Ecologically Derived Guidelines for Managing Two New Zealand Lakes

ALAN F. MARK
Botany Department
University of Otago
Box 56
Dunedin, New Zealand

PETER N. JOHNSON
Botany Division
DSIR, Private Bag
Dunedin, New Zealand

ABSTRACT / Lakes Manapouri and Te Anau, in Fiordland National Park, became the center of a major controversy after the New Zealand government offered their water resource to an overseas aluminum smelting consortium for electricity generation. Although the scheme proceeded, the lake levels were not raised as originally proposed. Rather, government sought guidelines to optimize hydroelectric potential while maintaining ecological stability of the vulnerable, largely forested, glaciated lakeshores. Guidelines were derived by relating the vegetation zonation to the natural lake-level fluctuations recorded daily for 37 years. A *high operating range* in the upper third of the lakes' natural ranges, based on flood tolerances of the woody shoreline species, restricts both duration and frequency. A *low operating range* (ca. lower third) safeguards stability of shoreline sediments by limiting drawn-down rates, duration, and frequency. The *main operating range* (ca. middle third) has few limitations. These guidelines, which allow utilization of ca. 93% of the water resource, have now been verified by instances of flooding and draw-down rates that exceeded the natural rates recorded earlier. The guidelines were officially accepted by the government in 1977 as a basis for managing the valuable multiple resources of these two lakes and their environs, and they were formalized in legislation in 1981. The details and merits of the guideline approach are discussed.

A formal agreement in 1959 between the government of New Zealand and an overseas multinational consortium to allow development of the hydroelectric potential of two impressive lakes (Manapouri and Te Anau) in New Zealand's largest National Park (1,023,520 ha) initiated a major conservation and political controversy that persisted for more than two decades. Recently the controversy was resolved to a satisfactory compromise. A case study of this controversy (Mark 1985) did not attempt to explain the details or ecological basis of the lake operating guidelines that are now formalized in legislation. While that is the purpose of this article, some other aspects of the controversy will be summarized here so as to place into perspective the scientific studies and their applications to lake management.

The interconnected Lakes Manapouri (14,245 ha) and Te Anau (35,740 ha) form part of the eastern, more accessible boundary of the once heavily glaciated and largely uninhabited Fiordland National Park in southwestern New Zealand (Figure 1). This region of high rainfall not only provides a favorable forest climate but also considerable hydroelectric potential for lakes with large catchments, adequate elevation, and proximity to the coast. Tourism in the region is being promoted and developed by both government and private enterprise under the supervision of the national parks administration. The undoubted scenic and recreational attractions of Lakes Manapouri and Te Anau (Figure 2) are significant in this context.

Among a range of proposals to harness the hydroelectric potential of these two lakes and their extensive catchments (Manapouri 1308 km^2 and Te Anau 3302 km^2) the one finally approved in the formal agreement between the government and the consortium involved construction of an underground power station some 180 m beneath the West Arm of Lake Manapouri with a 9.8 km tailrace tunnel to a new outlet at the head of Doubtful Sound on the west coast (Figure 1). The natural outlet of Manapouri was to be dammed and both lakes raised (Manapouri by 24 m, Te Anau only slightly) to create a single lake, the maximum level of which was set by the intent not to flood the township of Te Anau on its southeastern shore (Figure 1). When, in 1963, the government, at the request of the consortium, agreed to construct the power scheme on the same basis as the consortium would have done, water rights were formally exchanged for power rights in a new agreement. Despite this agreement, subsequent engineering investigations revealed that Lake Manapouri could be raised at most only 11.3 m. As a result, Te Anau was to become a storage lake with a control structure at or below its outlet. The agreement, however, provided for the level of Lake

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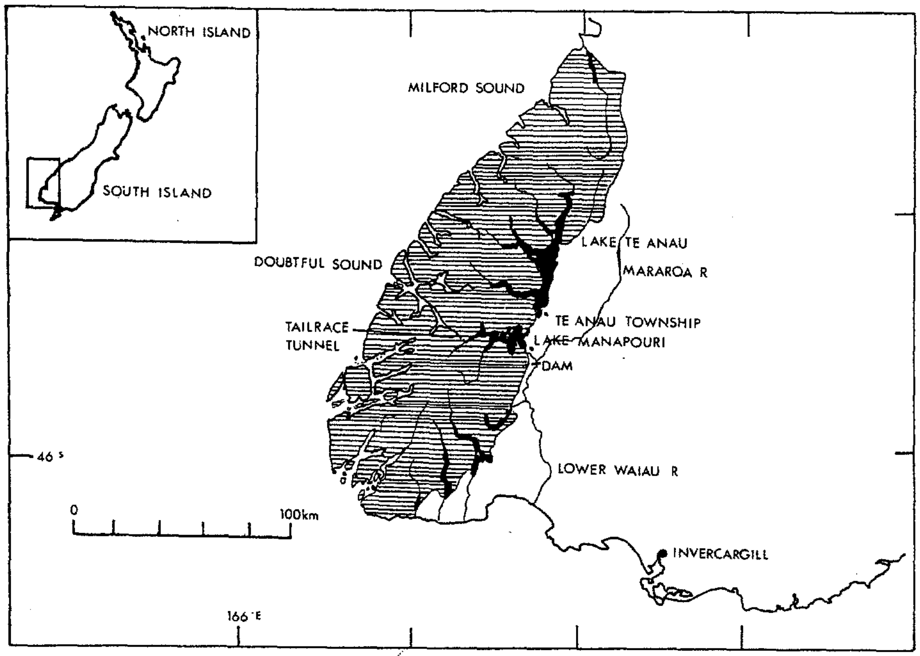

Figure 1. Map showing Lakes Manapouri and Te Anau forming the eastern edge of Fiordland National Park (*hatched area*) in southwestern South Island, New Zealand.

Figure 2. View northward across Lake Manapouri from above its Hope Arm showing tortuous forested shorelines, localized sandy beaches, and numerous islands.

Te Anau to be fluctuated up to 6.10 m, considerably beyond its natural range of 3.48 m, so as to retain the maximum head of water possible on Manapouri, the range of which was also to be almost doubled, from 4.82 m to 8.38 m.

Development of the hydroelectric potential was planned in two stages, the first, beginning in 1963, to involve the underground power station and associated access and tailrace tunnels as well as roads and transmission lines. The second phase was to control the level of Lake Te Anau and raise the level of Lake Manapouri to increase the overall efficiency of electricity production. There was considerable public expression of concern about the overall scheme, particularly about the proposals for lake raising and control that were conceived by government engineers and took no account of environmental or ecological aspects. These proposals violated the principles of a national park, including its legislation. Validating legislation to cover contravention of the 1952 National Parks Act was passed nine months after the formal agreement was signed.

A general lack of official information further aggravated the public, and what was released did nothing to allay their fears. A special Cabinet Committee of the government's senior politicians reported in 1970 that the average annual electrical generation of the Manapouri power station would be increased by a mere 4.3% (222 GWh) with the proposed raising of Lake Manapouri's level. Furthermore, it was revealed that an unraised lake could meet the consortium's legal entitlement of power for some 97% of the time and, if raised, could still not achieve this for all of the time. Thus the increased energy production possible with lake raising was considered by the many opponents of the scheme to be insufficient to justify the loss of extensive lakeshore environments (Te Anau ca. 320 km; Manapouri ca. 170 km) and the ecological instability that was predicted. The controversy resulted in two substantial petitions from New Zealand's largest conservation group (26,864 signatures in 1960 and 264,907 in 1970) and justified the establishment of a Commission of Inquiry, which reported within a year, in 1970, that "a considerable and highly responsible section of the community while accepting ... the large-scale aluminium industry ... is deeply concerned with the proposed raising of the level of Lake Manapouri." In addition, it determined that, despite official claims to the contrary, "the Crown [that is, N.Z. government] is contractually bound to Comalco [the consortium] to raise the level of Lake Manapouri." However, it also accepted that, if the level were raised, a number of beautiful islands would be submerged and the appearance of the lake detrimentally affected, the clearance of lakeshore forest would have to achieve a higher standard than that being recommended by the government, certain botanical features would be irretrievably destroyed, there would be serious damage to fishing and bird life, and it would probably take very many years for beaches to be reformed, but that a permanent serious setback in tourism was unlikely. The commission also found that the levels for Lake Te Anau had been set unacceptably high by the engineers responsible and now posed a threat to Te Anau township. The commission's recommendation that this level be lowered was adopted by the government, which by now was also preparing for another general election (October 1972).

The lake issue became a major controversy of this election, with the ruling party (National) undertaking to defer a decision on lake raising for six years while making provisions for it in the design of Manapouri's control dam. By contrast, the opposition party (Labour) undertook to operate both lakes within their natural ranges despite the formal agreement with the consortium and to design the dams accordingly. Meanwhile, some scientific studies had been undertaken, chiefly designed to assess the likely impacts of fulfilling the lake-raising proposals.

Scientific and Environmental Impact Studies

Surveys designed merely to establish the scientific aspects of the natural environment, particularly vegetation and animal life that were threatened with the lake-raising proposals, were carried out almost a decade after the initial decision and largely in response to the expressed public concern. Results of these studies were published only summarily as part of the wide-ranging report of the Cabinet Committee on Lake Manapouri (1970).

These surveys were followed by more detailed studies of shoreline plant ecology of both lakes, aimed particularly at understanding the patterns of lakeshore vegetation and assessing the environmental consequences of the proposed lake level changes for each lake.

The vegetation zonation pattern was found to be generally similar for both lakes, with such factors as elevation, substrate, and exposure to prevailing westerly winds being the most significant (Johnson 1972a and b, Mark 1972, Mark and Johnson 1972, Mark and others 1972). Elevation effects were largely a response to the natural fluctuations in lake levels and on the sheltered, more vegetated sites underlain by unconsolidated sediments—gravels, sands, or silts—there is a distinct zonation pattern (Figure 3) involving a sequence of up to seven plant communities (Johnson 1972a and b). In order, from below, there is a zone of aquatic vegetation that extends down to deep water (ca. 6 m below mean lake level) and is rarely if ever exposed. Dense carpets of *Isoetes alpinus, Myriophyllum elatinoides,* and locally the adventive *Elodea canadensis* Michx. form the lower part of this zone, with *Potamogeton cheesemanii* and *M. propinquum* more important in shallower water where the zone merges with subaquatic herbs of a species-rich turf. [Nomenclature follows Allan (1961) for all plant species except the monocotyledons, which follow Moore and Edgar (1970) unless authorities are cited.] This lake-edge turf occupies a relatively narrow vertical range of up to 1.8 m and consists of a diverse flora of some 45 species with generally similar growth habit (Johnson 1972b). On very gentle slopes a sedge zone dominated by *Carex gaudichaudiana* ca. 25 cm tall may form a belt some 50 m wide involving almost 1 m elevation, which merges upslope into a conspicuous zone of wiry jointed rush (*Leptocarpus similis*) up to 1 m tall. This brown fringe of rush in turn grades into a belt of scrub, typically dominated by the ubiquitous myrtaceous shrub *Leptospermum scoparium,* which may be several meters wide on gentle slopes. This "manuka" scrub increases in height upslope to ca. 12 m and merges with the lower edge of lakeshore forest. On rocky shoreline sites exposed to the prevailing westerly winds, vegetation is sparse and composed mainly of mosses and shrubs, and the lower forest edge is forced well above mean lake level by strong wave action, but on more sheltered rocky shores the forest abruptly replaces almost bare rock slightly below maximum lake level.

Figure 3. Vegetation zonation at Brod Bay, Lake Te Anau, showing the pattern typical of sheltered nonrocky sites. In order from the left the zones are: aquatics (partly exposed because of the low lake level), turf, jointed rush, manuka scrub, and beech-podocarp forest. Lake level 201.76 m, 6 March 1974.

The type of forest varies with slope, rock type, and the precipitation gradient across the lakes—from ca. 1150

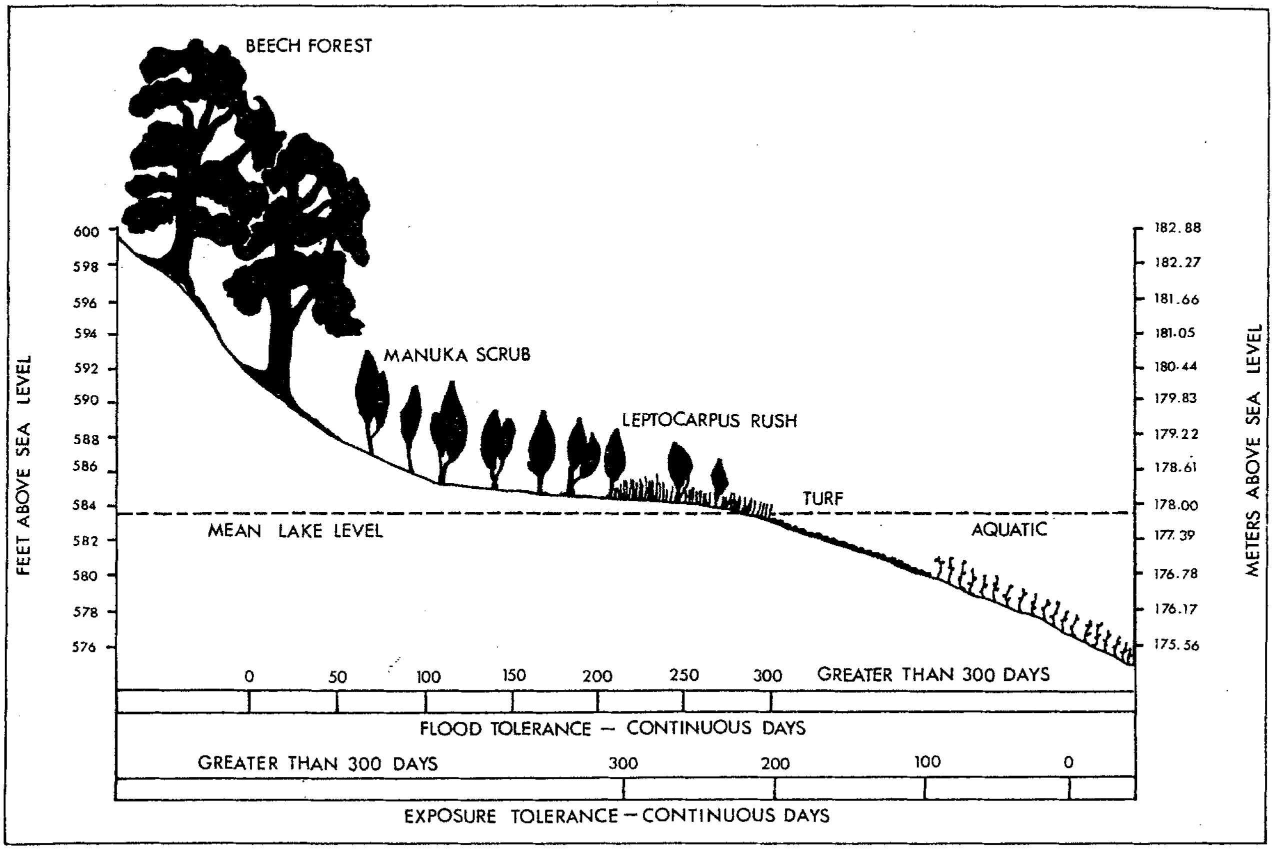

Figure 4. Diagram of typical shoreline vegetation zonation pattern on sheltered, nonrocky sites at Lake Manapouri. Distribution of each of the five zones is shown in relation to elevation and tolerance values to flooding and exposure that have been assumed from analyses of the 37-year record of daily lake levels.

mm annually along the eastern shores to ca. 3800 mm at their western extremities. Evergreen southern beech (*Nothofagus*) dominates most forested areas around the lakeshore. Mountain beech (*N. solandri* var. *cliffortioides*) is widespread, and silver beech (*N. menziesii*) is largely restricted to the wetter western regions. In wet depressions behind storm beaches and on low-lying flats (like those that occur extensively at the head of the Hope Arm of Lake Manapouri) are stands of semiswamp podocarp forest dominated by tall trees of *Dacrycarpus dacrydioides* (A. Rich.) de Laubenfels. Other podocarps, particularly *Dacrydium cupressinum,* emerge as scattered trees through the beech forest of the lower slopes, while the smaller *D. intermedium* is prominent with mountain beech on thin soils of steep slopes under high rainfall above the west and north arms of Lake Manapouri (Johnson 1972a). On the mainland, the larger islands, and the smaller ones close to the lakeshore, introduced red deer (*Cervus elaphus*) have opened out the forest interior by removing palatable plants. But on the several smaller islands more distant from the lakeshore, particularly on Lake Manapouri, palatable species, together with deep carpets of moss, persist in the absence of deer and there is also an abundance of normally epiphytic orchids (*Dendrobium cunninghamii* and *Earina autumnalis*) on the ground in well-lit areas. These islands, which are important in providing the only known remaining baseline of unmodified vegetation in eastern Fiordland, would all have been submerged with the proposed lake raising.

The conspicuous zonation pattern of lakeshore vegetation and flora, together with the consistency of its pattern between the two lakes (Johnson 1972b), suggested a dominant control by natural lake level variation. Indeed, analysis of the daily records collected by the N.Z. Electricity Department over the previous 37 years provided a strong correlation with the zonation pattern (Figure 4). In particular, values for the lower forest edge indicated that the beech trees would be likely to tolerate no more than about 55 days of continual submergence of their root systems, while for the shrub zone the period was up to 256 days. It was obvious that the proposal to raise the level of Lake Manapouri by at least 8 m took no account of these limitations. Even with Lake Te Anau, where the modified proposals for control (following the government's response to the Commission of Inquiry) did not involve exceeding the natural maximum level but, rather, maintaining high levels for unnaturally long periods, widespread damage was predicted on the basis of these studies (Mark and others 1972). Some 106 km or 44% of the forested shoreline of the lake, underlain as it is by unconsolidated sediments, was considered to be vulnerable to high water tables maintained for unnaturally long periods. This judgment was based on transect studies across representative shoreline sites and on an examination of root distribution and diameter growth rates of trees growing along the lake margin (Mark and others 1972).

Additional scientific studies were made following the decision of the new (Labour) government in 1972 to operate both lakes within their natural ranges rather than to proceed with lake raising. The responsibility for advising on management of the lakes was given to the Guardians of Lakes Manapouri and Te Anau, a group appointed by the government in April 1973 from among those who had led the campaign against lake raising. Despite their long involvement in the controversy and their knowledge of these lakes, the Guardians' only relevant professionals were a civil engineer and a plant ecologist. The Guardians were, however, given access to all official information pertaining to the scheme and, equally important, were able to commission additional scientific studies. The need to obtain a better understanding of lakeshore sediments and lacustrine processes was apparent from the collapse and slumping of localized sections of Manapouri's shoreline when that lake was lowered some 54 cm below its natural minimum for the first time in August 1972 (Figure 5). Although this shoreline collapse was studied briefly at the time (Andrews and McKellar 1973, McKellar 1974), more detailed information was required to determine management guidelines. Such a study of the lacustrine geomorphology of both lakes was soon completed (Pickrill 1976 and 1978a). It confirmed the apparent vulnerability of the beaches, related to their glacial origin ("incompetent" sediments, combined with narrow shelves that generally graded into very steep slopes).

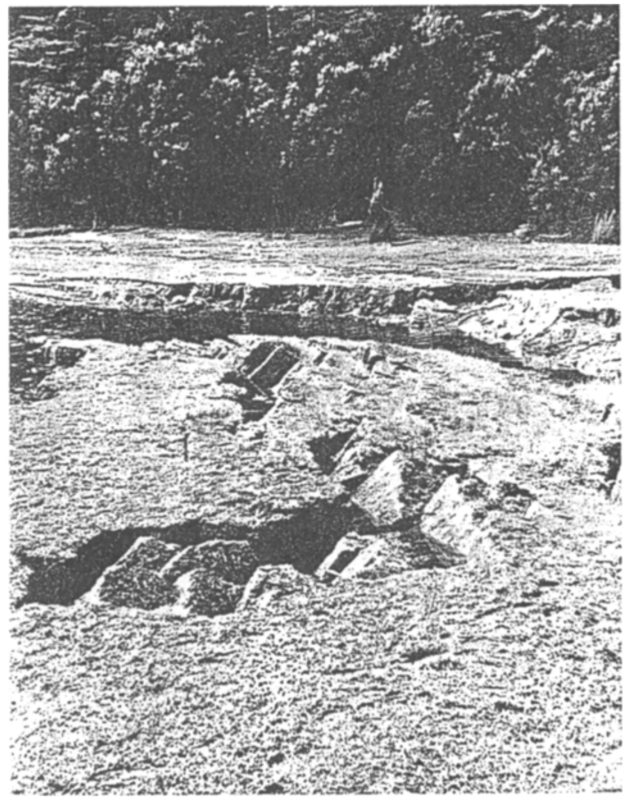

Figure 5. Collapse of shoreline through rotational slumping of fine sediments at Surprise Bay, Lake Manapouri, following the drawing down of its level at faster than natural rates to ca. 54 cm below its recorded natural minimum level in August 1972. Lake level 176.39 m, 3 March 1973.

Operating Guidelines Developed by the Guardians

The obviously separate problems of high and low lake levels within the lakes' natural ranges clarified the Guardians' need to recognize three categories of lake level operation in order to retain ecological stability of the shorelines. These categories have been termed the *high, main,* and *low operating ranges,* each occupying about one-third of the natural range of each lake.

In the *high operating range,* the problems are associated with the death of woody vegetation when the tolerance limits of its species are exceeded by either direct flooding or prolonged high water tables. The relevant information was derived from the results of the plant ecological studies described above. Two factors required consideration here: (a) the maximum period at any particular level above the main operating range, and (b) the minimum interval between periods at any particular level that would allow adequate drainage of water tables. Values for both of these factors were derived from what had been experienced naturally during the wettest of the 37 years for which detailed records were available.

While the Guardians accepted the advantages of maintaining some storage capacity in both lakes, particularly Te Anau, they recommended periodic operation of the lakes up to levels close to their natural maximums to prevent encroachment of woody vegetation, and thereby to retain stable and attractive shorelines. A complicating aspect of applying these guidelines for the high operating range was the assessment of excursions to any particular level in this range that are for shorter periods than the

Table 1. Operating guidelines for the levels of Lakes Manapouri and Te Anau.

Lake Manapouri				Lake Te Anau			
MAIN OPERATING RANGE[a] 176.8–178.6 m				MAIN OPERATING RANGE[a] 201.5–202.7 m			
HIGH OPERATING RANGE[b] Above 178.6 m				HIGH OPERATING RANGE[b] Above 202.7 m			
Elevation (m)	*Max. duration*[c]	*Min. interval between floods to this level*[c]	*Guideline ratio standards*[d]	*Elevation (m)*	*Max. duration*[c]	*Min. interval between floods to this level*[c]	*Guideline ratio standards*[d]
At 180.5	1	100	100.0	At 204.3	1	100	100.0
Above 180.4 and below 180.5	3	100	33.0	Above 204.2 and below 204.3	3	100	33.0
Above 180.1 and below 180.4	9	100	11.0	Above 203.9 and below 204.2	10	60	6.0
Above 179.8 and below 180.1	22	80	3.6	Above 203.6 and below 203.9	22	30	1.4
Above 179.5 and below 179.8	35	40	1.1	Above 203.3 and below 203.6	39	30	0.8
Above 197.2 and below 179.5	44	40	0.9	Above 203.0 and below 203.3	65	30	0.5
Above 178.9 and below 179.2	99	20	0.2	Above 202.7 and below 203.0	125	20	0.2
Above 178.6 and below 178.9	119	20	0.2				
LOW OPERATING RANGE 175.86–176.80 m[e]				LOW OPERATING RANGE 200.86–201.50 m[e]			
Elevation (m)	*Max. duration*[c]	*Annual frequency*		*Elevation (m)*	*Max. duration*[c]	*Annual frequency*	
Below 176.8 and above 176.5	105	4		Below 201.5 and above 201.2	80	2	
Below 176.5 and above 176.2	65	2		Below 201.2 and above 200.9	55	2	
Below 176.2 and above 175.9	52	2		At 200.86	1	<1[f]	
At 175.86	25	<1[f]					

[a]Continuous variation in level required in this range. Long-term mean values of 177.7 m (Manapouri) and 202.1 m (Te Anau) to be achieved as five-year running means (but +0.4 m for Manapouri and +0.1 m to −0.3 m for Te Anau) and also within −0.5 m on an annual basis for both lakes.

[b]Periodic operation up to 179.8 m (Manapouri) and 203.6 m (Te Anau) is required to retain stable attractive shorelines. Operations above these levels is not required for this purpose.

[c]Continuous days.

[d]The guideline ratio standard is obtained as the value for minimum interval/maximum duration and is based on the historical record of natural lake levels. Its application to lake level management is described in the text.

[e]Only in exceptional circumstances should Lake Te Anau be drawn down to 200.86 m. Operation within the low range must not exceed natural rates of drawdown, that is, 0.05 m/day for Lake Manapouri or 0.03 m/day for Lake Te Anau (both averaged over four days).

[f]Exceptional circumstances only with the best endeavors to avoid equinoxial periods (March, April, October, and November), when storms are common.

maximum allowed for that level. For these situations a simple proportioning method, based on the 37-year record of natural lake levels, was adopted, referred to as the *guideline ratio,* which is based on data that have been recorded for the natural regime of each lake. The ratio standards for particular levels (Table 1), against which any episode can be rated, have been derived by dividing the minimum interval (in continuous days) between consecutive floods to a particular level, by the maximum duration (also in continuous days) of a flood to the same level. When the ratio is calculated for a particular event in the high operating range on this basis and is found to be *less* than the guideline ratio standard shown in Table 1, then it is assumed that no benefit could be derived from such a temporary reduction in lake level. Hence no credit is accorded to the period of reduced level; rather, the interval of this period is added to the duration of the period when the lake reached or exceeded the level. For example, if the level of Lake Te Anau had been in the range 203.3–203.6 m continuously for 20 days (maximum permissible is 39 continuous days), then dropped below 203.3 m for only ten continuous days before again rising above 203.3 m, the guideline ratio would be 0.5, or *less* than the 0.8 guideline ratio standard for this range. Thus, the guideline requirements would not have been satisfied and therefore no credit would be allowed for the ten days at the lower level—for guideline purposes it would be assumed that the lake had been above the

203.3-m level for all 30 days. By contrast, if the 20 days with lake level continuously above 203.3 m had been followed by 17 days below this level before rising again to above 203.3 m, the guideline ratio (0.85) would be *greater* than the ratio standard, and credit would be allowed for the 17 days since the guideline requirements would have been satisfied.

Verification of these indirectly assessed guidelines came as a result of exceptionally high inflows in March 1975, when, at the time of the initial storm, there was some delay in opening the gates controlling Lake Te Anau's outlet in an attempt to protect vulnerable earthworks at the Manapouri dam site, then under construction. Subsequently, guidelines for the high operating range were exceeded for both lakes when high levels occurred for unnaturally long periods. The excess was less for Lake Manapouri than for Lake Te Anau, where the guidelines were exceeded on two separate occasions, up to 44 days in April–June and up to 53 days in August–December (Figure 6). The ensuing mortality of forest and scrub species that was apparent on most deltas of the Lake Te Anau shoreline by the following spring was subjected to a detailed study in autumn. There was a high incidence of pinhole borer (*Platypus* spp.) in the affected beech trees by this time, but there was conclusive evidence that mortality was a consequence of prolonged high water tables that exceeded the tolerance limits of many shoreline species (Mark and others 1977). The damage to shoreline vegetation was only locally conspicuous and could not be considered serious, but it was significant in confirming the reliability of the guidelines for the high operating range.

The *main operating range* is defined as that between the high and low ranges where there are no operating limitations. However, fluctuations in levels adequate to prevent development of wave-cut platforms and associated minicliffing are recommended (Table 1). Since substantial deviations from long-term mean levels could be detrimental to the shoreline environment, some restrictions have been placed on this deviation. Limited deviation from the recorded range of annual mean values, since it is advantageous for power production purposes, has been permitted. This has been based on available ecological data (Table 1).

In the low operating range the stability of shoreline sediments and possible impairment of recreational and amenity values are the important considerations. Rates of drawdown, absolute minimums, and maximum duration at particular levels within this range all appear to be important. Natural rates of drawdown are specified (Table 1) to allow adequate drainage of the fine glacial sediments that occupy many sections of the lower shoreline. The geological and geomorphological studies established that these sediments, being "incompetent," are liable to collapse (as occurred in August 1972—Figure 5), if inadequately dewatered as the lake level falls (Andrews and McKellar 1973, Pickrill 1976).

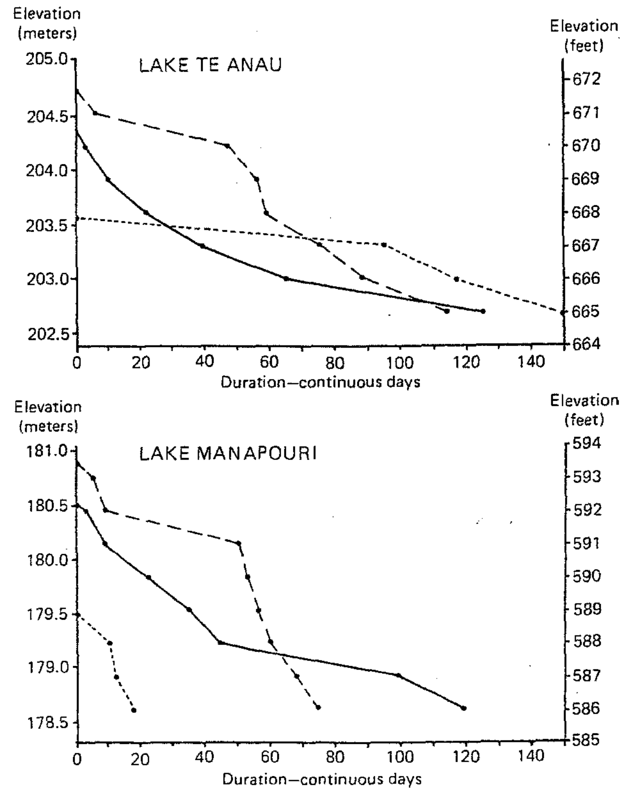

Figure 6. Guideline values for the high operating ranges of Lakes Te Anau and Manapouri (*solid line*), together with lake regimes for two periods in 1975 that resulted in substantial mortality of plants from forest and scrub along the Lake Te Anau shoreline. ●---●, April–June 1975; ●····●, August–December 1975.

Because of the evidence for "combing down" of beach sands, and the very limited resource of these sands (which overlie puggy silt or peat often containing logs) on many of the important beaches (Figure 7), together with the possibility of permanent loss of sand over narrow shelves when lake levels approach their natural minimums (Pickrill 1976), duration limits and annual frequencies both have been specified in this range (Table 1). Recreation may be increasingly impaired, or even hazardous when the lake levels are close to their natural minimums, either because of the proximity of the edge of the shelf on some beaches or because the weak fine-grained sediments that often occur here may be unable to support a person's weight.

Precautions are also required to ensure that wave action from the wake of boats does not damage those sandy beaches that are rendered more vulnerable because of a relatively short fetch (Pickrill 1978b). This problem

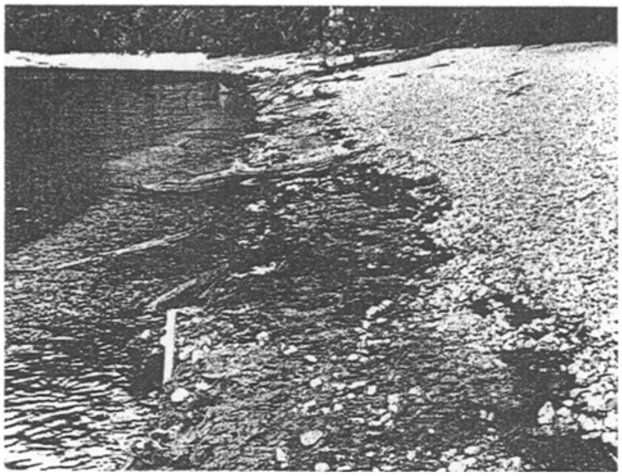

Figure 7. The "combing down" of coarse beach gravels to expose the underlying silt, peat, and wood remains at Stockyard Cove, Lake Manapouri, following an extended period of low lake levels. Lake level 175.76 m, 14 April 1973.

should be addressed by enforcement of appropriate clauses in official motor launch regulations that apply to both lakes and that state that a motor launch shall not exceed 8 km/h when passing within 200 m of the water's edge.

The important trout fishery of the lakes and the invertebrate fauna of the lakeshores were thought not to require special consideration since the lakes were to be operated within their natural ranges. The trout feeding beds of submerged aquatic plants, being located below the natural minimum levels of the lakes, should not be affected. Moreover, only those spawning beds located in the rivers draining each lake could be threatened by unnatural variations in river flow. Gate operating procedures for both the Te Anau and Manapouri Control Structures, while not formally part of the guidelines, have been devised by the N.Z. Electricity Division in consultation with the Guardians and other interested parties (local catchment and fisheries authorities) so as to ensure compliance with the guidelines, as well as to minimize problems of bank erosion and to safeguard the important trout fishery of the rivers downstream. Procedures for the Manapouri Control Structure include an important provision to divert the Mararoa River, which now contributes to the lake, whenever it reaches a state of flooding such that it would carry significant amounts of silt and weeds into Lake Manapouri from its relatively unstable and eroding, largely agricultural catchment.

Computer studies of the electricity production that would be possible while operating the two lakes within these guidelines have indicated that the energy shortfall compared with the raised lake levels originally proposed, amounts to some 432 GWh, or 8.4% of average annual generation. While this is greater than the 4.3% (or 222 GWh/year) official figure used by all parties during the campaign, it includes significant losses associated with unexpected friction in the tailrace tunnel as well as loss of some storage potential in Lake Te Anau.

The guidelines were devised to be as simple as possible, yet they are seen by many as being quite complex. This complexity reflects the many relevant ecological aspects and their interactions that have been considered. Constant surveillance is required by the N.Z. Electricity Division staff operating the power station and, because of the Manapouri power station's substantial output, the restrictions add considerably to the restraints in their operation of the national power system. The Electricity Division attempted to comply with the guidelines as they were being developed and refined, but it has never adopted them as inviolate rules.

Several difficulties face the division's staff in their endeavors to operate these two lakes within the guidelines. The problem of weather forecasting, especially rainfall prediction, is particularly difficult in the Fiordland region. There is also a constant desire not to waste energy by spillage of water merely to reduce lake levels. In addition, conditions in other parts of the New Zealand generation system also have important effects on the operation of the Manapouri power station. Nevertheless, their cooperation with the aims and objectives of the Guardians has been expressed by an undertaking to record in their annual report to the minister of energy the degree of compliance with the guidelines and to explain any departures from them.

Guideline Acceptance

The guidelines, having thus been substantially verified either in practice (high operating range—Mark and others 1977) or through observation and detailed scientific assessment (low operating range—Pickrill 1976 and 1978a), were duly approved and accepted by the government in December 1977. They were, according to a joint statement by the minister of energy and minister for the environment, a "satisfactory compromise between protecting the unique environmental and ecological features of the lakes' system and maximizing the energy output of the Manapouri power station." It was further stated that "the development of these guidelines is the culmination of a long period of hard work, careful communication, and improved understanding among scientists, engineers, and administrators. It is a real achievement in which opposing views have been brought together and reconciled to a very important end." The ministers' statement, however, also made it clear that the guidelines had been accepted as "indicative rather than absolute rules."

A permanent settlement of the Manapouri debate became a real possibility when, soon after, in January 1978, the minister for the environment announced that renegotiation of certain clauses in the agreement with the consortium meant that "the Government is no longer under an obligation to raise the level of Lake Manapouri." Resolution was finally achieved toward the end of the 1981 parliamentary session when the Manapouri–Te Anau Development Amendment Bill, drafted in collaboration with the Guardians, was passed into law unchanged, supported by all political parties. However, such legislation alone will not necessarily ensure the permanent security of these lakes. Continued vigilance will be required, since it is now possible to operate both lakes outside of their natural ranges and even one such excursion could cause substantial permanent damage. It seems reasonable to assume, however, that the compelling weight of responsible public opinion generated by the controversy will continue as a deterrent in the longer term.

While the outcome of this prolonged conservation issue has achieved a satisfactory compromise, the cost in time, money, and human effort and relations has been substantial. It should have served to emphasize to the government that there are values in the natural environment that, although often intangible, are considered by large and responsible sections of the community to be more important than financial returns from the maximum exploitation of those resources. Resolution of this complex controversy also demonstrates the value of careful scientific appraisal both of the potential and the limitations of a natural resource, and the application of this information in the responsible planning for its development. This is a feature which continues to be emphasized in New Zealand (Nature Conservation Council 1981).

Finally, the outcome of the Manapouri debate also reflects favorably on the innovative concept of "Guardians." Here a small concerned group of the general public were appointed by the government to collaborate with both the political and administrative sections of government in an atmosphere of cooperation and mutual trust, with the aim of achieving responsible and worthwhile objectives on a modest budget in the difficult but important field of multiple resource development and management.

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