SOME OBSERVATIONS ON THE ECONOMIC VALUE OF DUAL-PURPOSE FORESTRY IN THE WAIRAU RIVER CATCHMENT

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SYNOPSIS

The Wairau River catchment is selected as an example where dual-purpose forestry is likely to play a significant part in watershed management. The effect of applied watershed conservation and river control measures is briefly described. The area of steepland likely to require ultimate forest conservation treatment, either in whole or in part, is estimated to be approximately 402,000 acres. This has been classified into three categories of (a) 84,000 acres of short-rotation commercial forest species. (b) 88,000 acres of long-rotation commercial forest species and (c) 230,000 acres of high altitude steepland for which the major requirement is revegetation principally with grass, legume, scrub and some forest species. The commercial wood value of this latter category would be nil to slight, but on-site erosion control values would be high and considerable (although ill-defined) indirect off-site benefits are likely to accrue from this treatment.

From flood records data and catchment conditions postulated by Thomson (1965) it is assumed that the reforestation of all the areas cited would have considerable on-site and off-site benefits. These are listed and evaluated in monetary terms over an 80-year period. These benefits and associated costs are then discounted to present value using an arbitrary interest rate of 5%.

As the benefit/cost ratio thus obtained has a value close to 1.0 it is concluded that a major steepland conservation and reforestation programme of the upper Wairau catchment is reasonably justified even when intangible benefits are ignored.

It is further concluded that the analysis, besides clarifying logical priorities, also indicates the necessity for an integrated whole catchment approach as well as considerable justification for greatly increased research on the costly and extensive high altitude revegetation work.

INTRODUCTION

A paper with this sort of title can hardly be in precise terms, first, because of the size of the Wairau catchment (1,029,000 acres), secondly, because of the absence of complete data on which to base a full evaluation, and, thirdly, because protection forests are only part of the overall land-use pattern (see Fig. 1).

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However, data available even for smaller catchment areas are also just as inadequate and as the purpose of this study is to examine all the factors involved in a generalized way the selection of a catchment of this size appears to be justified.

In simple terms, an evaluation of protection forestry involves the comparison of the flow of costs against the flow of benefits expressed in monetary form. I would agree with Francois (1962) that it may be illusory or misleading to extend this type of analysis to infrastructure investments. On the other hand, there would seem to be some value in an economic study of protection forestry provided that hypotheses underlying estimates of the cost-benefit rates are stated clearly, and provided that it is also made clear that, at best, it can give only a partial and limited picture of any forest proposal.

It would appear from the acceptance of the Multiple Use Committee report of the Forestry Sector, National Development Conference (1969) that the protection forester-soil conservator is required to present a case that is reasonably convincing but which is something more than just a list of tangible and intangible benefits.

The most significant factor in the study of any river regime, however, must inevitably be the time factor. It would seem that, with river control design schemes based usually on flood incidences of the order of one in 100 years and with forest rotations, especially for slow growing protection species, measured in like terms, short time period studies are untenable. With these factors in mind, it would appear that only long-term studies can yield satisfactory conclusions and this hypothesis is examined.

PRESENT SITUATION IN THE WAIRAU CATCHMENT

This catchment has been previously adequately described by Dunbar (1956) and Macarthur (1960) and the major river control scheme for the catchment is now well advanced (Marlborough Catchment Board, 1959-70). Since 1960, major flood protection engineering structures have been constructed over much of the vulnerable flood plain and some $2.6 million has been spent out of the total estimate of $3.2 million. This work has ensured a very high level of flood protection and security to a highly settled and productive area with Blenheim as the centre, and will be fully completed in a few short years.

In the upper catchment, fire control measures by the Marlborough Catchment Board, Marlborough County Council and New Zealand Forest Service have led to a reduction in the incidence and extent of damaging fires, while a well conceived and executed programme of wildlife control by the New Zealand Forest Service has seen a marked lowering of levels of noxious animal population particularly in critical areas. Revegetation and conservation measures have also been applied by the Forest Service, the Marlborough Catchment

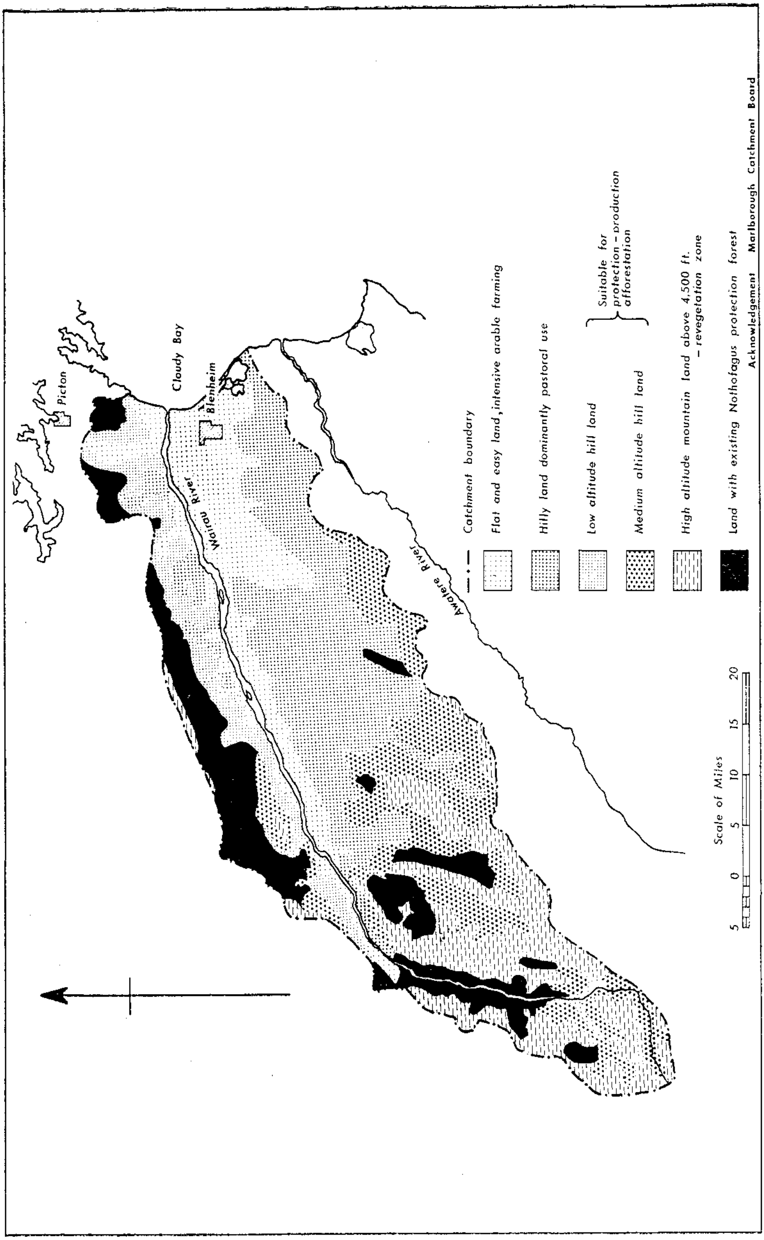

FIG. 1: *Wairau River catchment, Marlborough. Land classification, illustrating siting of protection and protection/production forests.*

Board and some land owners, including the Lands Department. These are now on a fairly substantial scale and have resulted in a marked improvement in the vegetative cover, more especially on the medium altitude, more favourable sites.

It was estimated (Waters, 1959) that the benefits from the Wairau Valley Scheme, in terms of reduced or eliminated flood damage, increased agricultural production, reduced river protection costs and land saved from loss would amount to $710,000 per year, at scheme end (1970 money values). The number of potentially damaging floods avoided and controlled to date (Marlborough Catchment Board, 1963-1970) would indicate this estimate to be conservative.

Costs of wildlife and fire control, soil and water conservation plans, and extensive gully stabilization and other erosion control measures by the Marlborough Catchment Board and the New Zealand Forest Service have not been recently collated. However, since 1958 total Board expenditure on these masures has been at least $500,000 of which close to $200,000 has been contributed by land owners. Forest Service expenditure would no doubt be at a similar or slightly higher level.

Although no detailed cost/benefit analysis has ever been made of this scheme, the figures quoted indicate the possibility of favourable economics of the procedures and works executed at national, local and individual levels. On closer examination, however, it is apparent that the scheme to date has merely written the first chapter in what promises to be a lengthy novel. The treatment of the Wairau catchment has not been approached on a fully co-ordinated whole catchment basis. All approaches to date have been piecemeal and this was my warning at the time the downstream scheme was conceived and remains so today. Others are voicing similar concern. In 1965, P. A. Thomson (Chief Engineer, Marlborough Catchment Board), prepared a report which demonstrated a rather unusual assessment of the effect of watershed management and treatment on the discharge of the Wairau River.

To quote: ". . . considerable downgrading of the standard of protection will result from continued erosion within the Wairau Catchment. The ultimate success of the Wairau Valley Scheme, especially for flood protection, therefore depends almost wholly on the performance of soil conservation operations in the catchment."

And again: ". . . erosion problems exist in most catchments and these . . . must be tackled if the Scheme is to survive and not require reconstruction in 50 to 100 years time."

Thomson's conclusions are realistic in that they are based on the experience of actual flood discharges related to known catchment condition. Table 1, prepared by Thomson, is reproduced below and indicates the relative effect of catchment condition in the Wairau on flood frequency and size.

In 1960, Waters estimated that a flood of the 1923 dimensions (approximately 100,000 cusecs) would cause damage and loss of production valued at $2.4 million (1970 values). In the last ten years more intensive settlement and increased usage mean that this figure would be considerably exceeded if the present secure system were broken or overtopped. Thomson's calculations sound a very severe note of warning.

When the catchment condition and trend are examined more closely, then (and this warning behoves that we should), it is estimated (Dunbar, 1956), that out of the 1 million-odd acres of the catchment some 876,000 acres comprise steep and eroding or erodible lands in land capability classes VI, VII and VIII (American standard land capability classification) including considerable high altitude land above the limits of natural forest vegetation at 4,500-5,000 ft (see Table 2).

TABLE 1: RELATIVE EFFECT OF CATCHMENT CONDITION ON FLOOD FREQUENCY AND SIZE IN THE WAIRAU CATCHMENT

	Estimated Occurrence of Peak Discharge once in —		
		Position in 100 years' time for —	
Peak Discharge (cusecs)	*Wairau Valley Scheme Report (yr)*	*Improved Catchment (yr)*	*Deteriorated Catchment (yr)*
180,000*	200	500	70
160,000	90	220	35
140,000	40	100	15
120,000	16	38	7½
100,000	7	12	4½

*Wairau Scheme design flood.

TABLE 2: LAND CAPABILITY CLASSIFICATION — WAIRAU CATCHMENT

(After Dunbar. From Wairau Valley Scheme Report, 1959)

Class	*Area (acres)*		*% of Total Catchment Area*
I	5,600		0.5
II	35,080		3.4
III	35,290		3.4
IV	16,940		1.7
III & IV (complex)	30,680		3.0
II & V (complex)	1,220		0.1
VI	221,850		21.6
VII	214,490		20.8
VIII	441,300		42.9
Other Urban, etc.	3,660		
Riverbeds	19,490	26,830	2.6
Lagoons	3,680		
Total area = 1,029,280 acres.			

Further analysis of these areas shows that some 160,000 acres are still clothed intact with steepland protection forests, mainly of mountain, red and silver beech. Of the balance, some 400,000 acres have been classified (Macarthur, 1960) as possessing extensive erosion, both sheet and gully, in varying degrees of intensity, and is mostly land that was once evolved under a forest or tall scrubland cover (see Table 3).

TABLE 3: EXTENT OF SOIL EROSION — WAIRAU CATCHMENT
(After Macarthur, 1960 and Dunbar, 1956)

	*Erosion Class**	*Extent (acres)*
0	No significant visible erosion	152,650
1	1-10% of area eroding	116,796
2	11-20% of area eroding	332,713
3	21-40% of area eroding	160,493
4	41-60% of area eroding	73,817
5	over 60% area eroding†	192,431
	Total =	1,029,000

*Recorded as an index based on the extent of visible erosion and the amount of bare ground exposed. Mapped at 40 chains/inch reduced to one mile/inch.

†Includes some geological erosion.

Fire control and animal control to the levels now attained are essential prerequisites to control of the erosion on these steeplands. These measures in themselves are, however, most unlikely (and there is little evidence so far to indicate response) to restore *adequate* natural cover over more than perhaps $\frac{1}{3}$ to $\frac{1}{2}$ of this vulnerable and critical area (Wraight, 1963). The principal climatic agencies of heavy rain, frost lift and wind continue to degrade these sites towards bedrock which is the ultimate and disastrous end if not checked.

THE SCOPE FOR DUAL PURPOSE FORESTRY

The question then arises of the part that can be played by forestry in restoring these extensive eroded steeplands and to what extent, and also whether forest cover is likely to be purely protective in function and/or productive.

Experience to date in the Wye and elsewhere (Macarthur, 1966), since 1959 indicates that European larch, Douglas fir and Corsican pine of variable origins and provenances are establishing and growing well up to 3,800 ft, with *Pinus contorta* similarly to 4,500 ft. Hand planting can give establishment rates up to 85% for these species, while aerial direct seeding of the same species is, I understand, showing considerable promise in the Branch catchment (L. J. Slow, pers. comm.).

Not all forest protection sites are at these high altitudes. Recent detailed surveys of the north bank or true left bank of the Wairau (Macarthur, 1966) indicate an area of 84,000 acres mostly below 2,000 ft and previously in

TABLE 4: DUAL-PURPOSE FORESTRY SITES — WAIRAU CATCHMENT

Classification	Principal Species	Location	Altitude Range (ft)	Estimated Area (acres)	Land Capability Classes	Main Soil Types	DSIR Soil Bureau Ref. No.	General Erosion Category (MCB Classfn.)	Vegetative Cover: Past	Vegetative Cover: Present
Low altitude protection/ production forests	*Pinus radiata*	Left bank	100-2,000	84,000	VI-VII	Tuamarina Onamalutu	32AH 47C	Moderate Locally severe	Tall scrub-land and beech forest	Fern, gorse, and heath Scrub reversion and general
Medium altitude protection/ production forests	*Larix decidua* *P. nigra* *P. contorta* *Pseudotsuga menziesii*	Right bank	1,500-3,500	88,000	VI-VII	Hurunui Tekoa Lewis Bealey	41A 57 65	Moderate to severe Locally severe to extreme	Fescue tussock Beech forest Minor areas broadleaf/ Podocarp forest	Generally degraded to fescue tussock danthonia, browntop and manuka scrub
High altitude revegetation zone	Grasses Legumes Shrubs	Left bank	above 3,500	24,000	VII-VIII	Kaikoura Bealey Spenser Lewis Alpine	57 57B 58 65 100	Moderate to severe Locally severe to extreme	Snow tussock with sub-alpine scrub with some beech forest Fell fields	Generally degraded to bare soil and *Notodanthonia setifolia* and *Celmisia* sp.
	Alnus viridis *P. mugo* *P. contorta*	Right bank		206,000						

Total area = 402,000 acres.

beech forest as highly suited for *Pinus radiata.* This hign rainfall area of low altitude steepland soils has fortunately never been cleared of forest to the summit of the range and large areas of *Nothofagus* protection forest are still intact. Extensive sheet erosion is in evidence on the cleared lower front country, while the potential for slip erosion is moderately high over large areas. Considerable trouble has been experienced with rivers and streams emerging from this area and its hydrological importance is very great as up to 30% of peak flooding in the Wairau can arise from this area which is only 8% of the total catchment surface. Despite intensive practical farm-scale trials of pastoral development on these sites, the conclusion has been reached that the optimum land use for this area is forestry in terms of both economics and conservation (Macarthur, 1970).

On the southern tributaries or true right bank, it is estimated that there are 88,000 acres in the medium altitude range of 1,500 to 3,500 ft. These areas have proved suitable for the exotics mentioned above with good forest production potential. Associated with these areas are some 230,000 acres of higher altitude montane sites which will require revegetation measures, principally with grass, legume, scrub and (in places) tree species in association, or as an ecological succession, in intimate mixture.

The scope for dual-purpose forestry in the Wairau therefore comprises some 84,000 acres of low altitude steepland sites, in *Pinus radiata,* with an average site index of 80 plus (Macarthur and Blakeley, 1967) and rotations of 25 to 30 years or less and some 88,000 acres of medium altitude steepland sites in Douglas fir, larch, *Pinus nigra* or *Pinus contorta* with estimated site indices of 20 to 30 and rotations (to millable size) of 80 to 100 years.

The location of these various areas requiring protection forest (*in toto* or in part) are shown in Fig. 1, and the estimated areas are based on the land inventory surveys of the whole of the Wairau Catchment (Dunbar, 1956). In addition, areas above the 3,500 ft contour level and rising to 5,500 ft, have been classified as "revegetation" zone in which tree growth would play only a limited part. Existing areas of tall scrubland and *Nothofagus* forest have also been excluded and the whole reduced for mapping purposes to 4 miles/inch.

These data are further summarized in Table 4.

THE RELEVANT FACTORS IN EVALUATION

General

As stated above in the introduction, it is essential that the hypotheses or assumptions underlying the various factors used in a cost/benefit analysis be clearly stated at the outset.

In the following analysis these basic assumptions have been made:

(a) That a short-term analysis of such long-term physical changes in catchment condition and vegetation would be quite misleading and erroneous.

(b) That the restoration of the steeplands defined will, in fact, have the hydrological effect on catchment condition of the order that Thomson (1965) and the Food and Agriculture Organisation Report (1969) suggest, and provided, of course, that the balance of the catchment and the less critical areas are retained without deterioration.

(c) That the land use of land capability classes I to VI (373,-000 acres or 34%) of the total catchment area (being mainly pastoral and arable use) while undoubtedly playing a major part in the pastoral and industrial activity of the catchment is not likely, because of the generally low erosion hazard and full vegetation cover, to greatly affect the overall position hydrologically.

Costs

Costs involve fire control and wildlife control. These are basic costs that can be fairly readily assessed. The other and major costs are forest establishment and maintenance and revegetation similarly. There are only limited data here as a guide. Current research is constantly adding to our knowledge but at present it would appear that anything between a few dollars and \$60 per acre is required for direct seeding of tree species on medium altitude right bank sites. (Hand planting of *Pinus radiata* at low altitude or *Pinus contorta* at high altitude would cost \$60 per acre.) Revegetation with heavy complete fertilizers, legumes and grasses would not be less than \$50 per acre, on present experience, on more difficult sites; at least \$20 per acre in favourable sites. Maintenance costs of \$2 per acre would not appear to be unreasonable for low altitude sites and \$0.1 to \$0.2 for the higher altitude lands. I have included noxious animal and fire control within these maintenance figures.

Benefits

These may be broadly classified into on-site and off-site and further into tangible and intangible benefits.

(1) On-site tangible benefits would comprise returns from salable wood produce and preservation of land values through soil saved from loss. (This latter is expressed in terms of site productivity — *i.e.*, wood produce — and is not further considered.)

(2) Off-site, are reduced costs of river protection works. Thomson (1965) estimates that this saving would be of the order of \$20,000 per year. There is also the reduction in frequency of peak flood flows estimated by Thomson. The 180,000 cusec flood would occur only once every 500 years instead of every 70 years if no action is taken. The effect of this cannot be predicted with any accuracy, but a more likely event is that, some time in the next 100 years, a peak flood in excess of 180,000 cusecs will overcome the protection works and cause damage to the extent men-

tioned earlier, *i.e.*, of the order of $3.0 million (1970 values). Even so, there will still be lowered agricultural production owing to higher water-tables and the need for increased drainage facilities — higher more frequent flood levels, plus silt and gravel deposition raising main bed levels. It would not be unrealistic to allow $5,000 per year for this factor. The potential benefit of the water resources of the catchment must be included in this study. At present only very limited use is made of this for agricultural irrigation, mostly through groundwater. The hydro-electric water potential of the upper Wairau is also contemplated as part of the proposed Braeburn (Upper Buller) scheme and would involve some diversion of this upper catchment flow through the St Arnaud Range to Lake Rotoiti. What effect this would have on the flow pattern of the Wairau River is unknown and is complicated by the possibility of a dam across the Acheron River on the Molesworth with diversion back to the Wairau.

Ignoring these possibilities meantime (natural gas and nuclear power being probable alternatives to a costly Braeburn Scheme), the irrigation potential of the Wairau Valley should be considered. Irrigable lands here are estimated at 95,000 acres and, with Blenheim Borough using 5.0 cusecs now and likely to expand to well over several times this amount and with one large single industry alone capable of requiring 50 cusecs, the full usage of all available water from the catchment appears a distinct possibility within 80 years — the period taken for this study. But what if the present low flow of 400 cusecs were to be badly reduced by the neglect of the hard core critical steeplands? There is ample evidence that this could happen (FAO, 1969).

If it is assumed that one cusec will meet the moisture deficit on 200 acres and if it is also assumed that the extra agricultural production value resulting from irrigation is $50 per acre, one cusec has therefore a gross value of $10,000. The industrial value of a cusec could no doubt also be very high as water is often an essential raw material in the manufacturing process or is vital to machinery operation as a coolant. Its absence can mean cessation of production.

Taking a pulp mill using 20 cusecs of water with a daily production of 400 tons of pulp and paper products valued at $150 per ton, loss of production for even one day could be $60,000 or $3,000 per cusec. (New Zealand Forest Service, 1969.) Alternatively, the prospect of a deteriorating base flow can mean the costly alternatives of either siting the industry elsewhere or of providing storage.

If it is assumed that a deteriorated catchment leads to a loss of only 20 cusecs that would be available from a treated catchment and that the cusec value is $5,000, the annual loss of production value is $100,000. This could be assumed to be an annual loss commencing in 30 years' time and carrying forward to year 80.

The Wairau Riverbed

Another off-site area affected by the river regime comprises the floodable but usable land within the floodway and berms of the Wairau Riverbed. These areas are extensive (some 30,000 acres) and plans are in hand following in the wake of river control measures to use a proportion of this land for pastoral purposes, lucerne, hay, and forestry with poplar culture and exotic timber production (Pascoe, 1968).

Probably a major effect of a protective programme would be to improve water quality with a marked reduction in sediment discharge. (The Wairau River is a notoriously "dirty" river.) Apart from the intangible values of improved water quality, the direct value will probably be reflected in a reduced need for filtration plant which is the necessary prerequisite for domestic or industrial use. Some allowance should be made for this.

Intangible Values

In addition to the above are intangible values such as maintained or improved recreational values both on-site in the forest areas and downstream along the river banks (less sediment, better fishing, better river access, better swimming, etc.). Preservation of natural and exotic fauna and flora on-site and off-site (ducks and swans) can be claimed in part.

Tourism and recreation could possibly lend themselves to a more detailed analysis. The Wairau Valley is the gateway to the South Island through the Tuamarina Valley and the main West Coast highway runs 50 miles up the valley, while the Tophouse-Island Pass route of 30 miles attracts many visitors even today as a private road. It is, however, beyond my capacity to express this aesthetic improvement in cash terms. The number of intangible benefits could no doubt be increased without difficulty.

A BRIEF MONETIZED COMPARISON

It now becomes necessary to compare these cost and benefit values in order to determine the financial justification for the protection measures suggested on the assumed basis listed above. The following analysis is entirely academic and intended to indicate merely on a rough generalized basis the approximate balance between costs and returns over a reasonably long period of eighty years. No allowance is made for inflation or for technological advances. An interest rate of 5% is assumed throughout except as otherwise shown.

Ignoring the intangible benefits and the pastoral, agricultural and industrial sector of the catchment (except for water use), and dealing only with the protection/production forest and revegetation sector, admittedly in simple terms, costs could be expressed as follows:

Basic Assumptions for Costs

(1) Low altitude *Pinus radiata* protection/production forest of, say, 80,000 acres. Assume an establishment cost of \$60 per acre, no pruning or thinning, and an annual maintenance cost of \$2 per acre; there would be three rotations harvested over an 80-year period, the second and third rotations costing merely \$20 per acre for re-establishment by natural seeding.

(2) Medium altitude *Pinus* and Douglas fir protection/production forests of 88,000 acres. Assume an establishment cost of \$20 per acre, mainly by aerial seeding with some hand planting, and with an annual maintenance cost of \$0.10 per acre (includes wildlife and fire control) and without any pruning or tending. Assume an 80-year rotation.

(3) High altitude protection zone of gross 230,000 acres of which assume 60% or 138,000 acres physically treatable with revegetation by grass, legume, scrub and some tree species. Assume costs to be \$50 per acre over 70,000 acres (less favourable sites) and \$20 per acre over the balance of 68,000 acres with maintenance at \$0.2 per acre (includes wildlife and fire control).

Basic Assumptions for Benefits

(1) Value of wood produce. For the low altitude *Pinus radiata* forests returns have been estimated at 7,000 cu. ft/acre at 6 cents/cu. ft royalty. For the medium altitude forests a yield of 6,000 cu. ft/acre at 80 years is assumed at 2 cents/cu. ft.

(2) Value of sustained or improved base flow of water from catchment for agricultural or industrial purposes. Assume a loss of 20 cusecs valued at \$5,000 per cusec, this loss occurring only in the years 30 to 80.

(3) The value of savings in costs of river protection works is \$20,000 per year over 80 years.

(4) The prevention of only *one* catastrophic flood which could cause damage valued at \$3.0 million on present-day values could be estimated to occur at, say, year 50. Assume this value to increase at 4% per annum growth factor to \$21.3 million at year 50 when the flood is assumed to occur.

(5) Assume savings in agricultural production to be \$5,000 per year on the protected land.

(6) Similarly it could be assumed that some 10,000 acres of unprotected berm land would continue in productivity under a protection scheme. Assume this to be only \$2 per acre per year.

(7) Assume that the protection work will have a marked and significant effect on water quality and that this results in a reduced need for water purification systems by the year 40 to the value of $2.0 million.

Summation of Costs and Benefits

In the following summation, all future costs and benefits have been discounted to present values.

Costs

		$ *million*
1.	Low altitude forest establishment (80,000 acres) at $60/acre	4.8
	Future re-establishment on 27-year rotation at $20/acre	0.5
	Maintenance at $2/acre/year	3.1
	Sub-total	8.4
2.	Medium altitude forest establishment 88,000 acres at $20	1.8
	Maintenance at $0.10/acre/year	0.2
	Sub-total	2.0
3.	High altitude revegetation and protection zone 70,000 acres at $50	3.5
	68,000 acres at $20	1.4
	Maintenance at $0.20/acre/year	0.7
	Sub-total	5.6
	Total costs	16.0

Benefits

		$ *million*
1.	Wood produce; low altitude forests — three crops over 80 years	12.0
	Wood produce; medium altitude forests — one crop in 80 years	0.2
2.	Improved water flow; 20 cusecs from year 30	0.4
3.	Savings in river protection costs $20,000 per year	0.4
4.	One flood at year 50 (present cost $3.0 m). Assume growth rate of 4%	1.9
5.	Savings in agricultural production, $5,000 per year	0.1
6.	Savings in productivity of river berm lands — $20,000 per year	0.4
7.	Value of improved water quality from year 40 onwards	0.3
	Total benefits and benefits	15.7

The V/C ratio is 15.7/16.0 or approximately at break-even point.

Some conclusions to be drawn from this admittedly simplified analysis could be as follows:

First, the case for the large-scale revegetation and reforestation of the critical steeplands of the Wairau catchment appears to be reasonably justified economically considering tangible factors only. At the very least, it appears within the bounds of possibility and therefore should be studied further and in more detail.

Secondly, no such conclusion would have been possible if a short time period analysis were made. Many of the benefits are only received after periods varying from 40 to 80 years. It would seem that only long-term studies of the order of 100 years should be used for considering questions of conservation and restoration of eroded catchments.

It is shown, I feel, that if we do nothing to arrest the present downward trend of a very large part of the Wairau catchment the losses are likely, in the long term, to be substantial, and severe. On the other hand, the remedial measures, whilst both extensive and expensive, have considerable productive and protective values apparently (on casual examination) equally as great as the costs without considering intangible benefits.

Thirdly, a very large part of the benefit is derived from the low altitude, productive, protection forests. Logically therefore this aspect should be given very high priority in any watershed management plan.

Fourthly, it is very plain that if the costs of medium altitude afforestation and high altitude revegetation can be reduced from the level of the figures quoted, the benefit/cost ratio becomes much more favourable. The corollary therefore is that with such large sums at stake much more should be spent on research into these aspects of restoring watershed cover and investigating their effects on water discharge.

One might also wonder whether the high altitude revegetation work, where the benefits are so long term and indirect, should in fact be a legitimate cost within the benefit/cost analysis. After all, nationally, we do not normally include other long-term aspects of the infrastructure such as defence and hospitals in studies of this kind. If part or all of this cost were excluded from the analysis, the result would be even more favourable to the conservation programme.

Intangible benefits also cannot and must not be ignored. Man's intuition (or more basically, his instinct for survival) continually suggests that in the long run they may become very critical to his future progress at levels and in ways as yet undreamt of. Both popular lay opinion and informed technical reasoning support this important consideration.

Lastly, the interdependence of each land unit in the catchment must be realized. It is fairly obvious that no single one of the programmes outlined could succeed without the other. The treatment of the catchment must be approached on the basis of an overall integrated programme with regard to the catchment as a whole.

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