUNBURY
COLLIE
WAGIN
WELLINGTON
CAPEL
DONNYBROOK
BUSSELTON
KIRUP
KATANNING
BOYUP BROOK
KOJONUP
GREENBUSHES
MARGARET RIVER
NANNUP
BRIDGETOWN
WHEATLEY
KARRIDALE
MANJIMUP
GLENORAN
CRANBROOK
AUGUSTA
PEMBERTON

coastal plain. Part of this sequence is represented in the Seldom Seen catchment.

The divides and upper slopes of the valley have the intact lateritic and bauxitic profiles of the Plateau, with deep pallid zones. This surface with its gravelly sand soils makes up about 70% of the catchment (Churchward & Batini, 1975).

The upper slopes grade gently (less than 1 in 10) down into the flat floored, sometimes swampy valley which conforms to the mature Beraking type and comprises some 20% of the catchment. The soils of the valley floor are silty, sandy and gravelly earths formed from transported materials deposited over mottled and pallid zone clays (Churchward & Batini, op.cit.).

Downstream the Seldom Seen becomes more deeply incised and adopts the young Darkin form. Outcrops of country rock and rapids occur in the stream bed. This surface with its steep valley walls (up to 1 in 7) comprises less than 10% of the study area. Soils range from alluvial loams in the narrow valley to sandy and gravelly earths on the valley walls (Churchward & Batini, op.cit.).

2.3 Vegetation: The vegetation cover of the valley has been grossly altered from the virgin state by timber cutting, jarrah dieback and more recently, by bauxite mining. Jarrah (Eucalyptus marginata Sm.) dominates the lateritic uplands with a lesser component of marri (Eucalyptus calophylla R. Br.) and an understory of banksia (Banksia grandis) and sheoak (Casuarina fraseriana Miq.). Bullich (Eucalyptus megacarpa F. Muell.) and tea tree (Agonis linearifolia) dominate the moist valley situations in the presence of long standing dieback infection (Plate III). In the zone between, where dieback infection is extensive, an open marri woodland exists with some blackbutt (E. patens) on the lower part. Ground cover is sparse. (Plates I and II).

2.4 Hydrology: A general model of the jarrah forest hydrological cycle has been proposed as follows: winter excess rainfall rarely runs off the gently sloping porous laterite uplands. It percolates deeply and is stored in the Kaolin clays of the deep pallid zone which is sealed at depth by unweathered country rock. Hydraulic conductivity of the pallid zone clays is low and water only slowly enters into the ground water system. West Australian trees, particularly jarrah, have evolved deep root systems to exploit this

Plate I

Old dieback zone. Looking upslope to uninfected area in the background.

Plate II

Open marri woodland on old dieback zone. Looking down slope to more dense marri-blackbutt woodland of the valley floor.

Plate III

Bullich-tea tree formation of the moist areas of the valley floor.

moisture source. A fully stocked jarrah forest is capable of transpiring much or all of stored winter excess in the arid summer. This theory can be used to explain salt accumulation, and the increased salt flow and ground water flow that occurs after clearing of vegetation (Shea et al, 1975).

The Seldom Seen catchment has been gauged by the Public Works Department since 1966. There is little information on rainfall in the catchment and figures from the nearest meteorological station at Wungong (some 4 km north west) have been used to give an estimate of yield. Total annual flows and yields are summarized in Table 1.

TABLE 1

Year	Total Flow in 1000m^3	Rainfall mm	Yield %
1966	1272	938	19.5
67	2968*	1309	32.7
68	2695*	1390	27.9
69	1408	743	27.3
70	2775	1273	31.4
71	2179	1002	31.3
72	1321	830	22.9
73	3105	1282	34.9
average	2215	1096	28.7

* Flows in 67 and 68 have been included in the calculations without allowing for missing data. The effect on the average yield figure was estimated to be small.

The mean yield figure of 29% is exceptionally high for an upland forested catchment in the northern jarrah forest. Havel (unpublished) suggests that this is due in part to the degraded nature of the forest due to dieback and recent heavy salvage logging. Inaccuracy in defining the catchment boundary could also be partly responsible. Not only is the delineation of topographic divide subject to error on the flat porous uplands, but it might also be a poor indicator of a more significant subsoil divide. In the unlikely event that this error was 10% the yield figure would be reduced to 26%.

The weighted average stream salinity (NaCl) from 1966-70 was 108 ppm (Public Works Department, 1972). Peck & Hurle (1973) have calculated that this flow represents a small excess over salt fall and that the characteristic equilibration time is 20 years. There was no detectable change in salt flow during the period 1966-1970 (Peck, pers.comm.). Stream salinity levels recorded in Jan.-Feb. 1976 were approximately 150 ppm (Slessor, pers.comm.).

Present base flow chloride levels may not be an accurate indication of likely salinity changes following extensive vegetation disturbance if there are large accumulations of salt in the soil profile above the current water table. Measurements of ground water table levels following mining at the Del Park site suggest that the water table may rise several metres following mining (Havel and Sanders, unpublished Project 3 data). This could mobilize salt which was previously kept separate from the water table. It is, therefore, critical to determine the quantity of salt stored in the soil profile, particularly on upland sites.

Salt storage of subsoils in the western scarp area has not been thoroughly investigated. Dimmock et al (1974) found from 10 bores in areas of rainfall greater than 1000 mm that salt contents ranged from 0.07 to 0.01 g/100g which was equivalent to a salt storage range of 0.2 to 5.1 x 10^2 kg/ha. There was no significant difference between topographic position but total storage was only 20% of that found in areas with less than 800 mm rainfall. Three bores in the Gooralong catchment, adjacent to the Seldom Seen, had extremely low salt levels. Recent bore data indicate moderate salt accumulation in two holes on valley floor sites in the Seldom Seen (Slessor, pers.comm.).

3. History of Land Use Activities

3.1 Forestry: In the 1870's Jarrahdale developed as the first large-scale timber producing centre in W.A. (Fall, 1972). The era of uncontrolled exploitation came to an end with the Forests Act of 1918. Dieback was recognized as a widespread problem by the late 40's but the causal organism was not isolated until 1965 (Podger et al, 1965). Salvage logging of infected areas became practice in the late 1960's.

The eastern half of the Seldom Seen catchment is currently being cut and the western half is due for cutting in 1976-77. The completion of this cutting seems likely to be the end of commercial jarrah production in this catchment. Even in the absence of mining it is considered that sustained jarrah production would be difficult to achieve in this area (Churchward & Batini, op.cit.; Lush, pers.comm.).

3.2 Water: The metropolitan Water Supply Department established a pipehead dam on the Wungong in 1925. In 1966 the Public Works Department built gauging stations on the Seldom Seen and on other streams flowing into the Wungong. The new Wungong Dam is planned for completion by early 1977.

3.3 Mining: Aluminous laterites are widespread in the uplands of the Darling Plateau region. Though this fact had been known for some time, commercial possibilities were first examined in the late fifties. ALCOA of Australia was formed in 1961 and negotiated an agreement with the State Government giving it rights to mine bauxite in some 700,000 ha of State Forest on lease MLI SA (Fig.I). Two other leases were negotiated by other companies, most notably by ALWEST (Fig.I).

Mining and refining commenced in 1963. The ALCOA agreement, which was negotiated under the direction of the Department of Industrial Development, did not foresee the environmental complexities of the mining operation and the Hunt committee was established in 1973 to co-ordinate and direct research into its effects.

Mining commenced in the Seldom Seen catchment in 1968. To date, about half the ore bodies in the catchment have been mined. Bauxite ore bodies are in discreet pockets of varying size, and are spread throughout the uplands. Being a mature valley and having a high percentage of upland, the density of ore bodies in the Seldom Seen is above average. The open cut mining operation removes 4-5 m of the upper laterized profile. Stockpiled topsoil is then replaced onto the exposed pallid zone clays, the pit floor is deep ripped and vegetation re-established. The pits are designed to contain any run-off they may generate in order to avoid problems of erosion, siltation and turbidity lower down in the catchment.

It is unlikely that the mining operation can avoid spreading dieback further (Shea et al, 1975). The occurrence of bauxite is restricted to the uplands where dieback is least established and which might otherwise remain free of infection for some time. Further, once an infection is introduced onto an upland surface, its spread downslope is rapid (Shea, 1975).

4. Past and Current Vegetation Distribution

4.1 Changes in Dieback Distribution 1941-1975: Stereoscopic aerial photographs from years 1941, 51, 60, 68 and 75 were used to map the old dieback zone (well advanced dieback infection) for the years 1941, 68 and 75. This zone was mapped as areas where long standing dieback infection had advanced to the stage of largely eradicating susceptible species and which showed up on photographs as unmistakeably sparsely vegetated (Plates I and II). This most conservative estimate of area infected had to be taken due to difficulty in photograph interpretation. The photographs were of differing scales (1:11,000 to 1:25,000), variable in quality, and logging and fire effects on vegetation density were apparent.

Dieback infection advanced from 21% in 1941 to 28% in 1968. A further 7% advance to 35% occurred during the mining period. The advance of dieback is illustrated in Figs. II and III and summarized in Table II.

TABLE II

Old dieback zone

Year	Area ha	% Total
1941	143	21
1968	194	28
1975	244	35

The levels observed here agree broadly with the findings of Batini (1965) in a rate of spread study over 1500 ha in this region.

The apparent acceleration in the rate of spread of dieback in the mining period cannot be attributed directly to the mining operation since initial infection of the old dieback zone could have preceeded mining.

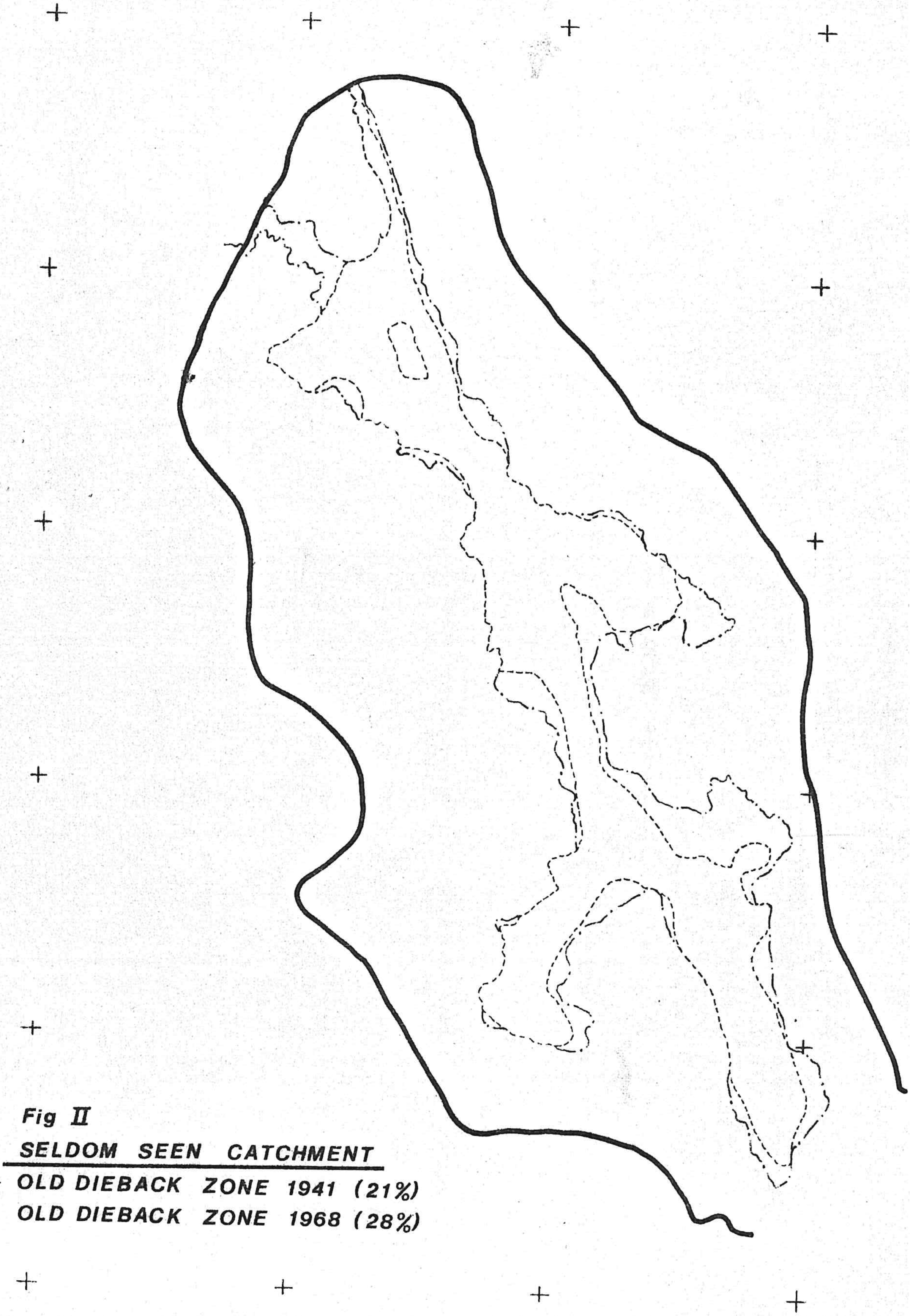


Fig II

SELDOM SEEN CATCHMENT

------ OLD DIEBACK ZONE 1941 (21%)

—·—·— OLD DIEBACK ZONE 1968 (28%)

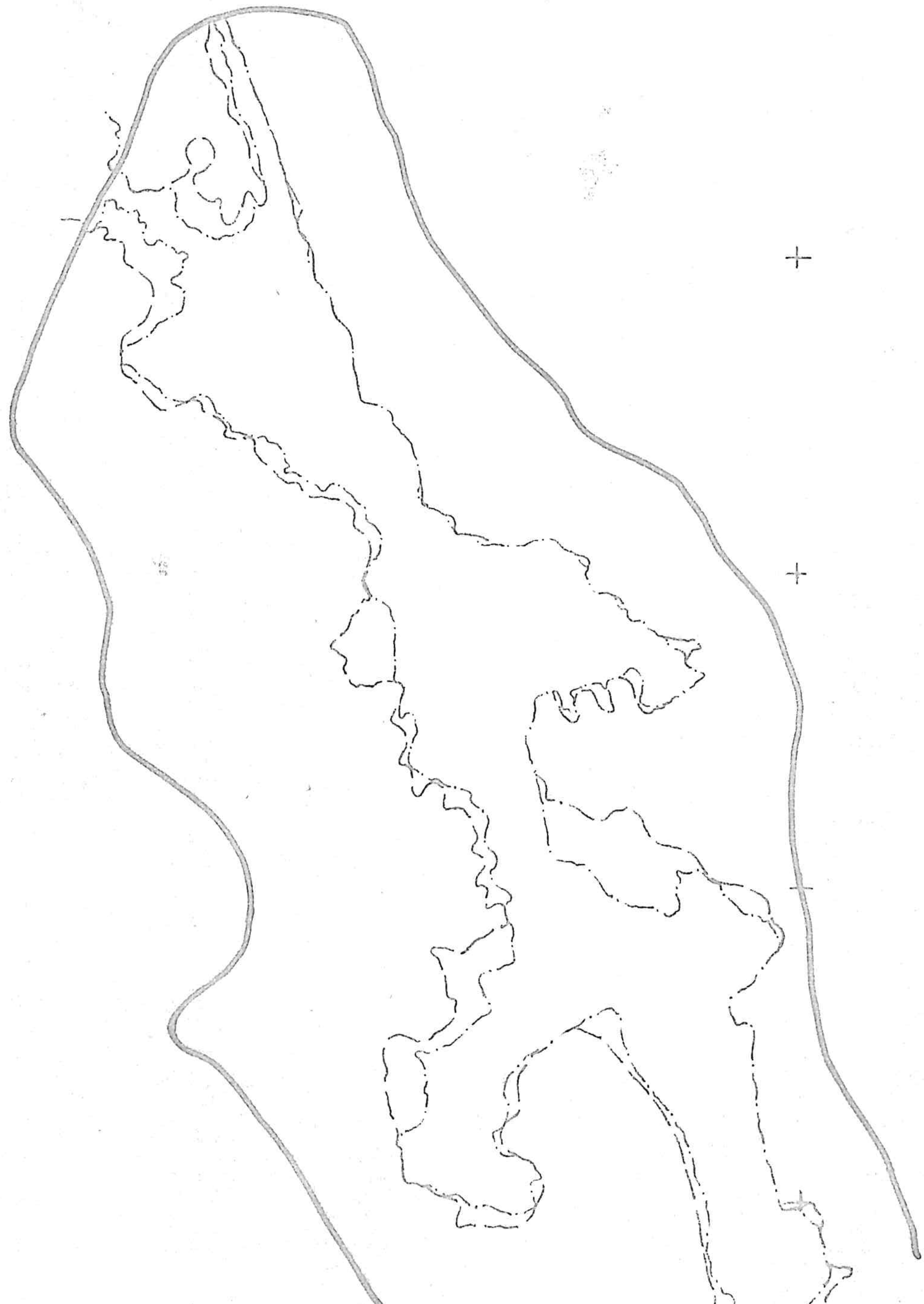


Fig III

SELDOM SEEN CATCHMENT

—·—· OLD DIEBACK ZONE 1968 (28%)

— — OLD DIEBACK ZONE 1975 (35%)

4.2 Current and Projected Vegetation Distribution: 1975 stereoscopic aerial photographs, contour maps and plans of ore body distribution were used to map current and projected vegetation distribution. The following zones were delineated -

(a). Old Dieback Zone: As defined in previous section.

(b). At Risk Zone: This zone was mapped as that area lying downslope from present or proposed pits and roads. It was expanded outwards from points of infection at 45° to the contour, down to the old dieback zone. Spread of infection downslope can be very rapid and upslope extremely slow (Shea, op. cit.). Lateral movement would vary between these extremes. The at risk zone was judged to be a reasonable medium term compromise (Heberle, pers.comm.). This zone comprised 26% of the catchment.

(c). Pits and Roads: This zone is the area that has been, or will be, active in the mining operation. So far the areas affected total 14%. It was estimated from the size and spread of unmined ore bodies in the catchment that a further 13% of surface would be cleared to give a total of 27%.

(d). Safe Zone: Elevated portions of forest at present unaffected by mining or dieback and likely to remain so, were defined as the 'safe' zone. In the long term, upslope and lateral spread will infect this zone unless deliberate measures are taken to prevent it. These areas total 12% of the catchment. They vary in size from about 20 ha down to 2 ha. Some are continuous with safe areas in adjoining catchments.

Each vegetative zone is mapped in Fig. IV and summarized in Table III.

TABLE III

Zone	Area ha	% of total
Safe	84	12
Pits & Roads	189	27
At risk	177	26
Advanced dieback	244	35
	694	

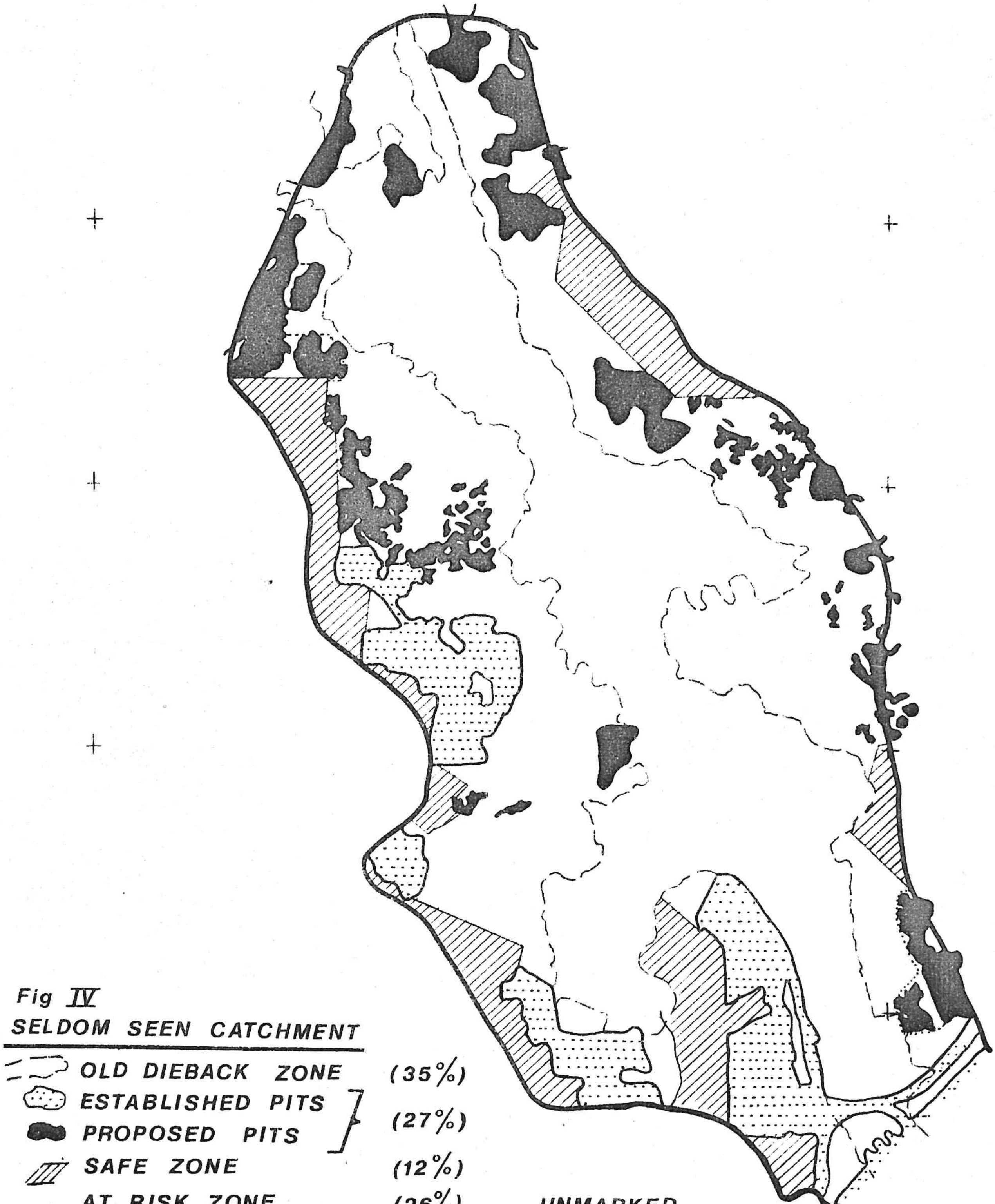


Fig IV
SELDOM SEEN CATCHMENT

5. Discussion

Possible rehabilitation options are discussed below in relation to the major land use activities in the western scarp.

5.1 Water Production: The primary land use of the northern jarrah forest is water production. The region produces good quality, cheap water and with the continuing growth of the metropolitan area this resource will be utilized to the full (Havel, 1976). Cost of delivering water from major future developments will be about double the cost from existing storages (Sadler & Field, 1975). Therefore, the marginal value of increased production from existing storages would be very large. The current price of water to metropolitan industrial and domestic consumers is 12.5 cents/m^3.

The Seldom Seen at present yields some 29% of its annual rainfall of 1250 mm as stream flow. This is equivalent to 3650 m^3/ha/an. Present altered areas in the Seldom Seen catchment total 49%. These consist of 14% of pit floors replanted to trees and 35% of old dieback which is very sparsely vegetated except in the swampy parts of the valley floor. The yield from this catchment is very high by jarrah forest standards. An analysis of stream flow data by Havel (unpublished) indicates that several fully forested catchments in the northern jarrah forest yield approximately 10%.

Further clearing for mining of 13% and dieback expansion of 26% will bring total altered areas up to 88% and is likely to further increase water yield. It is impossible to estimate accurately maximum yield possible. Extensive rehabilitation with tree species could reduce yield to pre-mining and pre-dieback levels (Hewlett, 1966). This could represent a reduction in yield in the Seldom Seen of approximately 2400 cubic metres/hectare/annum. Thus, an inverse relationship between total canopy density and water yield must be accepted in considering rehabilitation. However, the precise nature of this relationship, especially at the extreme of minimum canopy, is not clear.

Reduction in canopy cover in the catchment will only have a beneficial effect if it does not result in an increase in stream salinity. It is unlikely that further disturbance will increase stream salinity because -

(a). Data from 1966-70 show that the weighted average salt level (108 ppm) was very low.

Some 21% of the catchment, largely valley floor, had been thinned of vegetation by dieback for over 30 years. Ground water discharge and stream flow during this time must have been increased over pristine levels. From 1966-70, therefore, levels of salt in the ground water of the valley must have been too low to adversely affect water quality, perhaps through already having been depleted by many years of elevated stream flow.

(b). The exceptionally high yield (29%) also indicates that the uplands must have been contributing to ground water discharge. Even presuming 100% run off from the 194 ha of dieback affected valley and nil from the uplands, does not account for total flow over the period 1966-70. This might be taken as a reasonable indication that salt problems are not likely, because ground water emanating from the uplands should have had opportunity to begin flushing any stored salt from the system.

(c). Base flow salt levels of February 1976 (see Section 2.5) are not above 1970 levels. An expansion of approximately 7% in dieback and the clearing of 14% for mining during this time has not yet affected salt flow.

(d). General experience in the western scarp indicates that salt problems are unlikely. For example, the farmed catchments of the irrigation weirs near Harvey have no problem.

However, a further 13% is due for clearing for mining soon, and a further 26% is likely to become dieback affected. Also, recent bore hole data indicates unexpectedly high salt storage in two holes on the valley floor. It may be premature to draw any firm conclusion on present information.

It is imperative that in future a more thorough assessment of potential salt problems is made, since it is the dominant consideration in deciding the direction rehabilitation should take. Such an assessment is planned for the Seldom Seen (Slessor, pers.comm.).

5.2 Timber Production: Timber production has historically been an important land use. However, its role in altered areas such as Seldom Seen, is in question.

Jarrah will be restricted by dieback to safe areas totalling 12% of the catchment, and made up of several discontinuous 'islands'. Such a spread is not conducive to long term survival from dieback nor to economical logging operations. Prospects for timber production with dieback resistant species are good on the lowlands (30% of the area), but unproven on the uplands (70% of the area)(Shea et al, op.cit.). Pines are generally unsuited to the soils of the Seldom Seen (Havel, op.cit.) and slower growing, less profitable, eucalypts are the only alternative being considered.

A possible rehabilitation option is to maximize tree planting throughout the catchment. But this option should be considered in relation to:-

(a). The effect on water yield (see section 5.1).

(b). The viability of timber production per se in soils of the western scarp.

It is possible that a low level of timber production might be compatible with high yields if it positively interacted with water quality and recreation. However, the full relationship between tree density, water yield and quality and recreational satisfaction is unknown.

5.3 Aesthetics and Conservation: The need to protect catchment areas to ensure the quality of water supplies, has historically performed a significant secondary role of conserving native forest ecosystems and landscapes. The future significance of this role in altered areas such as the Seldom Seen, is much diminished. Dieback irreversibly alters the forest ecosystem by reducing the range of plant species able to survive and mining modifies the landscape.

Despite this loss of pristine condition these areas will still form valuable bushlands worthy of protection. Rehabilitation and future land use have demanding roles to play in maximizing where possible aesthetic and conservation values. Just what these values are is obviously very subjective and should be carefully investigated. The zones defined in the survey will be considered to indicate where the more obvious conservation or aesthetic demands might be significant in modifying the direction rehabilitation should take.

(a). Old dieback zone (35% of total): In the Seldom Seen a large portion of this zone is in excess of 35 years old. The bullich-tea tree swamps are a contrast in the landscape (Plate III) and probably still provide sustenance and sanctuary for much of the original fauna. Aerial photographs indicate that the extent of bullich has increased since 1941. It would obviously be unacceptable to clear these areas in the interest of increased water production especially since it might also create a soil conservation problem.

The margins of the swamps and stream channel form open marri-blackbutt woodlands, becoming more sparse and perhaps less attractive upslope (Plate II).

Overall the effect of dieback in this zone might be considered a fortuitous balance of conservation needs with enhanced water yielding capacity and might be difficult to improve upon artificially.

(b). At risk zone (26% of total): It can be presumed that the vegetation cover on this zone will progressively degenerate. The end result will be a sparse marri woodland similar to the upper portion of zone 1 (Plates I & II). Once the dead timber is removed and it loses the derelict lock this formation may be aesthetically acceptable. Firewood cutters are active in this area and removal of dead timber should not be a problem.

Slopes of up to 1 in 7 occur in this zone. If devegetation is rapid the less permeable soils of the lower slopes may be exposed to soil erosion. This possibility would have to be considered if a minimum revegetation policy was adopted.

(c). Pits and roads (27% of total): This zone is a new type of surface in the forest. It need not be displeasing aesthetically even if only a minimum of trees are used in rehabilitation. From the soil conservation point of view the pits with their internal drainage and relatively impermeable soil, have yet to prove that they can contain their run off in years of exceptional rainfall. Even dense tree cover is unlikely to help much in this regard. This area of rehabilitation research needs further investigation.

(d). Safe forest (12% of total): This zone with its full complement of native flora and fauna could justify rigorous protection. Its worth as a relic of the past may justify its consumption of water that might otherwise find its way into stream flow. In addition it may produce timber in the long term. Some protection could be afforded by forming roads around the islands of uninfected forest to break the continuity of roots with infected forest. There are examples of roads barring natural uphill spread of dieback elsewhere in the forest.

The marri woodland vegetation type could come to occupy more than 50% of the catchment. Since it develops naturally and therefore requires only minimal management it should be thoroughly investigated from the following points of view:-

(a). Is it aesthetically acceptable over such a large area?

(b). Is it a soil erosion risk and will it yield sediment free water?

(c). Does it yield maximum water or could changes be made in tree or ground cover?

5.4 Catchments and Recreation: Maximizing the aesthetic appeal and flora and fauna conservation roles of catchments is only rational if people have access to catchments for leisure time activities. At present the Metropolitan Water Supply Department has a restricted access policy in the interest of maintaining cheap, high quality water supplies. Passive recreation is tolerated in areas away from the main water body. The pressure of demand will inevitably grow and systems of regulation of visitors must be developed so as to minimize conflict with water production.

The rehabilitation of mined catchments presents an excellent opportunity to cater for possible future recreational demand. To take full advantage of this opportunity it is necessary for the Metropolitan Water Supply Department, the Water Purity Committee and other responsible authorities to establish firm guidelines.

The pits, comprising 27% of the Seldom Seen are potentially an outstanding recreational venue for the following reasons:-

(a). Total internal drainage reduces the significance of pollution and erosion problems;

(b). The pits are subject to major earthworks in the process of rehabilitation. Landscaping specifically to cater for visitors should be little extra expense;

(c). Risk of spread of dieback is reduced by the fact that much of the area is already infected;

(d). Good quality access roads already exist;

(e). The pits are on uplands away from streams and water bodies.

More active forms of recreation might possibly be entertained, for example camping, motorbike riding and horse riding. Unfortunately, the pits adjoin the safe zone and active recreation may put this area at risk.

6. Conclusion

Present rehabilitation practice centres too narrowly on the pit area which constitutes less than 25% of the total catchment. It has been shown that the combined effects of dieback and mining may ultimately affect 90% of whole catchments. The scale of this alteration to the environment indicates that bauxite mine rehabilitation should be considered a part of total catchment management. The role of rehabilitation must be defined by a catchment land use plan. Two factors will decide the outline of such a plan:-

(a). Salt: It is essential to determine the size and significance of any salt accumulation in catchments to be mined. If significant salt is present then this will be the over-riding factor in rehabilitation and tree cover must be maximized.

(b). The appropriate revegetation level: If salt accumulation is not significant, as seems likely in the western scarp, vegetation density should be kept at a level which maximizes water yield. What this level is, whether it is compatible with some timber production, and whether it is acceptable aesthetically, are unknowns.

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