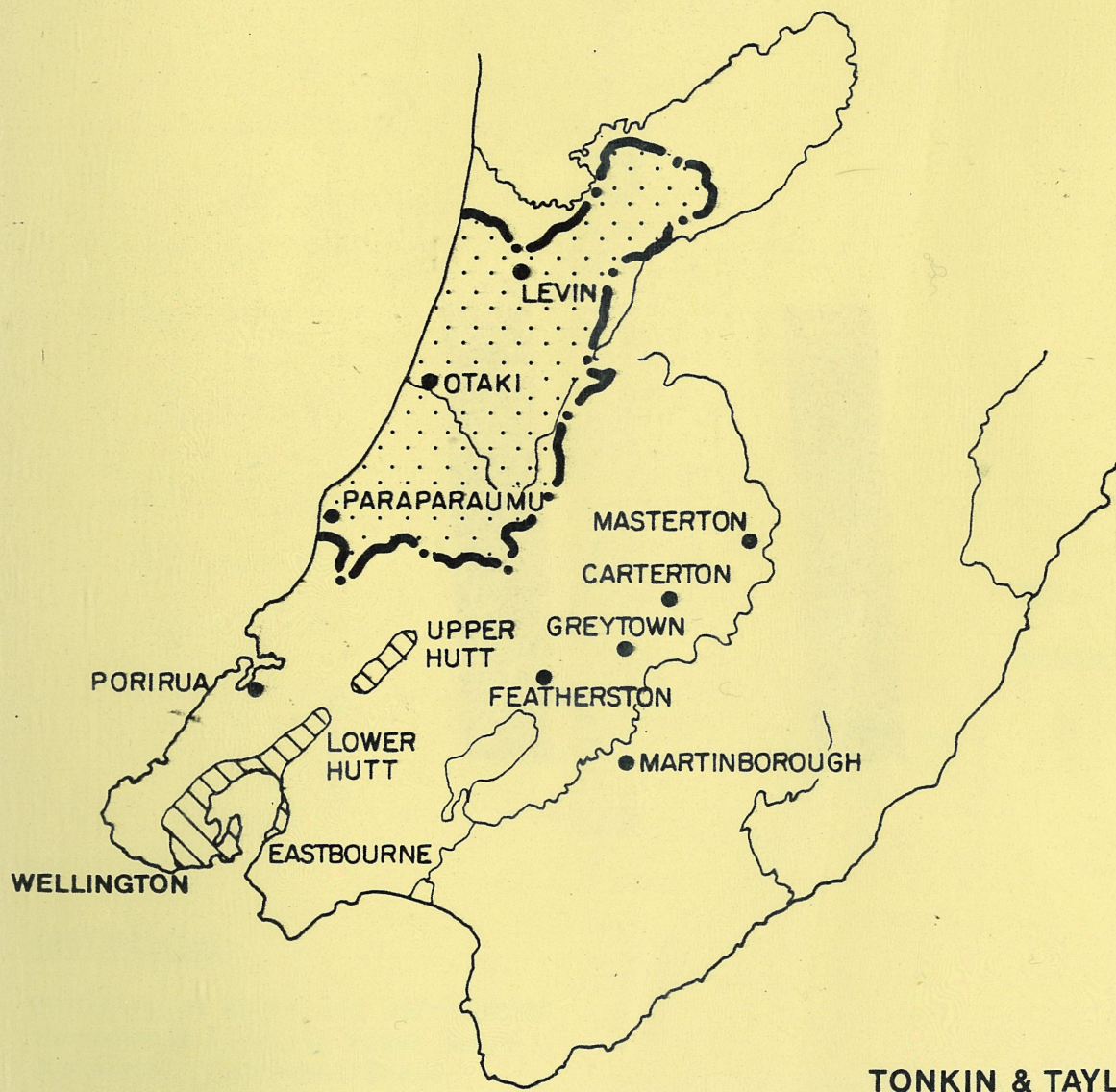




Assessment of Local Hydro-electric Potential

Horowhenua Region



TONKIN & TAYLOR
Consulting Engineers

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REPORT1.0 INTRODUCTION

1.1 SCOPE OF STUDY

In accordance with the brief from the District Commissioner of Works Wellington, by letter dated 19 February 1979, the study region lies within the territory of the Manawatu Catchment Board. It comprises all the territory of the Horowhenua Electric Power Board, but modified at the northern boundary to exclude the Manawatu River while including the Tokomaru and Mangaore river catchments. (Fig. 1.1 and Fig. 2.3).

A draft report, covering Phase I of the study, was submitted on 23 November and discussed at a meeting with the co-sponsors on 11 December 1979. Phase I was limited to a desk study of the hydroelectric potential of the area.

The District Commissioner's letter of 18 December 1979 gave financial approval for completion of Phases II and III of the study. Inspections were made of most of the sites in November 1979 and April 1980.

Existing topographical mapping was supplemented by collation of other local surveys and aerial photographs and by aneroid barometer readings.

The hydrology of the southern part of Wellington province has been reported upon separately. (Ref. 11). Some additional data was obtained for particular Horowhenua sites together with details of the existing Mangahao hydroelectric project.

1.2 ASSESSMENT METHODOLOGY

1.2.1 Perspective

This assessment of the small hydroelectric resources of the Horowhenua region follows the broad guidelines and evaluation methodology established by the study of hydroelectric potential in Northland (Ref. 1). Chapters 3 and 4 of the 'Northland Report' present the basic details of this approach, which was modified in minor respects to reflect certain features of the Horowhenua region.

Reference was also made to the subsequent regional hydroelectric assessments for the East Cape and Nelson Regions Refs. 2 and 7.

Sections 1.2.2 and 1.2.3 which follow present a brief resume of the methods employed for locating and evaluating hydroelectric potential.

1.2.2 Requirements of a Suitable Site

The two fundamental requirements of a site for potential development of a hydroelectric generating station are:

- an adequate and reliably defined flow of water, which may include water diverted from adjacent catchments. The economic viability of hydro schemes is sensitive to errors in flow assessment.
- topography which favours the development of generating head by some combination of dam and conduit. Small hydro installations are likely to be economic only when the water can be made to fall without elaborate and expensive civil engineering works.

Investigations of generation potential should initially concentrate upon these two factors and, if a suitable combination of them exists, proceed to examine the following factors which will have significant effects upon the viability of the scheme:

- topography favouring the storage of water behind a dam; i.e. a valley which is wide and of relatively flat longitudinal gradient upstream of the dam.
- possibility of inclusion of nearby streams or of diversion from adjacent catchments.
- inundation by the storage lake of areas of productive land, scenic attractions or significant human habitation.
- requirements of other competing water uses such as:
 - industrial, agricultural or domestic water supply
 - residual stream flow required to maintain the biological habitat
 - alternative hydroelectric schemes
- proximity of the site to centres of electricity demand, or to existing transmission lines.
- interference with public communication routes, particularly highways and railways which will require diversion.
- possible complementary water uses.
- other environmental factors.

1.2.3 Evaluation of Schemes

A preliminary scanning of potential sites is necessary to identify schemes which exhibit sufficiently suitable engineering and economic characteristics to warrant further study. This is achieved as follows:

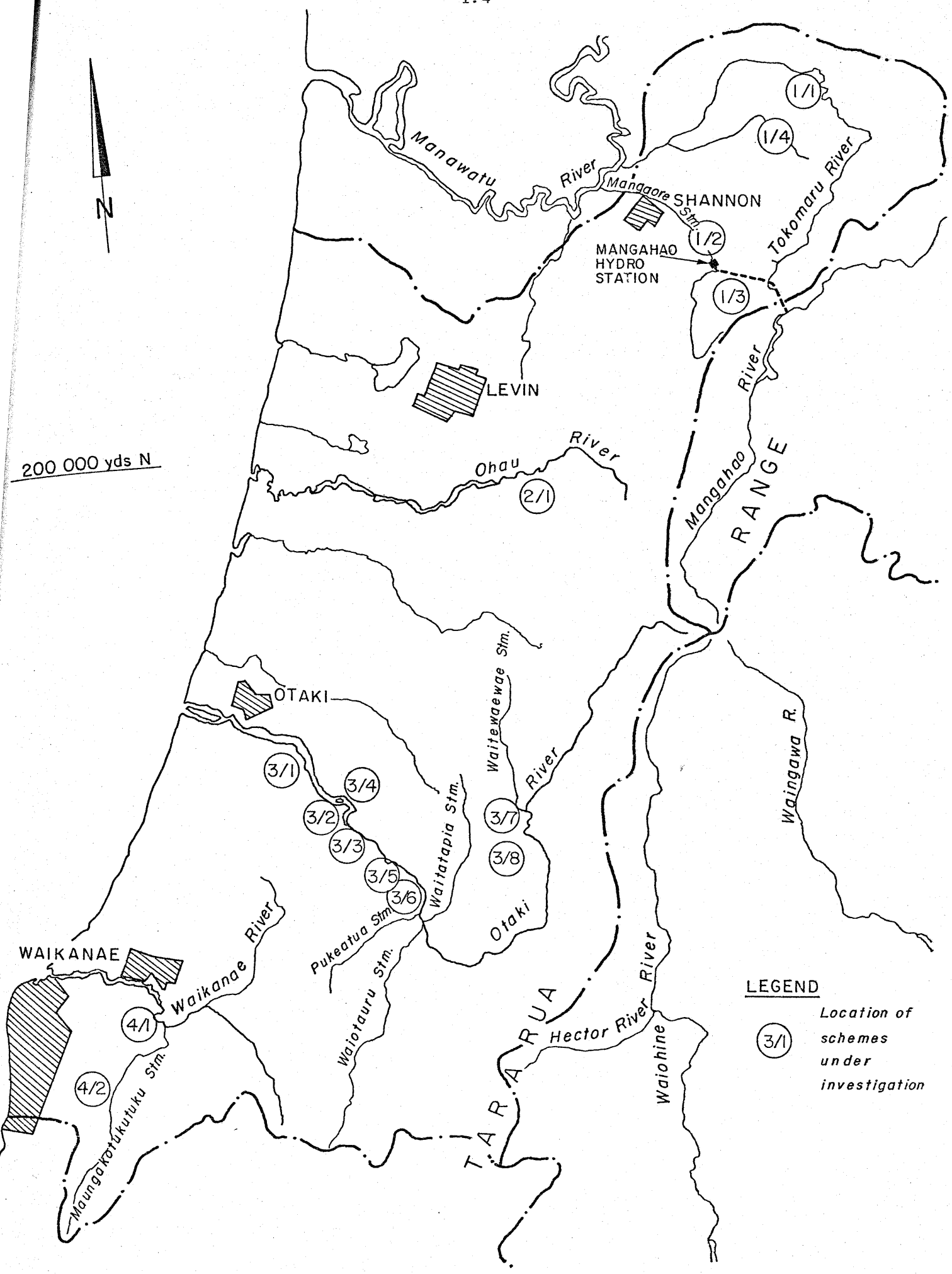
- (i) topography
 - . locate potential sites and identify relevant topographical features from available maps and aerial photographs.
- (ii) hydrology
 - . determine mean and flood flows, and the flow duration characteristics from existing hydrological records.
- (iii) engineering
 - . formulate a probable hydroelectric development configuration to include:
 - conduit from intake to power station
 - power station including turbo-machinery
- (iv) costing
 - . carry out very approximate costing of these items in December 1979 terms - if the scheme costs exceeds about \$2500/kW installed at a plant load factor of 50%, it can be discounted as not warranting further study.

Then, having narrowed the field of investigation, the study proceeds as follows:

- review costing of all the principal scheme components
- first appraisal of apparent environmental factors
- site inspection on the ground and simple survey measurements to identify factors meriting reappraisal of the preliminary findings
- sketching possible scheme components on the site plans
- reappraisal of capital costs, power available and environmental factors
- ranking of schemes worthy of prefeasibility study investigations.



200 000 yds N



LEGEND
Location of schemes under investigation
3/1

HOROWHENUA REGION

2.0 HOROWHENUA REGION

2.1 LANDSCAPE

The area covered by the study extends from Waikanae in the south to Shannon in the north and is bounded on the west by the Tasman Sea and on the east by the Tararua Range. (Fig. 1.1).

The catchments of the study area are those of the Tokomaru, Mangaore, Ohau, Otaki and Waikanae rivers, all of which drain westwards from the Tararua Ranges.

All the catchments are typified by river valleys incised into the greywacke basement rock of the Tararua Ranges and discharging across coastal plains. Adjacent to the foothills, the plains are in the form of alluvial terraces formed of erosion products from the hinterland, while along the coast are extensive sand hills and flood plain deposits.

No waterfalls or steep rapids have been identified at this stage: elevational differences for hydroelectric generation, (i.e. head) would have to be developed by construction of dams in the narrower valleys, formation of canals along the alluvial terraces, or tunnels, or a combination of these features.

2.2 GEOLOGY

The Tararua Ranges are formed of alternating argillite (mudstones) and greywacke (sandstone) - Fig. 2.1 shows the delineation between these rocks and the coastal alluvial sands and gravel. Some additional detail is provided by N.Z. Geological Survey mapping, (Ref. 9). The greywacke/argillite sandstones and their alluvial derivatives on the coastal plains would be suitable for construction of rockfill dams, or of concrete dams and other hydraulic structures.

Although only the Waikanae catchment is traversed by a fault known to be active, all catchments lie in the Wellington seismic region and seismic activity is to be expected.

2.3 RAINFALL AND RUNOFF

The mean annual rainfall varies widely over the area with the highest falls around 6000 mm occurring in the Otaki watershed. Further north and on the east the rainfall decreases to around 1000 mm per annum.

The stream flow records reflect the distribution of annual rainfall, and, apart from the Otaki river, flows are relatively meagre and the flow distribution too variable to be favourable for hydro generation.

Because of steep and relatively impermeable catchment surfaces with no natural lakes the flow-duration characteristics are not as favourable as other North Island catchments such as the central volcanic plateau. Reservoir storage and annual flow regulation would be needed to improve normal flow conditions by storing some part of flood flows to supplement lower flows, but only the Otaki river has features suitable for a storage reservoir large enough to achieve significant flow regulation. Flood discharges are high by N.Z. standards because of the above noted catchment characteristics, and hence substantial spillways would be required if dams were to be constructed.

2.4 LAND AND WATER USE

Much of the Tararua hill country is administered by the N.Z. Forest Service as forest park, (Fig. 2.2) and provides a recreational asset for the population of Wellington and the coastal towns.

Urban water supplies for Levin and Waikanae towns are taken from the Ohau and Waikanae rivers respectively and the Waikanae catchment is designated a water collection area by the Wellington Regional Water Board. Otaki town water comes from the Waitohu stream. Sources of Shannon and Tokomaru supplies are not known, but presumably use the adjacent Mangaore and Tokomaru rivers.

The N.Z. Electricity Division of the Ministry of Energy operate the 20 MW Mangahao hydroelectric station on the Mangaore stream 5 km from Shannon. The power station draws water from reservoirs on the Mangahao river, a tributary of the Manawatu river not in the study area. The Otaki catchment has been reviewed for hydro potential by the Horowhenua Electric Power Board, but studies did not progress beyond the prefeasibility stage.

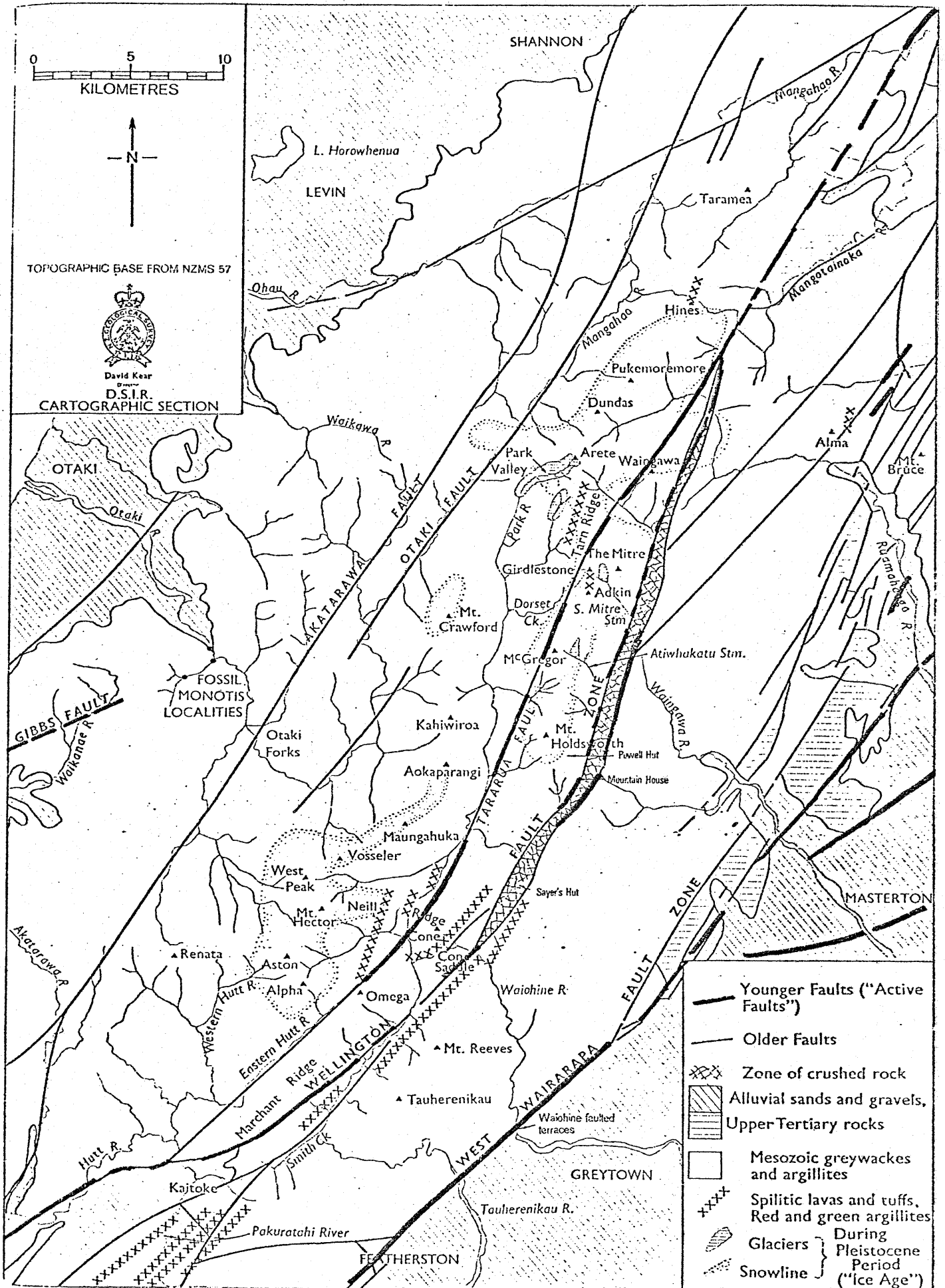
Some preliminary studies are understood to have been made into irrigation of the fertile plains of the Otaki-Levin area. This potential indicates that any hydroelectric proposal in the area, particularly one involving a storage reservoir, should be related to other uses of the water resource, especially when reservoir storage may offer additional benefits for urban or irrigation water supply.

2.5 REGIONAL ADMINISTRATION

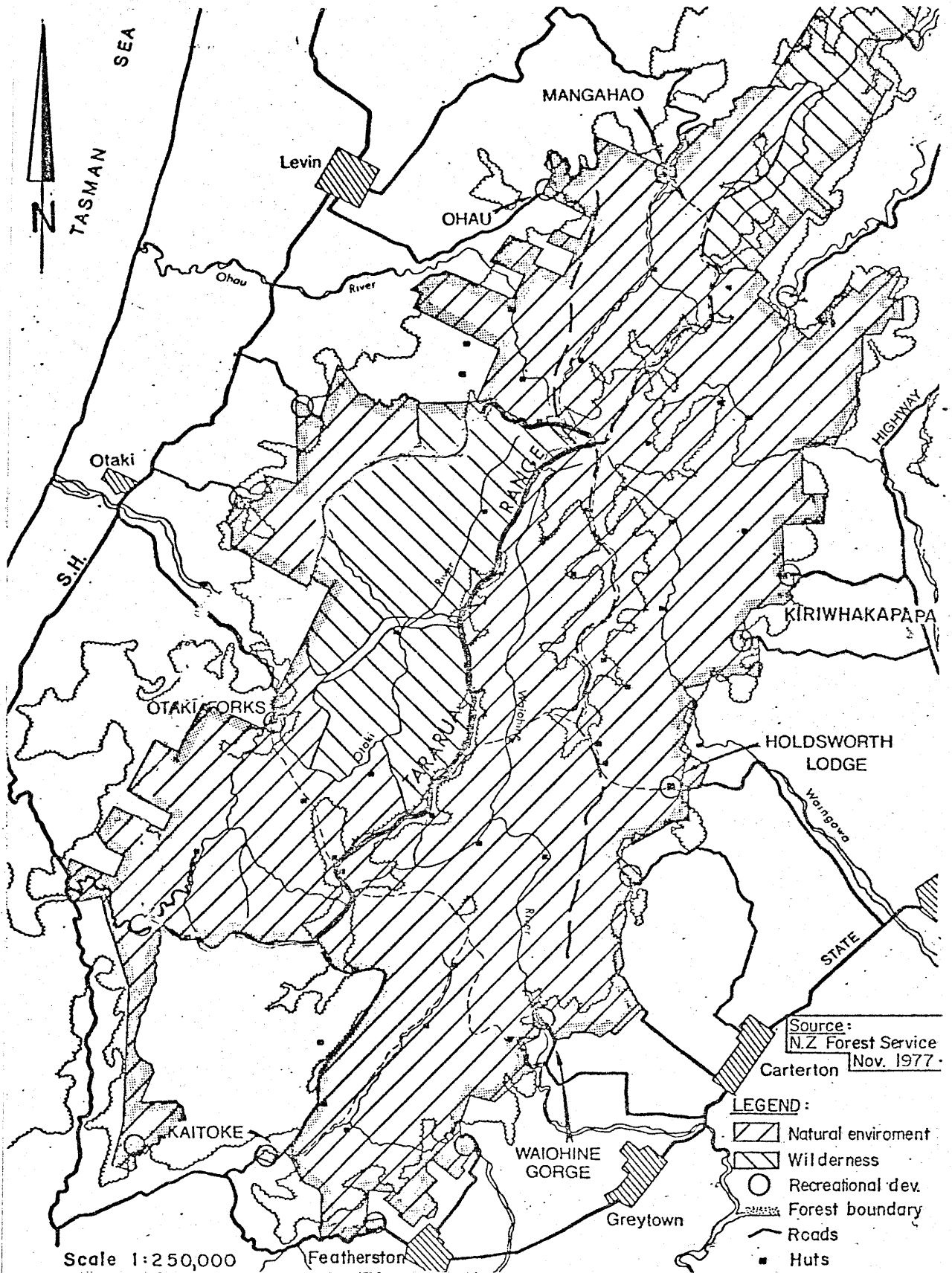
River and catchment control of most of the region under study is the responsibility of the Manawatu Catchment Board and Regional Water Board based in Palmerston North, but the Waikanae catchment is administered by the Wellington Regional Water Board.

The territorial authorities are the Horowhenua County Council, and for a small part of the region in the north the Kairanga County Council, together with the Borough Councils of Otaki and Levin and the County Boroughs of Shannon and Waikanae.

The Horowhenua Electric Power Board's distribution system is shown on Fig. 2.3, together with the main NZED 110 kV transmission line. All hydroelectric sites studied are favourably sited for connection to the existing systems with relatively short linking lines.



GEOLOGY OF THE TARARUA RANGES



Scale 1:250,000

TARARUA FOREST PARK

Source:
N.Z. Forest Service
Nov. 1977.

LEGEND:







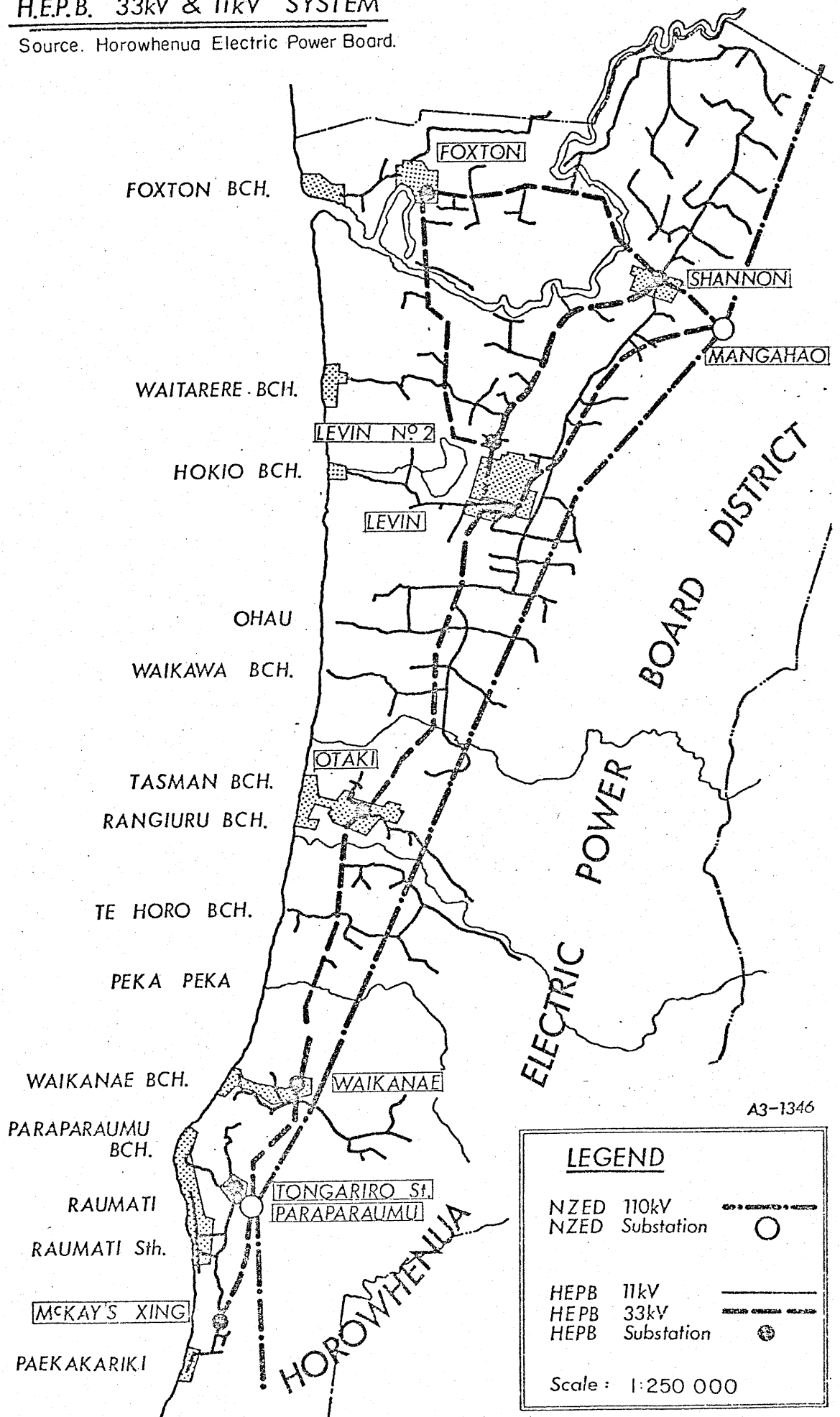
-  Natural environment
-  Wilderness
-  Recreational dev.
-  Forest boundary
-  Roads
-  Huts

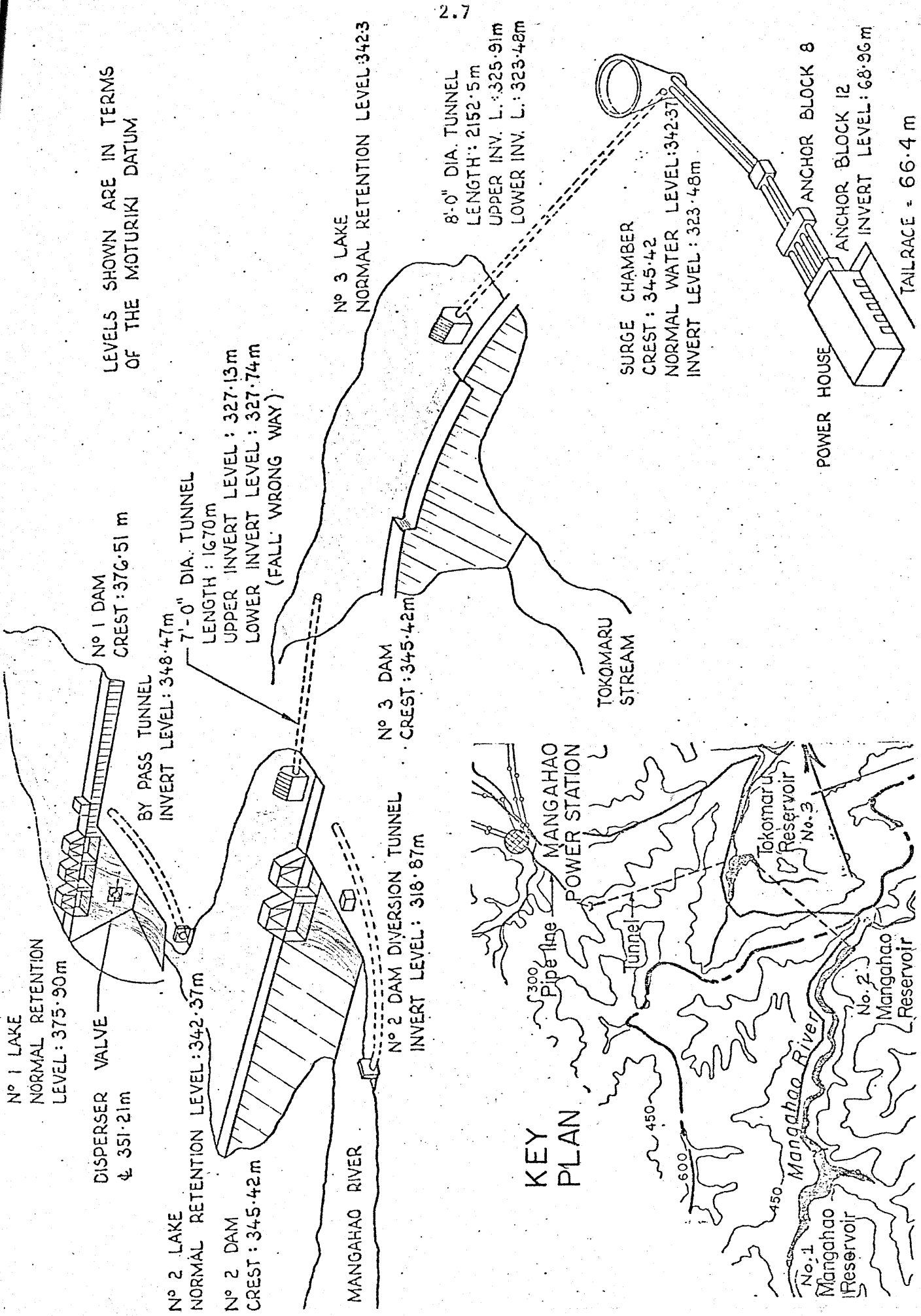
FIG. 2.2

H.E.P.B. 33kV & 11kV SYSTEM

Source. Horowhenua Electric Power Board.



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MANGAHAO HYDRO-ELECTRIC PROJECT

3.0 IDENTIFICATION OF HYDROELECTRIC POTENTIAL

3.1 GENERAL APPRAISAL

The accuracy of assessment of hydroelectric potential in an area depends primarily on the adequacy of two main categories of data:

- (a) sufficient topographical information to identify possible scheme sites, and then to define available generation head and to permit a sketch scheme layout for cost estimating
- (b) river flows, and/or rainfall data, sufficient to estimate long term mean discharges and flow duration statistics, and hence (knowing available head), to assess potential power and energy.

Along the western flank of the Tararua Ranges the four main rivers carry relatively well regulated flows and emerge from the hills through series of terraces which in places appeared suitable for diversion schemes, i.e. diversion weir or low dam, supply conduit (canal or pipeline) and power station some distance downstream. For only a few sites on the Otaki river is the gorge narrow enough, yet with a large enough reservoir upstream to warrant consideration of a conventional scheme, i.e. a dam and spillway with adjacent power station.

Because of previous studies for the Horowhenua Electric Power Board, much useful data was already available for the Otaki river. As this is the 'best' potential hydro river in the region much of the effort in this study was focussed on possible Otaki schemes. Also studied to the extent permitted by budget constraints was the full potential of the existing Mangahao hydroelectric project, and the possibility of additional generation downstream using Mangahao discharges.

3.2 PREVIOUS STUDIES

The first appraisal of hydroelectric potential in the region would have been the 1904 report to Parliament by P.S. Hay Ref. 3. In his review of the region, Hay envisaged developing potential from the Otaki by running a race some distance along the north bank of the river, to a power station of the order of only 3.0 MW.

The 1924 paper by Lawrence Birks, Ref. 4 envisaged the Mangahao potential, to be constructed shortly thereafter but made no mention of the Otaki.

A national review of hydroelectric potential in 1974 by the Ministry of Works and Development for the N.Z. Energy and Research and Development Committee (Ref. 5) makes no comment on Tararua Range potential other than "several local bodies are already examining possibilities".

For these reports the authors were hampered by the lack of reliable flow data, and in the case of lower head schemes by dearth of topographic detail.

In 1974 the Tonkin Muir Energy Group prepared for the Horowhenua Electric Power Board a prefeasibility report in two volumes covering hydroelectric investigations of the Otaki river (Ref. 8a). This was followed by an interim report on high head diversion schemes in 1976 (Ref. 8b) and a brief review study of lower gorge potential in 1978 (Ref. 8c).

In 1976 the Ministry of Works and Development prepared a paper for the N.Z. Forest Service reviewing hydroelectric potential in the Tararua Ranges, which arose from the Horowhenua Electric Power Board Otaki river proposals. The M.W.D. concluded that,

"There is likely to be a significant amount of hydro power in the ranges, though storage of water for the generation of power may be a problem. It is unlikely that any schemes would be large enough for development by government, but there are opportunities for power on a scale which would match the needs of power supply authorities.

An examination of this potential must take into account, not only the engineering circumstances, but also the conditions under which the scheme will be financed and operated, and the loads it will be required to meet. The appropriate Power Board is the only body aware of all these conditions and it is also the authority which will have to bear the financial outcome of the scheme".

However,

"Permission to construct work within the Forest Park will, of course, have to be sought from the N.Z. Forest Service whatever means of examination is used".

The M.W.D. report assessed the overall potential of the area but did not make any specific power assessments for particular rivers.

3.3 DATA AVAILABILITY

3.3.1 General

The identification and evaluation of hydro potential requires the collection and analysis of a wide variety of data. The initial identification of possible schemes, Phase I, was performed as a desk study making use of information currently available from Governmental agencies, as outlined in Sections 3.3.2 - 3.3.5.

The subsequent more detailed scheme evaluation phase made use of additional information collected during field inspection visits of the individual sites and through the co-operation of local agencies.

3.3.2 Topography

Adequate topographical data is essential for realistic identification of hydroelectric potential, especially contour information which enables head and water storage availability to be evaluated.

Head may be developed in three ways, i.e.

- . Use of natural falls, rapids etc.
- . Impounding water by means of a storage dam
- . Diversion of flow by conduit to a point of lower elevation, either downstream or on an adjacent river.

Storage may be evaluated in two categories:

- . headpond or small reservoir to give daily or possible weekly regulation
- . larger reservoir, to permit storage and use of some parts of flood flows which otherwise would be spilled.

Topographical information collected and examined for this study is listed in Table 3.1.

Following the precedent proved on earlier regional studies, (Refs. 2 and 7), all schemes worthy of more detailed evaluation following the Phase I study were drawn up at 1:10,000 scale. Base plans for this purpose were produced, using a planvariograph enlarger, from 1:25,000 Lands and Survey contour plans as listed in Table 3.1, or from NZMS 1 1:63.360 series if no other mapping was available.

3.3.3 Hydrology

Accurate estimates of mean annual river flows, together with estimates of flood flows and of "flow-duration" statistics, are essential prerequisites for efficient evaluation of local hydroelectric potential.

Because of the importance of the high rainfall Tararua Ranges, and the concurrent studies of hydroelectric potential in the Wairarapa and Wellington/Hutt regions, a comprehensive hydrological study was done to collate all available data for the southernmost part of the North Island, and is reported upon separately (Ref. 11).

Figures 3.1 to 3.4 derived from Ref. 11, indicate that the hydrology of the Horowhenua area is effectively represented by the "Wellington" region, covering the Tararua Ranges (Fig. 3.1).

As explained in Ref. 11, regional dimensionless flow duration curves were developed, shown plotted logarithmically on Fig. 3.1, and linearly for the Wellington region on Fig. 3.2 together with the derived plant factor curve.

The plant factor curve is the integral of the area under the curve for any given flow value, expressed as a percentage of that flow for 100% time.

For each hydroelectric site an annual mean flow was derived using the isohyds (contours of equal runoff) presented in Ref. 11. The conduit capacity, or maximum flow to be diverted through the power station is derived from the mean river flow by applying the appropriate ratio for the selected plant factor - 50% for this and similar reports.

Flood flows for sites with catchments of given area have been grouped for three flood regions as shown on Fig. 3.3. These flood regions are similar to but not necessarily coincident with the mean flow regions on Fig. 3.1.

The values of mean flow, used to estimate annual energy generation, are as accurate as permitted by available data, probably within an accuracy of $\pm 15\%$, but it should be emphasised that further development of hydro or other water use proposals would require accurate gaugings at particular river sites over a time span of at least 1 year.

3.3.4 Geology

A geological appraisal of possible locations for major engineering works is necessary to assess the likely site conditions and to highlight possible construction problems.

Geological data for the area is limited to the N.Z. Geological Survey Map, Sheet 12 Ref. 9, and to the useful publication in "A Trumper's Geology of the Tararuas" Ref. 10. There are evidently no N.Z. Geological Survey bulletins or 1:63360 maps covering the Horowhenua region.

Brief inspections of some of the sites took note of particular features evident and of items that would need further investigation should particular schemes proceed further.

3.3.5 Sedimentation

In any hydroelectric development on the Tararua rivers, the disposal or accommodation of sediment particularly shingle bed load would be an important factor in obtaining statutory approvals and during project design.

While individual calculations of reservoir sedimentation are beyond the scope of this study, provision has been made in the planning and costing of schemes for bottom sluices in the smaller dams to encourage movement of sediment during and after floods.

Experience with flushing finer sediments from the Mangahao reservoir is reviewed in the Hydrology report (Ref. 11). Estimates of suspended sediment deposition can be made using data such as presented in Ref. 11, but less is known about quantities of shingle movement.

Some control of shingle deposition within a reservoir can be achieved by lowering the reservoir during floods, and this can also have benefits in storing, for power generation, flood flows which otherwise would have been spilled (e.g. Aniwhenua reservoir currently being commissioned in the Bay of Plenty).

However all but the largest reservoirs can be expected eventually to fill with shingle: at this time the live storage may be substantially reduced but experience with alpine schemes has shown that conduit intakes can be designed to exclude shingle.

3.4 CATCHMENT APPRAISALS

The preliminary desk study collated most of the data referred to above, and was followed by an initial appraisal of all catchments in the region.

It soon became evident that topography and hydrology would be favourable for hydroelectric potential generally only where the larger rivers emerge from the Tararua foothills, and would probably only be economically attractive on the Otaki river, and on the Mangaore stream downstream of the existing Mangahao powerstation.

Further effort during Phases II and III of the study accordingly focussed attention on the Otaki and Mangaore catchments, but the results of the initial reviews of the Tokomaru, Ohau and Waikanae catchments are included in this report for completeness.

The principal catchments are shown on two drawings: 4153A-1 Tokomaru, Mangaore and Ohau Rivers; 4153A-2 Otaki and Waikanae Rivers; on which are indicated the locations and extent of the schemes studied.

The preliminary desk study finished with a tentative listing of schemes lying within the Horowhenua region.

It should be emphasised that, at this stage of the study, experience from earlier work had been confirmed with regard to the inviability of larger dams and associated spillways, on rivers of average flow and without topography suited to developing a storage reservoir. Hence with the exception of the Otaki river, office study and field work was concentrated on 'diversion' schemes, i.e. those envisaging a canal or pipeline running from a river weir or at most a low dam of height sufficient only to lift the water onto the adjacent valley terrace.

In his letter of 8 February the District Commissioner of Works advised that costs should be estimated to a common pricing date of December 1979 with an approximate cost index of 1130. Instructions were also given that potential schemes should be ranked economically in the following categories for the purposes of completing the study.

- A - very attractive - less than \$1200/kW
- B - attractive - \$1200 - \$1800/kW
- C - possibly attractive - \$1800 - \$2400/kW
- D - probably uneconomic - more than \$2400/kW

These categories are followed in the conclusions reached in this report (Chapter 6.0).

It was found essential in Phases II and III of the study to have visited the sites of any potentially favourable scheme. Despite the high standard of NZMS 1 '1 mile' mapping and the availability, for all major rivers except the Otaki of larger scale mapping, in most cases the concept of the scheme was modified to suit particular physical features which showed up only in field inspections.

3.5 SCHEMES IDENTIFIED

Preliminary scanning during the Phase I study identified some nine sites in the Otaki catchment exhibiting sufficient potential to warrant the preliminary estimation of scheme costs, taking account of earlier work for the Horowhenua Electric Power Board. (Ref. 8).

For each of the Tokomaru, Mangaore, Ohau and Waikanae rivers, only one or two sites seemed worthy of further consideration, in most cases near the downstream end of the river valley where a low dam or intake could be feasible to feed a canal running on an alluvial terrace. An alternative dam scheme was included for each river, except the Mangaore stream, to allow for possible complementary use of the stored water for urban irrigation supply, but the estimated costs confirmed that dam schemes were quite uneconomic for hydroelectric generation.

Potential for high level diversion from one catchment to another was evident from the preliminary scan only from the Maungakotukukuku stream in the Waikanae catchment, and of course the existing Mangahao scheme, and from part of the Tokomaru catchment to the Maungaharaki stream.

As a general rule, streams with mean flows of less than about 1.5 m³/s were not included in the evaluation because the resulting generation capacity could rarely exceed about 250 kW, and transmission and remote operation costs would make such schemes uneconomic for public development. There may be smaller schemes not identified which could be considered for private development where a suitable local electricity demand exists and for which standard "packaged" turbine-generation sets are available at suitable prices.

Approximate costing of all schemes was carried out using parameter based data similar to and comparable with that presented in Ref. 7 to eliminate schemes which were obviously uneconomic. Where the present (i.e. December 1979) cost of the scheme exceeded about \$2500/kW installed at a plant factor of 50% (i.e. a unit energy cost of approximately 6.0¢/kWh) it was discounted as not warranting further study.

On this basis three schemes in catchment 1, and schemes 3/2 to 3/7 on the Otaki river were subjected to further evaluation, usually incorporating a field inspection to confirm the practicability of constructing a scheme similar to that envisaged in the desk study and to collect additional information to enable the scheme configuration and cost estimate to be refined.

Finally a total of 14, 'preferred' potential hydro schemes, at two sites in catchment 1 and six in the Otaki catchment, each with an alternative, were identified as appearing sufficiently economic to warrant reasonably explicit documentation for future detailed evaluation.

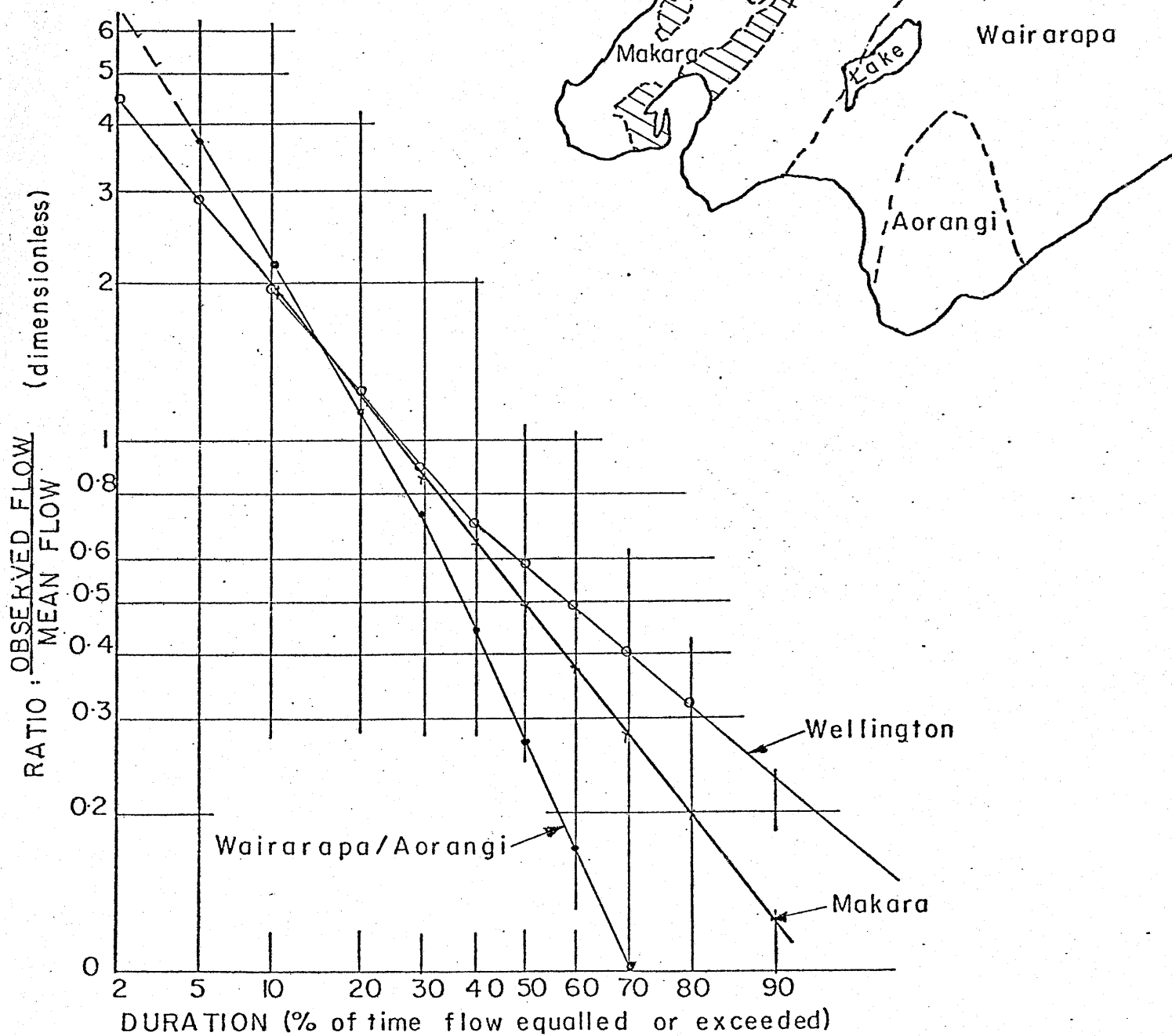
Chaper 4 presents a general appraisal of the hydro potential in each of the river catchments within the study area, followed by an outline of the 'preferred' schemes in Chapter 5.

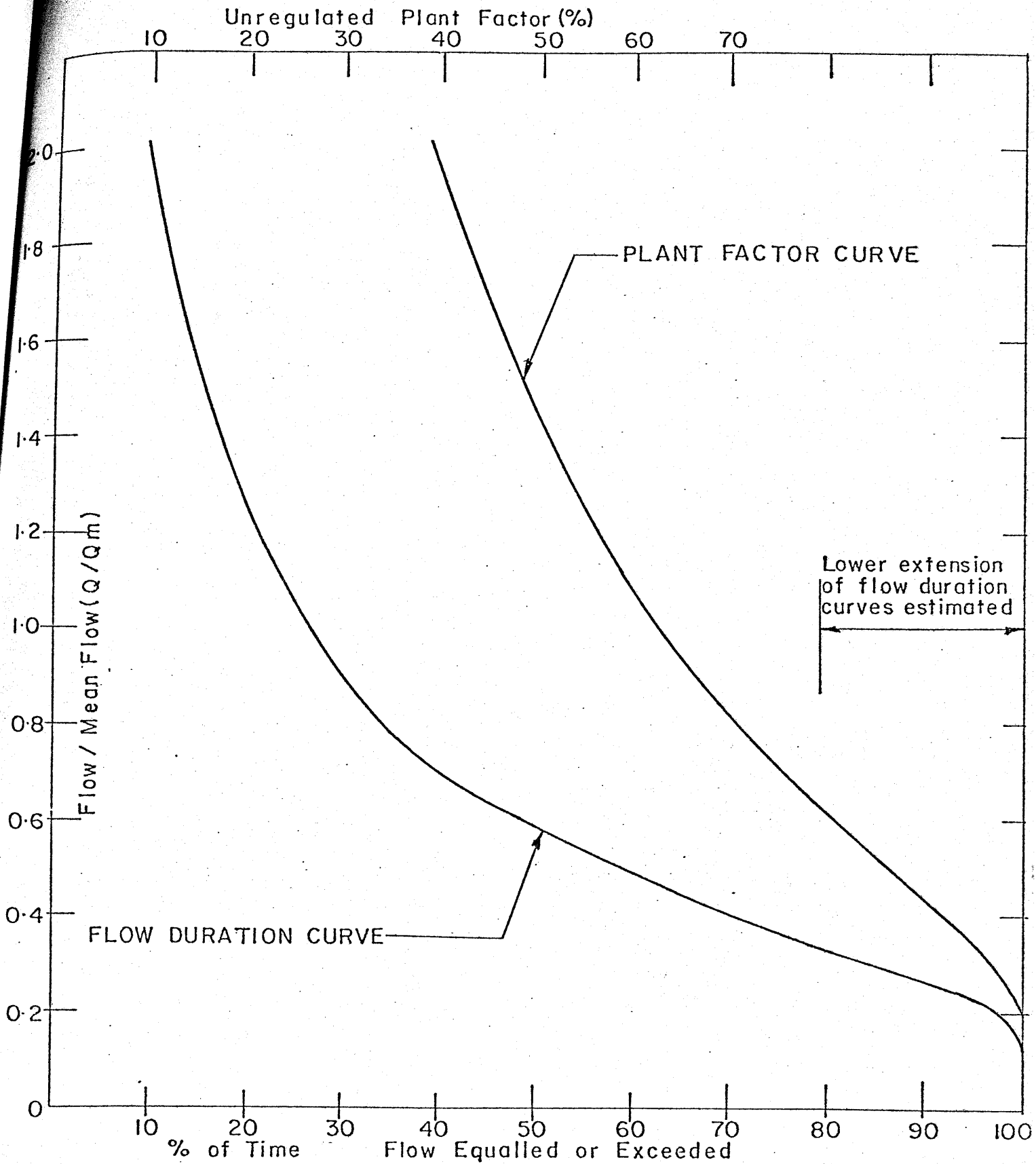
TABLE 3.1
TOPOGRAPHICAL DATA USED FOR SCHEME PLANNING

River	"1" = 1 mile" 1:63360 (100 ft contours NZMS 1	1:25000 Lands & Survey Dept.	1:10000 "Cadastral" Block Sheets Used	Other Surveys
Tokomaru & Maungahara- kieke	N 152 & N 153	S 24 D 20 m contours	-	-
Mangaore	N 152	S 24 D (Part)	-	1:10,000 Lands & Survey Dept. 10 m contours. Ref. AP 1262 January 1980 Photography dated 5.2.68
Ohau	N 152	N 152/7,8 & Pt.9 50 ft contours	-	-
Otaki	N 157	-	1:10,000 S 25/1.4 & 2.4 and S 26/1.2	1:10,000 Lands & Survey Dept. 10 m contours. Ref. AP 1262 January 1980 Photography dated 20.11.78 1:5,000 Aero Surveys 10 m contours, photography dated 23.7.77
Waikanae & Maungakot- ukutuku	N 156 & N 157	R 26 A & B 20 m contours	-	-

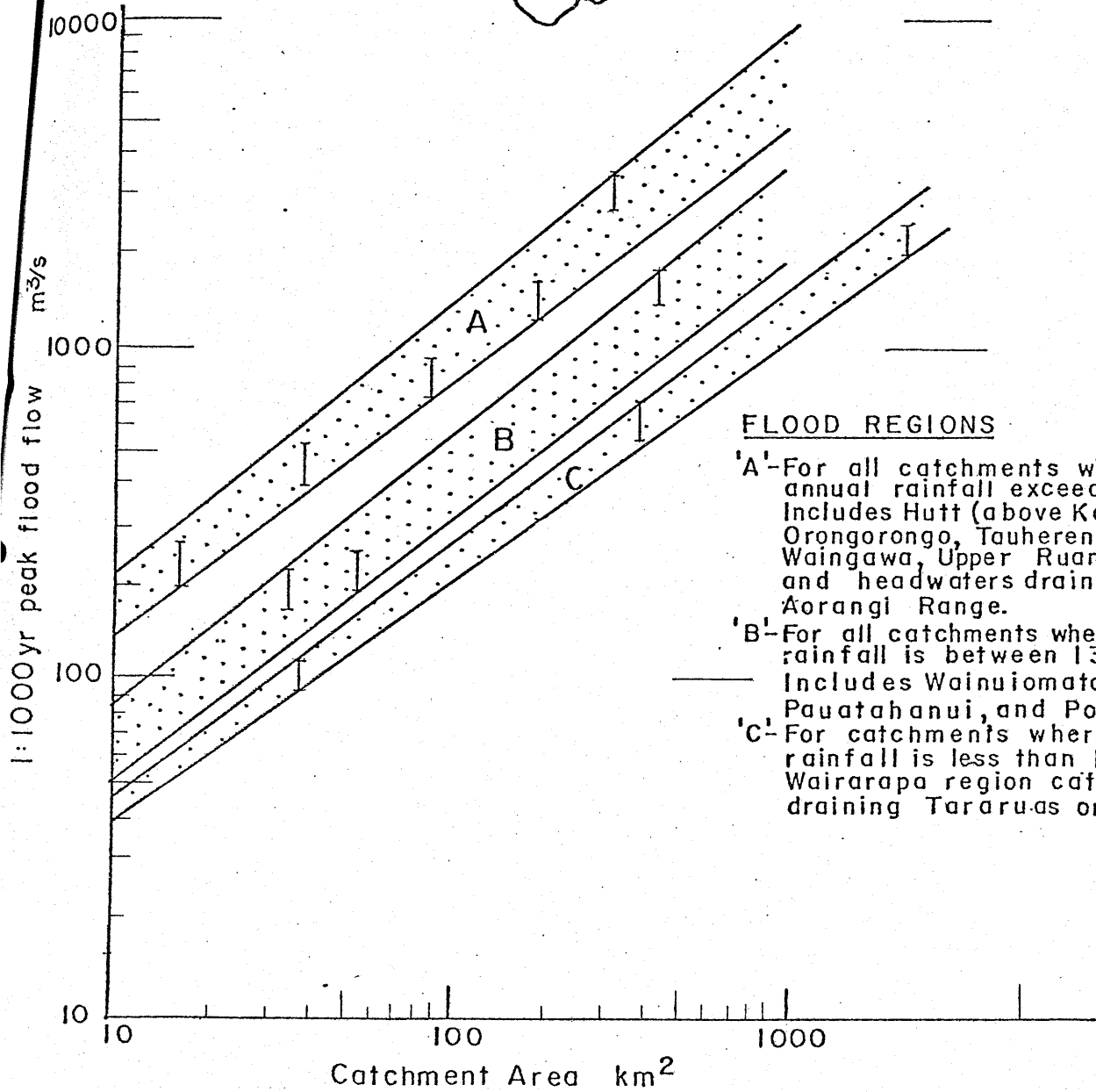
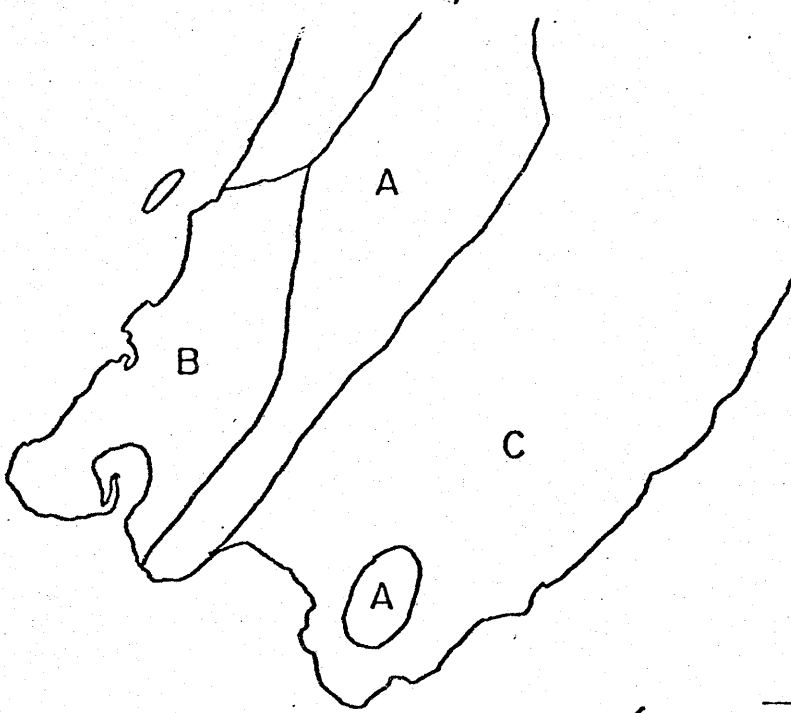
HOROWHENUA, WELLINGTON & WAIRARAPA REGIONS

Dimensionless Flow Duration Curves





'WELLINGTON' REGION
Flow Duration and Plant Factor



FLOOD REGIONS

- 'A'-For all catchments where average annual rainfall exceeds 2200mm. Includes Hutt (above Kaitake), Otaki, Orongorongo, Tauherenikau, Waiohine, Waingawa, Upper Ruamahanga, Ohau, and headwaters draining the Aorangi Range.
- 'B'-For all catchments where average annual rainfall is between 1300 and 2200 mm. Includes Wainuiomata, Whakatiki, Pauatahanui, and Porirua.
- 'C'-For catchments where average annual rainfall is less than 1300 mm. Includes Wairarapa region catchments not draining Tararua or Aorangi Ranges.

HOROWHENUA, WELLINGTON & WAIRARAPA REGIONS

Regional Floods - 1000yr. Estimates

TONKIN & TAYLOR
SEPT. 1980

FIG. 3.3

4.0 HYDROELECTRIC DEVELOPMENT POTENTIAL

4.1 TOKOMARU AND MANGAORE RIVERS: CATCHMENT 1

4.1.1 Tokomaru Scheme 1/1

Relatively low flow and the lack of a narrow damsite or a substantial area for a reservoir indicate no potentially viable hydro scheme, nor an economic combination with a complementary water user drawing from reservoir storage, on the Tokomaru river.

A simple diversion scheme incorporating a 2.2 km canal and 470 kW powerstation is shown on Drawing 4153A-3. The principal parameters are listed in Table 4.1 but the scheme is uneconomic and not worthy of further study.

4.1.2 Mangaore Scheme 1/2

Although a small natural catchment, the Mangaore stream carries the discharge from the N.Z. Electricity Division's Mangahao hydroelectric powerstation which uses water diverted westwards from the Mangahao river catchment in the Tararua Ranges. The diverted flows have passed through a series of three reservoirs including one on the headwaters of the Tokomaru stream, and the powerstation discharge offers potential for further hydro generation, using the natural terrace formations between the Mangahao powerstation and Shannon township.

The scheme is described in more detail in Chapter 5: the principal parameters are listed in Table 4.1.

4.1.3 Mangahao Powerstation Scheme 1/3

The N.Z. Electricity Division's 20 MW Mangahao hydroelectric powerstation was commissioned in 1924 and at that time was the largest powerstation in N.Z. Flow is diverted from the Mangahao river high up in the Tararua Ranges through a system of three reservoirs and two tunnels.

The powerstation is located at the western edge of the Tararua foothills and discharges into the Mangaore stream.

For the purposes of this report a brief assessment has been made of the total potential diversion westwards from the Mangahao river to evaluate the maximum potential of the Mangaore scheme referred to above.

The N.Z. Electricity Division are currently re-evaluating the Mangahao station potential, with regard to improved efficiency from new Pelton turbine buckets and minor modifications to the spear control equipment, and are also understood to be considering increasing the conduit capacity of the scheme, principally by enlarging or renewing the smaller No. 1 tunnel.

While it is both inappropriate and beyond this report's scope to duplicate NZE's studies, brief evaluations are given in the following chapter of:

- (i) enhancement of Mangahao output in the category of a diversion into the Horowhenua region
- (ii) increased flow available for the Mangaore scheme.

4.1.4 Mangaharakiemie Scheme 1/4

The Mangaharakiemie stream rises on a high plateau lying in the elbow of the Tokomaru river, and flows to the coastal plains down a high waterfall which is visible from State Highway 57 north of Shannon. Although the scheme was not appreciated in Phase I of the study, and its output at 110 kW is less than the lower limit of 500 kW nominally taken for current regional hydro studies, the scheme has been included in this report because it is a good example of local "mini-hydro" potential which is receiving increasingly more attention in N.Z and overseas.

The scheme envisages enhancement of the Maungaharakiemie waterfall flow by diversion of flow from a small adjacent catchment, as described in more detail in the following chapter.

4.2 OHAU RIVER: CATCHMENT 2

4.2.1 Gladstone Scheme 2/1

Alternative schemes were considered utilising the combined flow of the Ohau river and its principle tributaries the Makahika and Makaretu streams. The combination of the relatively narrow valley through which runs Gladstone Road, 5 km southeast of Levin and alluvial terraces either side of the river suggested possibilities for a terrace-canal scheme, possibly combined with a storage dam of modest height.

Two schemes were considered having the following features:
(A - canal only, B - dam and canal).

- A - a diversion weir feeding a 3.2 km canal on the south bank terraces running to a 1.55 MW powerstation in the vicinity of Otarere hill
- B - a 30 m earth and rockfill dam with a spillway, a 2.7 km canal running to a 3.9 MW powerstation in the vicinity of Muhuroa East settlement. The reservoir formed by the dam, at an elevation of about 122 metres, would cover an area of some 120 ha.

Scheme A is shown on Drawing 4153A-5 and its principle parameters are listed in Table 4.1. Scheme B is outlined on Drawing 4153A-5.

The sites of the diversion weir or dam lie in greywacke sandstones and argillites. The canals would run initially along the boundary between the greywacke hills and Hawera series terraces; penstocks and powerstations would be founded in recent undifferentiated alluvium.

The topography was depicted adequately for the study purposes by L & S 1" = 20 chain mapping. Flow data from the MWD gauging station, Ohau river at water race, from four years of records was considered to be of reasonable quality.

However the low power potential of the river, a function of relatively light rainfall in the catchment and the absence of steep river gradients or a narrow dam site, meant that there was little case for a straightforward diversion type hydro scheme (A).

Complementary use of water from storage was not likely to assist sufficiently with the economics to warrant further examination of a dam scheme (B). Levin town water supply is drawn from the Ohau river at the selected site; additional supply capacity from storage would probably be obtained most economically from off-channel storage.

Adverse environmental effects of either scheme would include:

- dewatering of the stretch of the Ohau river running through the Kimberly Scenic Reserve
- rearrangement of Levin town water supply
- some interruption to land use by canal formation, to some degree offset by local water supply benefits, possibly encouraging irrigation.

The power cost in \$/kW for scheme B was estimated at about 50% more than for scheme A, and hence neither scheme has been investigated further in Phases II and III of the study.

4.3 OTAKI RIVER: CATCHMENT 3

4.3.1 General

Being the largest catchment in the region and encompassing the area of highest rainfall, the Otaki river offers the most attractive hydro potential apart from the Mangaore scheme 1/2 above.

The alluvial terraces at the downstream end of the lower Otaki gorge suggest opportunities for canals for diversion type hydro development.

The terrace canal schemes appeared the most economic potential for straight hydro but further consideration has also been given to dam and high head schemes, possibly with canal extensions, which could provide storage for urban and irrigation water.

Between 1974 and 1978 the Tonkin Muir Energy Group on behalf of the Horowhenua Electric Power Board evaluated the potential of medium head schemes entailing dams in the lower gorge, and high head schemes involving tunnel diversions across the Otaki upper catchment.

The results of these prefeasibility studies have been used in this study and the more promising schemes are also discussed in a following section.

4.3.2 Schemes 3/1 - 3/4

A range of terrace canal schemes was considered in the Phase I desk study, with generating heads dictated principally by the elevation of respective terrace formations.

Schemes 3/1 and 3/2 envisaged low barrage structures diverting normal river flows into canals running on the left (south) bank terraces and feeding low head powerstations adjacent to the river.

Schemes 3/3 and 3/4 entailed medium height rockfill dams with associated spillways located near the downstream end of the lower gorge. Canals running on higher terraces respectively on the left and right banks would feed powerstations further down the river valley.

Preliminary cost estimates indicated that while schemes 3/1 and 3/2 would not be economically attractive, schemes 3/3 and 3/4 would be worth further investigation, and the latter are considered in more detail in the following chapter, together with a more promising variant of 3/2, incorporating concrete rather than embankment dams.

4.3.3 Schemes 3/5 - 3/8

As part of the study for the Horowhenua Electric Power Board, larger rockfill dams were envisaged, located towards the upstream end of the lower Otaki gorge, and forming substantial reservoirs over the river flats of the Otaki Forks area.

Also considered were high head diversion schemes involving tunnels from above the upper Otaki gorge to powerstations in the lower gorge.

Within the terms of this study some of these schemes are economically attractive and are described further in the following chapter.

4.4 WAIKANA E RIVER: CATCHMENT 4

4.4.1 Reikorangi Schemes 4/1

The catchment configuration and flow characteristics are similar to the Ohau river, and likewise the river is used for urban water supply, to Waikanae town. No particular economic hydro potential has been identified but the catchment is designated a water collection area by the Wellington Regional Water Board, and possible low head hydro schemes were briefly reviewed.

Alternative schemes were considered utilising the combined flow of the Waikanae river and its southern tributary the Maungakotukutuku stream. The two schemes considered, A canal only, B canal and dam, would have the following features:

A - a diversion weir at the Waikanae/Maungakotukutuku confluence, feeding an 2.0 km east bank canal to a 1.0 MW powerstation on the outskirts of Waikanae town.

B - a 20 m dam and associated spillway feeding a canal on the same route as A but at a higher elevation, to a 2.2 MW powerstation at the same site as A. The Maungakotukutuku stream would be incorporated into the scheme by a stream bed intake and conduit. The dam would form a 50 ha lake in the Reikorangi valley.

The Waikanae river valley is incised into greywacke sandstones, and infilled at the weir or dam site and along the canal route with older Hawera terrace material.

NZGS 1:250,000 scale mapping Sheet 12 shows the active Gibb's Fault crossing the Waikanae river about midway along the proposed canal route. The significance of this feature and its influence on any scheme would need further study, but provision should be feasible to accommodate or minimise the effect of fault movement.

Lands & Survey 1:25,000 mapping shows the topography of the scheme site adequately to estimate potential head and the reservoir area. Flow data is of reasonable standard, from the MWD gauging station Waikanae river at Treatment Plant over a three year period.

The main environmental effect of the dam scheme B would be loss of farm land in the Reikorangi valley, and interruption to hinterland access requiring rerouting of a short length of Reikorangi Road. A 2 km stretch of river would be effectively dewatered.

Basic parameters are summarised in Table 4.1 and the alternative schemes are shown on Drawing 4153A-10.

While the preliminary estimates of scheme cost are more favourable than the Ohau schemes of comparable size, the small hydro potential is not economically attractive.

4.4.2 Maungakotukutuku Scheme 4/2

This southern tributary of the catchment of the Waikanae river contains a low saddle on its western boundary which suggested some potential for diversion of stream flows to a small powerstation on the coastal plains at Paraparaumu, possibly combined with urban water supply. Although not economically attractive for hydro generation the scheme was reviewed in the same terms as 4/1 above, to which it is an alternative.

The alternative schemes considered comprised:

A - diversion weir on Maungakotukutuku stream, 4.0 km race across saddle to feed penstock and 700 kW powerstation on the outskirts of Paraparaumu town.

B - earth and rockfill dam and spillway feeding a similar race to a 1000 kW powerstation at the same site. The dam would form a lake about 30 ha in area.

Structure sites and the race route would lie in weathered argillite and greywacke sandstones, with a section of race in high level Hawera series terrace materials.

The race route would cross the active Gibb's Fault, and particular study and accommodation would be required as noted for schemes 4/1 above.

The flow in the Maungakotukutuku stream has been estimated from rainfall data. The topography of the scheme area is adequately displayed for this study by 1:25,000 mapping.

The principle environmental effects of the scheme would be effective dewatering of the Maungakotukutuku stream, and in the case of the dam scheme, B, inundation of 30 ha of upland valley.

Preliminary cost estimates show scheme A to be only marginally attractive for pure hydro generation: with provision of a reservoir as typified by scheme B the scheme could hold more promise for regulated water supply for Paraparaumu and Paekakariki but the extra cost of dam and spillway indicate that such a scheme would not compete economically with other sources of urban water supply, and be unattractive for hydro generation. The two schemes are shown on Drawing 4153A-10 and their basic parameters are listed in Table 4.1,

4.4.3 Waiotauru - Waikanae Scheme 4/3

Brief consideration was given to the possibility of hydro generation should water be diverted at some future date for urban water supply from the Waiotauru river, an Otaki tributary, through a tunnel into the Waikanae catchment. About 100 m gross head could be available, with a mean flow of about 5.8 m³/s from the Waiotauru, suggesting some 8 MW of power. However the tunnel cost, even assuming most favourable conditions and rates, would render this hydro scheme completely uneconomic unless the total cost of the tunnel could be ascribed to water supply. As it is assumed that more economic sources of water would be available, the scheme has not been considered further and is not listed in Table 4.1. The tunnel line is however indicated on Drawing 4153A-2 for the record.

TABLE 4.1 HYDRO POTENTIAL - TOKOMARU, MANGAORE, OHAU AND WAIKANAE CATCHMENTS

(For Otaki Catchment 3 refer Table 3)

River & Site Name	Scheme No	Intake or Dam Site Grid Ref.	Catchment Area km ²	Mean Flow m ³ /s	Intake or Reservoir		Net Head m	Output Power MW	Energy Output GWh/yr	Capital Cost (1)		Features	* alternative schemes
					Top m	WL Area ha				mill. \$	/kW		
komaru R. Horseshoe Bend	1/1	NZMS 1 N153: 028 185	50.9	1.90	40	-	21	0.47	2.06	1.69	3600	Diversion weir, 2,200 m canal	
	1/2	N152: 953 086	25.3	0.65	Mangahao	(4) Reservoirs	48	4.54	21.9	6.07	1340	Diversion weir, 3300 m canal/pipeline	
	1/2A	"	"	0.65 +12.89 (4)	ditto		48	5.07	22.7	6.37	1270	As 1/2 but 20% increase in Mangahao peak discharge	
ngahao Diversion existing power station	1/3	N152: 953 083 (P/S)	(10.74) (4)	(10.74) (4)	Mangahao Reservoirs		257	20.40	100 approx.	---	---	Existing NZE powerstation on Mangaore stream	4.8
	1/3A		(4,9) (5)	(4,9) (5)	ditto		257	9.20	40.3	18.40	2000	Maximum addition to Mangahao scheme	
ngaharaki waterfall	1/4	N153: 020 163	2.5	0.05	370	-	260	0.11	0.5	0.18	1640	Diversion bank and race to penstock bypassing waterfall	
	2/1A	N152: 848 978	104	5.70	915	-	23	1.55	6.8	3.63	2340	Diversion weir, 3200m canal	
au R. Gladstone Rd	4/1A	N157: 604 687	120	4.4	46	-	205	1.07	4.7	2.18	2030	Diversion weir 2000 m canal	
	4/1B	606 687	120	4.4	61	50	35.5	2.20	8.6	4.44	2020	20 m E/R dam & S/W, intake on M'tuku stream, 2000 m canal	
ungakotukutuku	4/2A	576 654	22	0.62	115	-	90	0.70	3.0	1.26	1795	Diversion weir 4000 m race/pipeline	
	4/2B	581 667	22	0.62	115	15	90	1.00	4.4	3.00	8000	20 m E/R dam & S/W 3000 m race/pipeline	

Notes (1) At 1979 cost levels; MWD Construction Cost Index = 1130; excluding interest during construction.

(2) Sized for plant capacity factor of 50%, except Mangahao and Mangaore 55%. (4) Max. discharge from Mangahao powerstation

(3) E/R dam = earth and rockfill dam. S/W - spillway (5) Max. additional diversion from Mangahao catchment.

5.0 ATTRACTIVE SCHEMES WARRANTING FURTHER INVESTIGATION

5.1 MANGAORE SCHEME 1/2

5.1.1 General

An economically attractive hydroelectric scheme on the Mangaore stream appears feasible using the Mangahao powerstation discharges and the fall in the Mangaore stream between the existing powerstation and Shannon town. The scheme would comprise:

- a diversion weir and canal intake structure some 200 m downstream of Mangahao powerstation
- a 2300 m canal formed in the alluvial terrace on the north bank of the Mangaore stream feeding a 1300 m concrete pipeline and short penstock to
- a powerstation of 4.54 MW situated about 1300 m upstream from the Shannon road and rail bridges, with tailrace deepening of the Mangaore stream over about 1000 m

The scheme is outlined in plan and profile on Drawing No. 4153A-4.

5.1.2 Details of Scheme

The Mangahao powerstation turbines discharge into a concrete lined tailrace which also carries the Mangaore stream flow. (Photo P1).

A short distance below the access bridge leading to the Mangahao powerstation, the stream and powerstation discharges flow in a bouldery bed with some rock exposed in the walls. (Photo P2).

A diversion weir would be formed in the left (south) bank in this vicinity and the stream course realigned downstream of this, to free the existing course for construction of a canal intake and the start of the canal. The top water level of the pond formed by the weir would be such that Mangahao turbine operation was not affected.

Once clear of the constricted stream course the canal would run on the right bank river flats and progressively rise up the steep northern boundary of the Mangaore valley, as shown on Photo P3 and Drawing 4153A-4.

After some 2300 m the right bank terrace is no longer high enough to carry the canal and a concrete pipe would be provided for a further 1300 m to the top of a penstock feeding a 4540 kW powerstation.

The powerstation would contain two turbines to give operation flexibility to match varying discharges from the six Mangahao turbines. Pressure surges in the penstocks and pipeline would be controlled by a pressure relief valve on the turbines.

The Mangaore stream downstream of the new powerstation site (Photo P4) would be deepened, to provide extra head on the powerstation, over a length of about 1 km, i.e. about as far as the railway and state highway bridges.

A rock lined chute would be formed near the powerstation to control normal flood flows from the Mangaore catchment. Exceptionally large flood discharges would be encouraged by training banks to spread over low lying river flats under pasture as occurs naturally at present.

Energy from the powerstation would be transmitted by a short line to the Shannon substation. Access to the powerstation would mainly use existing roads.

5.1.3 Geotechnical Aspects

The weir and powerstation sites and the canal route lie in the Hawera terrace series, comprising alluvial deposits in which the gravels are moderately or well weathered.

Terrace material excavated from along the canal route should be suitable for supporting the valley sides where the canal would be benched into the edge of the terrace. Over such lengths the canal would probably need lining with a relatively impervious local material.

Alluvial material below the powerstation should be sufficiently stable for tailrace excavation.

5.1.4 Land and Water Use

The canal would run along the edge of the Mangaore stream valley, the Shannon golf course and the local rifle range and should not affect these land uses. No major environmental problems are anticipated, but fishery needs of the Mangaore stream could require an assured minimum flow and a small "compensation release" would be desirable in any event to preserve a reasonable ecological condition in the stream channel between the intake weir and the proposed powerstation.

5.1.5 Appraisal of Mangaore Scheme

Contour mapping AP 1262 at 1:10,000 scale with 10 m contours, produced by the Department of Lands and Survey in January 1980 is satisfactory for preliminary appraisal of the scheme, supplemented by spot levels around the Mangahao powerstation from NZE records.

The present Mangaore stream flow is comprised predominantly of Mangahao powerstation discharge, which was gauged by MWD in August 1980 having a maximum value of 10.74 m³/s. The Mangaore stream flow on the same day was 0.35 m³/s.

Perusal of recent NZ Electricity Annual Reports shows that the Mangahao load factor has averaged about 55% over the past three years; operation of a downstream scheme would be tied to the existing station and thus the same plant capacity factor has been taken for evaluation of the Mangaore scheme, rather than the 50% nominal figure taken for the other schemes in this study.

Preliminary cost estimates as summarised in Table 4.1 indicate that at \$1340/kW the scheme could be economically attractive and should be studied further. If the annual energy generated at 55% load factor is considered as equivalent to that coming from a larger theoretical installed capacity at 50%, i.e. comparable to the other schemes reviewed in this study, the cost per kilowatt could be taken as \$1220/kW.

Recommendations for further investigation of this scheme are given in the following chapter.

5.1.6 Implications of Mangahao Up-rating

The Mangahao project itself is currently under review by the NZ Electricity Division, as briefly discussed in the following section. The implications for a Mangaore scheme are:

(a) Increase in Mangahao Tunnel Capacity

This would lead to increased total annual volume of water available to a Mangaore powerstation, i.e. the annual plant capacity factor could increase to about 70%, but the peak flow would remain as at present.

With a Mangaore installed capacity fixed at 4.54 MW the annual energy could increase to 28.7 GWh. If this energy were then considered as coming from a station at 50% plant capacity factor, the equivalent theoretical power would be 6.55 kW, giving an equivalent cost/kilowatt of \$1080/kW. Although not an accurate basis for comparison because only the energy generated and not the maximum power is increased, this evaluation does indicate the benefits to a Mangaore development from enhancing the utilisation of storage from Mangahao reservoirs.

(b) Increase in Total Mangahao Power

If enhancement of Mangahao storage utilisation were coupled with installation of additional turbines to maintain a Mangahao plant capacity factor around 55%, the installed power in a Mangaore scheme could also be increased.

However this exercise is not expected to prove economic (see following section) so the implications on a Mangaore scheme have not been considered further.

(c) Increase in Discharge from Existing Mangahao Station

If Mangahao discharge were increased to 12.9 m³/s (refer following section) Mangaore capacity could rise to about 5.0 MW, at an equivalent cost/kilowatt of \$1270/kW (Table 4.1).

The above examples are relatively superficial examples of how design of a Mangaore scheme should be closely linked with any imminent or future modifications to Mangahao.

5.2 MANGAHAO HYDROELECTRIC PROJECT 1/3

The general layout of the NZ Electricity Division's Mangahao project is shown on Fig. 2.4, and a profile of the reservoirs, tunnels and penstocks is included on Drawing 4153A-4.

NZ Electricity have advised that they are currently reassessing the potential of Mangahao: from our limited appreciation of the project, such reassessment could include:

- increase in tunnel capacity, particularly for tunnel No. 1, 2.13 m dia. which acts as a throttle on full utilisation of Nos 1 and 2 reservoirs
- raising of dams or at least top water levels to increase storage utilisation, plus provision of an additional tunnel
- minor modification of spear nozzles or spear strokes to increase maximum station discharge by up to 20% without major changes to generating equipment (NZE letter of 18.6.80).

For the purposes of evaluating the Mangaore potential (see previous section) we have briefly assessed the following three possible modifications to Mangahao.

(a) Increase in No. 1 Tunnel Capacity

The 10.74 m³/s max. powerstation output measured on our request by MWD in August 1980, can apparently be carried satisfactorily by the No. 2 tunnel with the No. 3 reservoir drawn down to 331 m and a surge chamber elevation of about 326, i.e. tunnel inlet and penstocks intake drowned by at least a diameter over the soffits.

To carry 10.74 m³/s, tunnel No. 1 would need to be enlarged to about 3.0 m dia. to utilise full drawdown on No. 1 reservoir. For the purposes of Mangaore scheme evaluation it has been assumed that the cost of this enlargement would all be borne by improvements to Mangahao output.

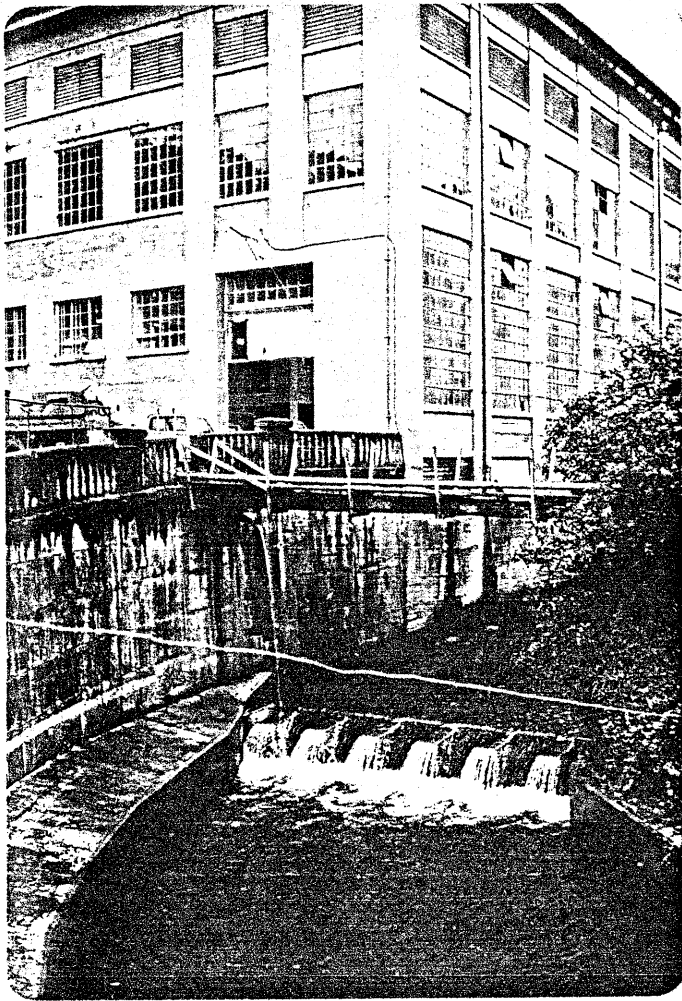
(b) Maximum Increase in Total Power Output

Using the regional flow duration curve (Fig. 3.2) and associated plant factor curve, and assessing a reasonable annual utilisation of all available live storage, an additional 4.9 m³/s maximum flow could be diverted for generation at 0.55% plant factor.

An additional tunnel/penstock system would be required, parallel to the existing conduits, and an additional one or two turbines in an extended powerstation. However, our very preliminary cost estimates show that the cost per kilowatt of the extra power, some 9.2 MW would be about \$2,000/kW (Table 4.1) and hence it seems unlikely that Mangahao would be extended in these terms.

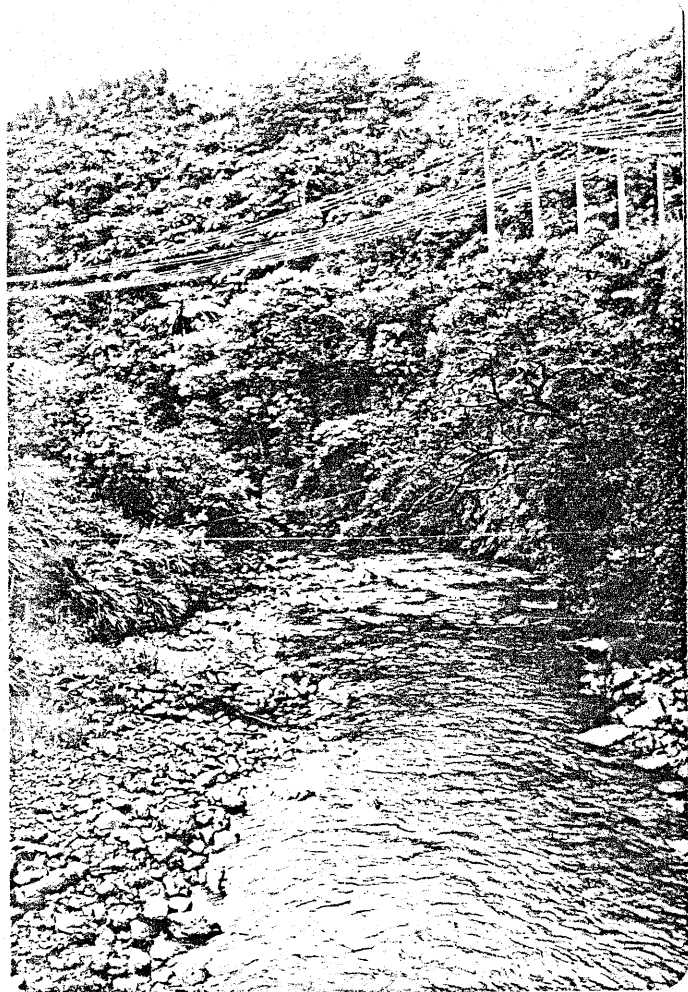
(c) Maximum Increase in Existing Station Discharge

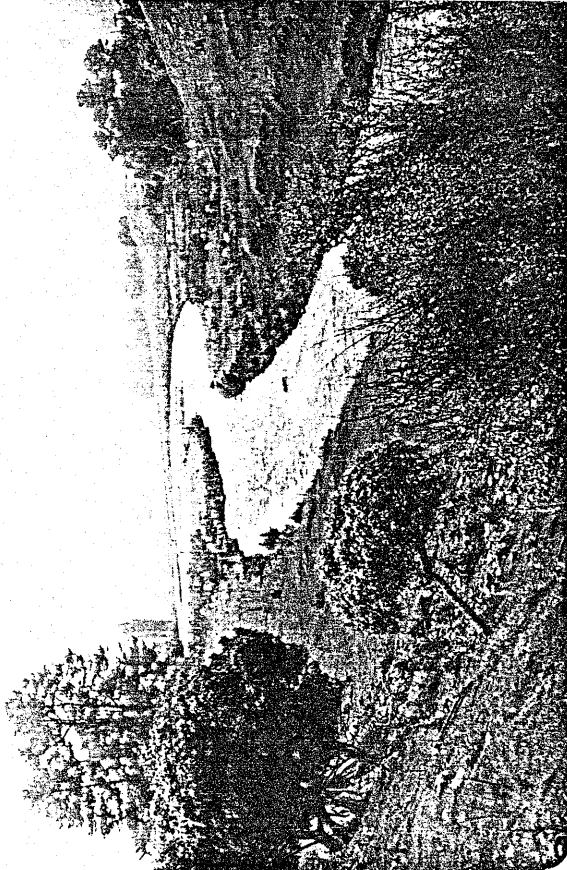
Coupled with the recent introduction of load limiters, turbine modifications could permit maximum station discharge to increase up to about 12.9 m³/s, and Mangaore scheme output would be enhanced accordingly.



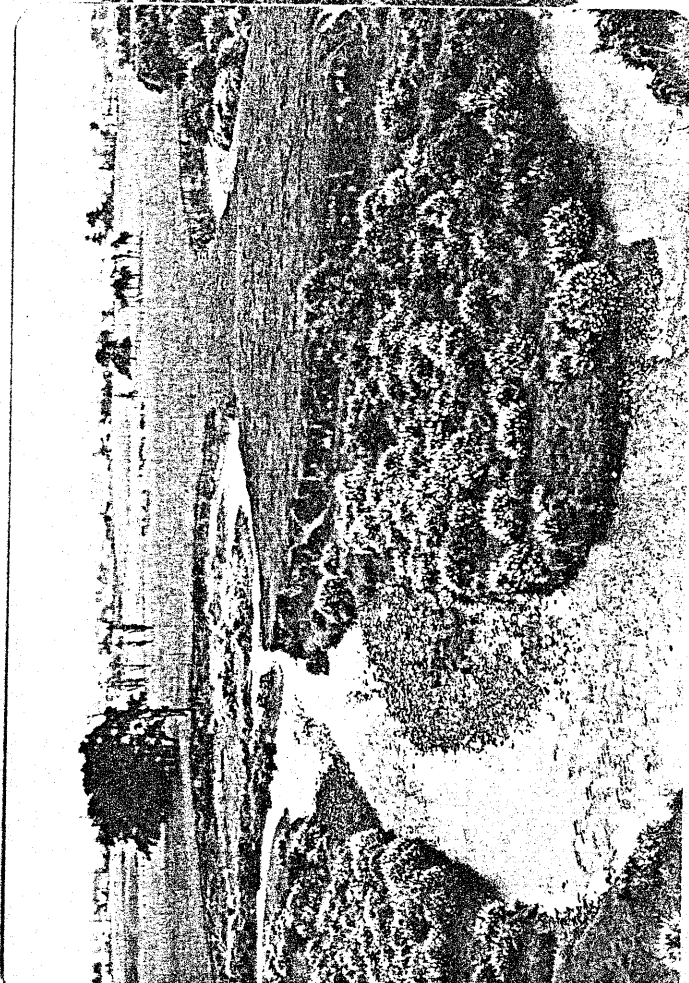
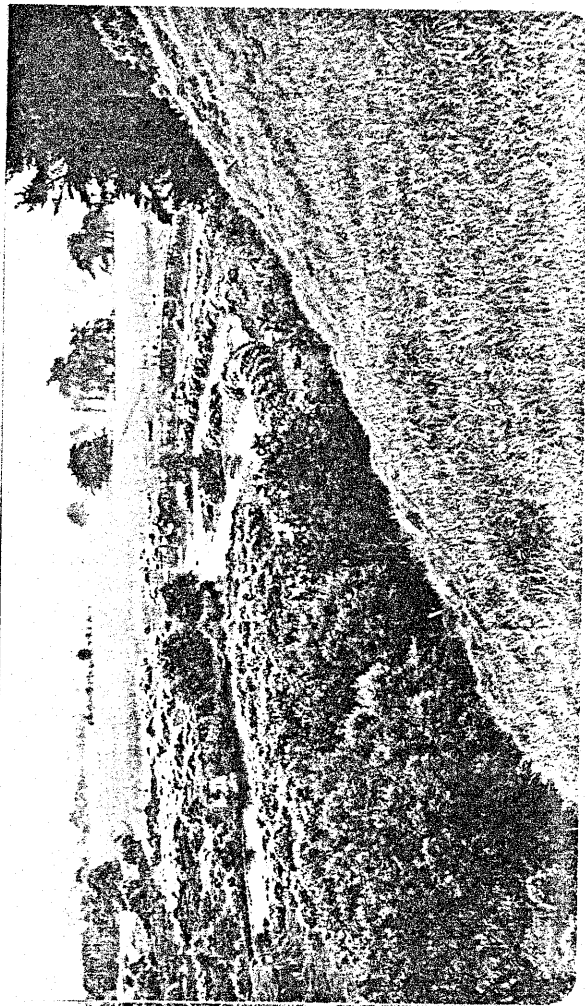
P1
Mangahao Powerstation
Tailrace

P2
Mangaore Stream
Proposed intake site





P3 Mangaore Stream below intake site -
canal route on right bank



P4 Mangaore Stream - proposed powerstation site

5.3 MANGAHARAKIEKIE SCHEME 1/4

Further brief consideration has been given to this very small scheme because it provides an opportunity to place in perspective the "mini-hydro" type of scheme which is receiving increased attention both for back country power supply in NZ (Ref. 12) and for rural electricity supplies in developing countries.

The scheme is shown in plan and sketch profile on Drawing 4153A-3. Simple diversion races, excavated by dozer or grader would collect flow from a series of streams and concentrate these at a small intake structure near the head of the Mangaharakiemie stream waterfall.

A small diameter high pressure pipe, similar to those used for farm water supplies, would bypass the falls to a Pelton turbine and induction generator sited on the Mangaharakiemie stream near the farmstead at the end of Albert Road.

No flow measurements are available for these small elevated catchments, but based on rainfall data, as explained in Ref. 11, the maximum divertable flow should be of the order of $0.05 \text{ m}^3/\text{s}$. A head of some 260 m should produce about 110 kW of power, which could be transmittable back to Shannon substation using existing power lines.

Basic parameters of the proposal are given in Table 4.1. In estimating the approximate cost of such a small scheme it has been presumed that the work would be co-ordinated by the Power Board or by a co-operative group of farmers, using local contractors' or farmers' equipment to keep establishment and access costs and overheads to a minimum.

A cost of \$1,640/kW is considered indicative of all costs to install the conduits and a simple small powerstation, and it is recommended the Power Board investigate the scheme further, as summarised in the following chapter.

5.4 OTAKI RIVER

5.4.1 General

As explained in Chapter 4.0 the Otaki river should demonstrate the best hydroelectric potential in the region and in addition should offer the best chance for complementary water uses viz:

- crop irrigation in the Otaki fruit growing area
- long term water supply for the northern Wellington area

The Otaki valley is also an important recreational facility for the Wellington region: while there have been strong objections raised by conservation groups in response to the 'high head' schemes proposed by the Horowhenua Electric Power Board, there was some cautious enthusiasm for reservoir formation in the Otaki Forks area, and the amenity value of a reservoir in the lower gorge should be appraised as part of any scheme on that stretch of the river.

The Otaki river carries large amounts of sediment in flood, and accommodation or passage of shingle bed load would be important in design of any dam or barrage.

Because of its catchment characteristics the Otaki river experiences particularly large floods, and spillway provisions therefore constitute the principal feature of any diversion or impounding structure on the river. This is particularly relevant to all the canal schemes in the lower gorge viz schemes 3/2 to 3/5, where the river is invariably entrenched, requiring substantial dam structures to lift water for transport by terrace canals.

Scheme 3/1 is a low head weir-diversion scheme not economically competitive with other schemes and it is not considered further in detail.

5.4.2 Tuapaka and Gorge Schemes 3/2A and 3/3B

Drawing 4153A-6 shows alternative schemes comprising a relative low concrete gated barrage or gravity dam feeding a canal formed along the Otaki left bank terraces.

The barrage for scheme 3/2A would incorporate a group of large low level steel radial gates, probably four in number and a substantial stilling basin for handling floods up to about the once-in-100 year return period.

Flood flows in excess of this value would also be handled by a wide overflow auxiliary spillway formed on the right bank terrace. Normally grassed and in pasture, some scour damage would be envisaged following an extreme flood, and some local repairs would be necessary.

River diversion during construction should be straightforward at this relatively wide site. The reservoir area is shown in Photo P6.

Effective control of sediment deposited in the reservoir should be achieved by low level gate discharges, coupled with some degree of drawdown on receipt of flood warnings.

The dam for scheme 3/3B would be a conventional concrete gravity structure passing all floods over the crest and incorporating a flip bucket at the base to ensure that the resultant scour pool would develop in the river bed a safe distance downstream of the dam.

A conduit through the base of the dam would handle minor floods during construction and would subsequently be available for some limited scouring of sediment deposits near the dam and possibly to assist with extreme flood discharges.

The canal for scheme 3/2A would run on alluvial terraces to a pair of short penstocks. A tailrace channel would be formed in the flood plains of the river to develop a few metres extra head.

For scheme 3/3B the canal would run along the foot of the hills bordering the south side of the Otaki valley, in parts benched into rock. Photos P5 and P6 show the lower end of the gorge and the route of the canal. The configuration and elevation of scheme 3/3B have been determined by the constraint of routing the canal at the toe of the steep hillsides. (Photo P7).

From the end of the canal for scheme 3/3B twin concrete pipelines would run to a powerstation situated close to the river.

Access to the headworks and powerstations would be straightforward, using mainly existing roads or farm tracks.

New transmission lines would be required, running to the Horowhenua Electric Power Board's substation in Otaki Forks.

The basic parameters of the two schemes are summarised in Table 5.1.

5.4.3 Rahui Road Scheme 3/4A

The concept of a canal running along the edge of the north bank foothills was investigated, as shown on Drawing 4153A-7, as an alternative to schemes 3/2 or 3/3 .

As with the other schemes, the canal elevation and hence the generating head, would be dictated by terrace levels related to the best dam site (Photo P8). The same concrete dam site as for 3/3 was used, and use made of aneroid barometer readings in areas not covered by the recent 10 m contour survey.

The foothills are dissected by several sizeable streams and allowance was made in preliminary cost estimates for the canal to cross these gullies on culverted embankments.

A small elevated headpond would be proposed at the end of the canal, feeding twin concrete pipes joining to steel penstocks. A substantial tailrace channel would be formed to return powerstation discharges to the river (Photo P9).

Basic parameters of scheme 3/4A are given in Table 5.1. Also listed is an alternative scheme 3/4B which was briefly considered to check the benefits of a shorter canal against lower generating head. Scheme 3/4B is indicated in plan and profile on Drawing 4153A-7. Estimates of cost/kW show that the longer canal scheme would be economically more attractive.

5.4.4 Pukehinau Scheme 3/5A

Similar in concept to schemes 3/3 and 3/4, but differing in dam type this scheme would comprise an earth/rockfill dam and two associated spillways, two kilometres below the Otaki Forks, a 1.5 km canal along the south bank terraces of the Otaki gorge and a powerstation located a short distance upstream of the Otaki river/Pukehinau stream confluence. (Photo P10).

The scheme was originally considered at the end of the Tonkin Muir Energy Group prefeasibility studies for the Horowhenua Electric Power Board, and the scheme then appeared the most economic of three canal schemes in the locality. The site is covered by good topographical mapping at 1:5,000 scale with 10 m contours.

The reservoir would have an area of 180 ha at elevation 120 m and would inundate the river flats above Otaki Forks and extend several kilometres up the Otaki main stream and the principal tributaries the Waitatapia stream and Waiotauru river.

Head and flow are adequately defined, but the installed power and annual energy would be also a function of reservoir operation, i.e. the number of times that the live storage volume could be utilised annually.

The cost estimates are particularly dependant on the provision of a gated spillway to discharge about 75% of the 1000 year flood: it is envisaged that the remainder of such a flood would be handled by a combination of flood warning plus discharge through an unlined auxiliary spillway formed in rock together with operation of the drawoff conduits.

Flood drawdown would also work towards keeping live storage substantially free of sediment deposition: however bottom flushing using the drawoff culvert would be effective only when sediment deposition had reached close to the dam after some decades.

The scheme is shown on Drawing 4153A-8, and basic parameters are listed in Fig. 5.1.

5.4.5 Pukeatua Scheme 3/6

The Tonkin Muir Energy Group's prefeasibility study for the Horowhenua Electric Power Board also considered embankment dams over a range in heights in the gorge some 800 m downstream of the Otaki Forks near the confluence of the Otaki river and Pukeatua stream (Photo P11). Details of two representative schemes A and B have been extracted for this review with the following features:

- 3/6 A - 75 m earth and rockfill dam with service and auxiliary spillways, and adjacent 25.0 MW powerstation; reservoir elevation 143 m, 310 ha
- 3/6 B - 100 m earth and rockfill dam with service and auxiliary spillway and adjacent 35.0 MW powerstation; reservoir elevation 169 m, 520 ha

A 33 or 66 KV transmission line would be required to Otaki town for either scheme, as also for schemes 3/4 and 3/5.

The reservoir, dam and spillways for scheme 3/6B are shown on Drawing No. 4153A-8, and the basic parameters for either scheme are listed in Table 5.1.

Hydrology and topography are to similar adequate standard as for scheme 3/5, but likewise the accuracy of preliminary cost estimates were dependant primarily on basic assumptions regarding spillway provisions and flood routing. Although much larger than the reservoir for scheme 3/5, similar comments apply regarding sedimentation: flood lowering should maintain live storage substantially free of deposits and it should be several decades before finer sediment was deposited near the dam.

5.4.6 Waitewaewae Schemes 3/7 and 3/8

The prefeasibility studies for the Horowhenua Electric Power Board included an appraisal of the potential for high level diversion of flow from the upper Otaki river and its main tributary the Waitewaewae stream, to discharge through a powerstation into the lower Otaki gorge.

The studies considered a range of heads and storage/diversion arrangements, of which the most economic was found to be scheme 3/7A, as shown on Drawing 4153A-9. A 45 m concrete arch dam in the vicinity of the Waitewaewae hut would form a 105 ha reservoir from which would run a 5.6 km tunnel to feed a 30 MW powerstation under the high head of about 230 m. Flow from the Waitatapia stream would be picked up by a streambed intake.

A variation on this high level diversion concept, scheme 3/7D, has also been examined briefly, the main difference from 3/7A being the replacement of the arch dam with a less sophisticated stream bed intake forming a small headpond rather than a reservoir. The long tunnel would be at a lower elevation thus developing less head, and the flow regulation provided by a reservoir would not be available, but as indicated in Table 5.1, the economics (\$/kW) of scheme D should be appreciably more attractive than scheme A.

For scheme 3/8 a diversion weir on the upper Otaki river just downstream of the confluence with the Waitewaewae river would feed a 4.4 km tunnel to the Waitatapia stream. From the tunnel outfall would run a 3.8 km canal along the valley side in the vicinity of the old bushtramway route, to a 12.5 MW powerstation. Preliminary costing (Table 5.1) showed this concept not to be economically competitive with schemes 3/7.

Flow data for the upper Otaki river are of moderate quality based on nine months of record obtained for the Horowhenua Electric Power Board prefeasibility study. The headworks areas in the Upper Otaki valley were mapped at 1:10,000 scale for that study. The subsequent mapping of the lower gorge (schemes 3/5 and 3/6 above) showed there would be more head than indicated by contours on the 1" = 1 mile mapping, and this factor has been allowed for in the figures given in Table 5.1.

The accuracy of preliminary cost estimates for the two high head schemes depend primarily on the unit rates taken for tunnelling; which costs can vary markedly as a function of anticipated and/or encountered ground conditions. Sufficient cost data is now available for tunnels of similar size in comparable rock in the North Island to show a range of likely costs: assuming the lower range of tunnel costs, schemes 3/7A or 3/7D appear to be competitive with the best of the lower gorge schemes.

However if adverse tunnelling conditions and higher costs are assumed, the schemes rank no better than the schemes with larger dams in the lower gorge.

5.4.7 Geotechnical Aspects

From the small scale data available, NZ Geological Survey 1:250,000 scale Sheet 12, the powerstations for schemes 3/2, 3/3 and 3/4 would be sited on recent undifferentiated alluvium, while the canals would run in Hawera series terrace material.

The lower Otaki gorge is incised into greywacke rock. Shingle bars and terrace materials of the Hawera series may occur locally similar to those mapped in the Waikanae valley. The intake for scheme 3/2 would be sited on alluvium, while the dam site for schemes 3/3 and 3/4 is a rock walled gorge, probably with an alluvial gravel bed below water level.

The dam site for scheme 3/5A is in more weathered rock with indications of instability a short distance upstream which initiated the shift of dam location from that indicated in the Phase I report. The canal would run on a greywacke terrace, possibly containing localised alluvium, and the powerstation would have to be excavated into the rock wall of the gorge.

The dam site for schemes 3/6 is also in more weathered rock; but further study would be needed, as at all dam sites.

The tunnel routes for schemes 3/7 and 3/8 would lie in the alternating argillite and greywacke sandstones of the Kawhia, Horangi and Balfour series. All structure sites would be expected to be on rock.

No known faults cross the Otaki valley but seismic activity is to be expected, requiring appropriate design.

Suitable concrete aggregates should be obtainable from the alluvial gravels or rock quarrying. Material from local excavation should be satisfactory from earth or rockfill embankments.

5.4.8 Water and Land Use

No significant water abstractions are currently made in the vicinity of the proposed schemes. The major impact of the canal schemes 3/2 to 3/5 would be the substantial dewatering of the bypassed stretch of river but ecological requirements should predominantly be met by undiverted discharges from substantial tributary streams from the right (north) bank. Local water abstractions are discussed below.

The effect of the canal schemes on land use should be limited to localised disruptions of on-farm access and some rearrangement of field boundaries could be necessary, as also for the scheme 3/4A tailrace.

The reservoirs for schemes 3/4, 3/5 and 3/6 would inundate increasing areas of the Otaki Forks river flats and scrub-covered foothills, requiring some rerouting of traditional tramping tracks.

Some lengths of fast flowing river suitable for canoeing or rafting would be lost by implementation of one of the canal schemes.

The Otaki district is a recognised market garden/orchard fruit area and the larger reservoirs could offer potential for intensive irrigation on the coastal plains, as typically outlined in Ref. 14, accepting some minor loss of electrical generation in the dry years of maximum demand.

Shingle replenishment to the lower Otaki river would be affected by the dam schemes 3/3 to 3/6. Local surface and groundwater abstractions are identified in Ref. 13. Any further promotion of the lower Otaki schemes 3/1 to 3/4 would have to include accommodation of such water uses.

The lakes would present a recreational facility for a populated area which has available to it only the exposed coastal beaches for water sports at present, apart from the Horowhenua dune lakes.

When the Horowhenua Electric Power Board first publicised the high head schemes strong environmental objections were raised, particularly with regard to the effect of access and project construction, but conservation and recreational bodies were less vocal in their opposition to the lower head dam schemes.

The Tararua Forest Park boundary crosses the Otaki river in the vicinity of the Forks (Fig. 2.2) and scheme 3/7A or 3/7D would continue to receive close scrutiny by the NZ Forest Service should development proposals proceed further, with particular regard to access during and after construction.

Scheme 3/7A envisaged the inundation of some 100 ha of upper Otaki valley in the vicinity of the Waitewaewae hut (Photo P12): variant 3/7D would replace the dam and reservoir with a low intake impounding only a few hectares in normal or low flow conditions and causing negligible interruption to higher flows; and these less obstrusive headworks could mitigate some of the environmental objections to a high level diversion scheme.

5.4.9 Appraisal of Otaki Schemes

Flow data for the Otaki river is satisfactory, being based on the MWD Tuapaka gauge with six years of record. Analyses of the data were carried out by the Tonkin Muir Energy Group for the Horowhenua Electric Power Board.

As noted in Chapter 3, topographical detail for the downstream half of the lower Otaki gorge schemes is limited to 30 m (100 ft) contours, and these schemes 3/2, 3/3 and 3/4 must therefore be considered only as illustrative until an additional survey can be obtained.

In the course of these studies, it has become confirmed that the high annual rainfall and catchment configuration of the Otaki river, while producing the highest runoff of the region also results in unusually large flood flows (Fig. 3.4). The attendant spillway costs mean that the larger dam schemes are uncompetitive for hydroelectric generation.

In estimating the costs of spillways it was found that for the medium height dams, schemes 3/3 and 3/4, there was negligible difference in cost in providing for a concrete dam with all flood discharges over the crest rather than the separate spillways needed for the embankment dams envisaged in Phase I of this study. However for the higher dams, schemes 3/5 and 3/6 at wider sites, an earth/rockfill dam with spillways formed in adjacent rock borrow areas was shown to be less costly.

Basic parameters and preliminary cost estimates are given in Table 5.1 for all Otaki schemes, including for schemes 3/1 and 3/8 not shown on larger scale drawings.

Fig. 5.1 shows all Otaki schemes in diagrammatic profile, and demonstrates the available alternatives for overall river development excluding scheme 3/1,

e.g. 3/2A + 3/5A + 3/8

or 3/3B + 3/6 or 3/7

or 3/4A + 3/8

Based on the preliminary cost estimates in Table 5.1, the most economically attractive combination would be the modest height concrete dam and canal of scheme 3/3B and the 'run-of-river' tunnel diversion of scheme 3/7D, and recommendations for further investigations are given in the following chapter.

Should an additional requirement for downstream water regulation be identified, e.g. for irrigation on the coastal plains, then the larger reservoirs of schemes 3/5 or 3/6 could become economically more attractive, possibly coupled with a modified high head diversion such as scheme 3/8.

It should also be noted that the economics of the high head tunnel schemes depends critically on the estimates made for tunnel conditions and costs: this factor is illustrated by the range of costs given for schemes 3/7A and 3/7D in Table 5.1.

TABLE 5.1 HYDRO POTENTIAL - OTAKI RIVER

River & Site Name	Scheme No	Intake or Dam Site Grid Ref.	Catchment Area km ²	Mean Flow m ³ /s	Intake or Reservoir Top WL m	Intake or Reservoir Area ha	Net Head m	Output		Capital Cost (1) \$ mill.	Features*	
								Power (2) MW	Energy GWh/yr			
OTAKI - Hautere Tuapaka Gorge	3/1	N157 703 810	320	28.0	30.5	-	13.5	4.3	18.8	9.04	2100	
	3/2A	718 793	310	28.0	61.0	30	31.5	10.5	46.0	18.00	1720	Gated barrage, 3000 m canal
	3/3A	732 778	305	28.0	105.0	100	65.5	22.0	96.3	44.90	2140	64 m concrete dam, 3700 m canal, 650 m concrete pipeline
Rahui	3/3B	732 778	305	28.0	75.0	30	35.5	12.0	52.6	19.63	1635	36 m concrete dam, 3700 m canal, 650 m concrete pipeline
	3/4A	732 778	305	28.0	95.0	60	64.5	21.4	93.7	38.53	1800	55 m concrete dam, 5000 m canal
	3/4B	732 778	305	28.0	95.0	60	51.0	17.0	74.5	33.82	1990	55 m concrete dam, 1700 m canal
Pukehinau	3/5A	755 752	300	27.0	120.0	180	60.5	21.0	92.0	37.34	1780	60 m rockfill dam and spillways 1500 m canal
Pukeatua	3/6A	157 741	300	27.0	143.0	310	64.0	25.0	109.5	45.00	1800	75 m E/R dam) spillways and adjacent
	3/6B	157 741	300	27.0	169.0	520	90.0	35.0	153.3	73.60	2100	100 m E/R dam) powerstation
	3/7A	823 771	84	10.5	320	100	230	30.0	131.4	51.00	1700	45 m concrete arch dam 5,600 m tunnels #
Waitewaewae	3/7D	823 771	84	10.5	280	-	200	24.9	109.0	35.80	1400	Diversion weir 5,600 m tunnels #
	3/8	820 779	80	10.0	300	-	150	12.45	54.5	28.63	2300	Diversion weir, 4,400 m tunnel and 3,800 m canal

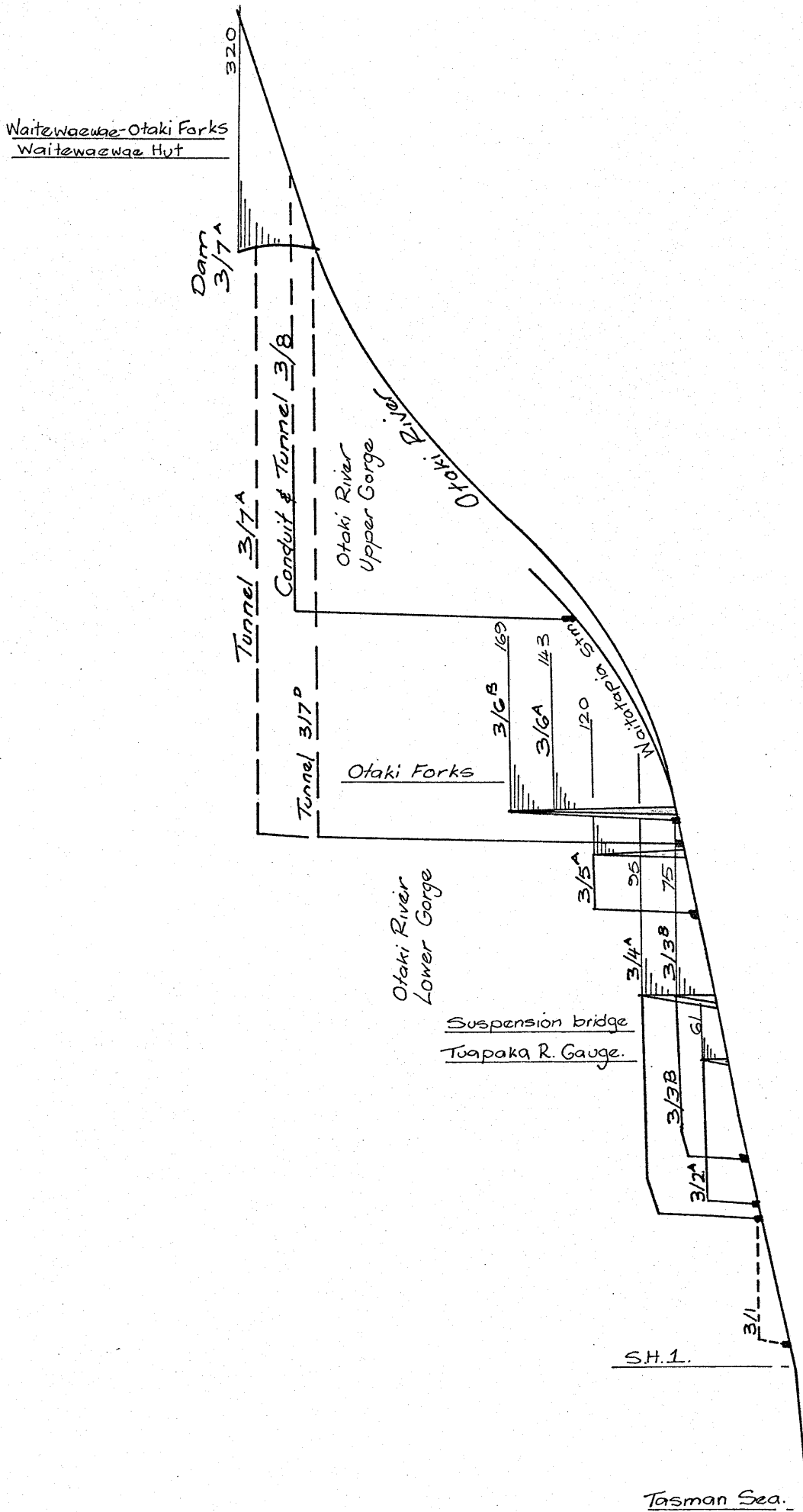
cost range covers favourable and unfavourable tunnel conditions

Notes (1) At 1979 cost levels; MWD Construction Cost Index = 1130; excluding interest during construction.

(2) Sized for plant capacity factor of 50%. * Feasible combinations are (3/2A + 3/5A + 3/8

(3) E/R dam = earth and rockfill dam. 3/1 + { or 3/3B + 3/6 or 3/7

(4) S/W = spillway. { or 3/4A + 3/8

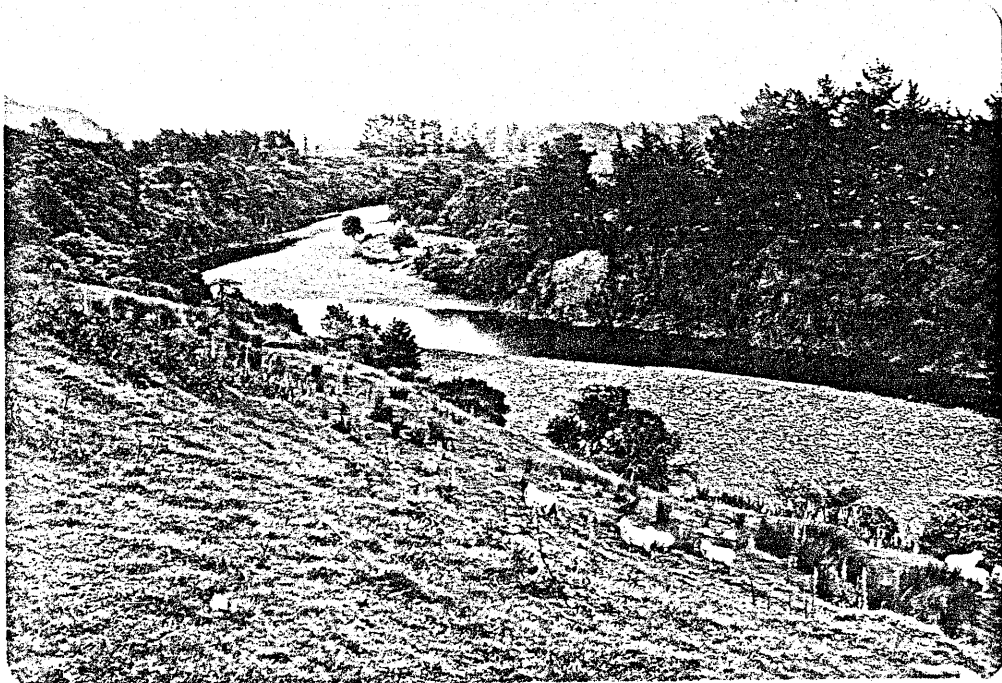


OTAKI RIVER SCHEMES

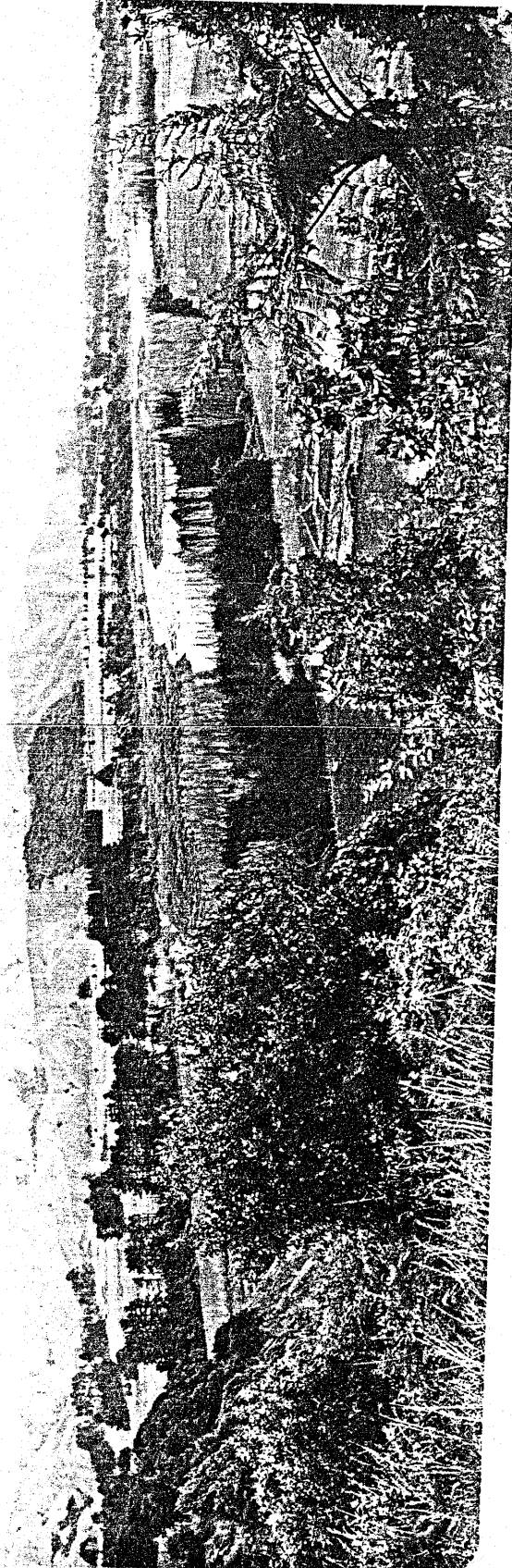
FIG. 5-1



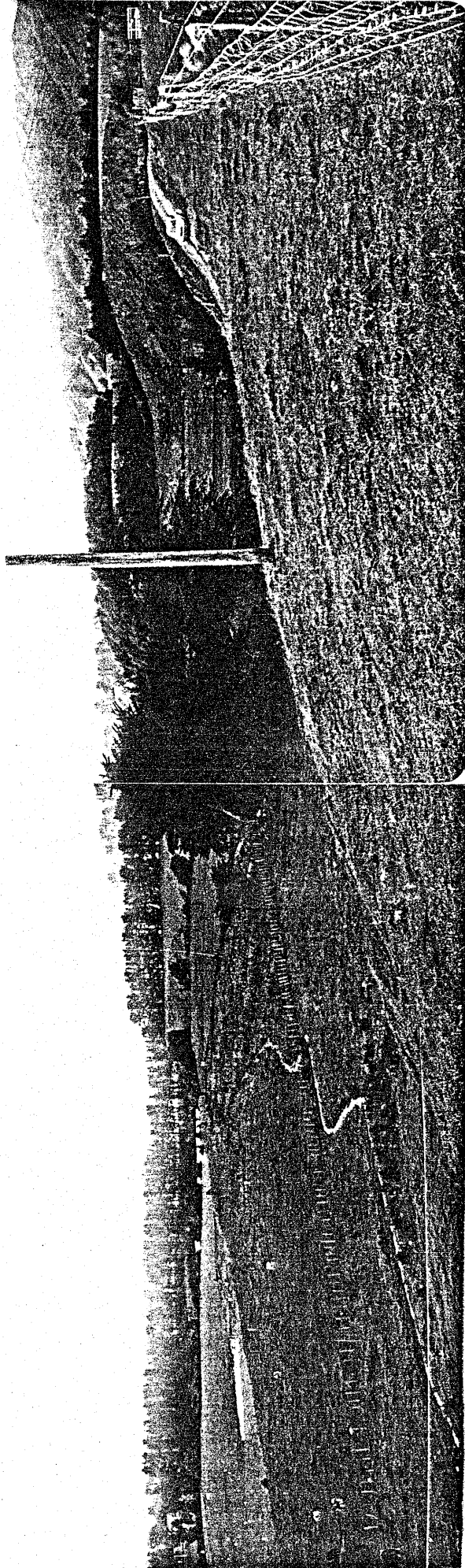
P5 Lower Otaki Gorge - looking upstream
from suspension bridge - canal route
3/3B on right side



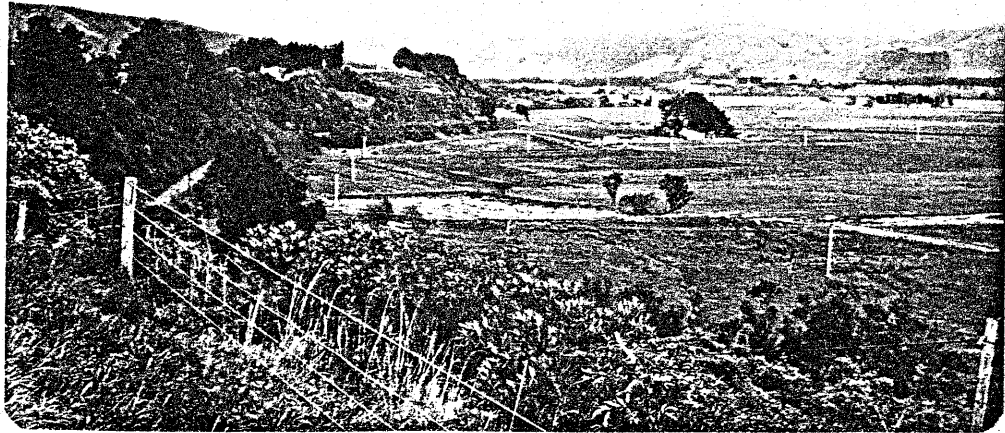
P6 Lower Otaki Gorge - looking downstream
across area of reservoir for scheme 3/2A.
Canal route 3/3B on left side



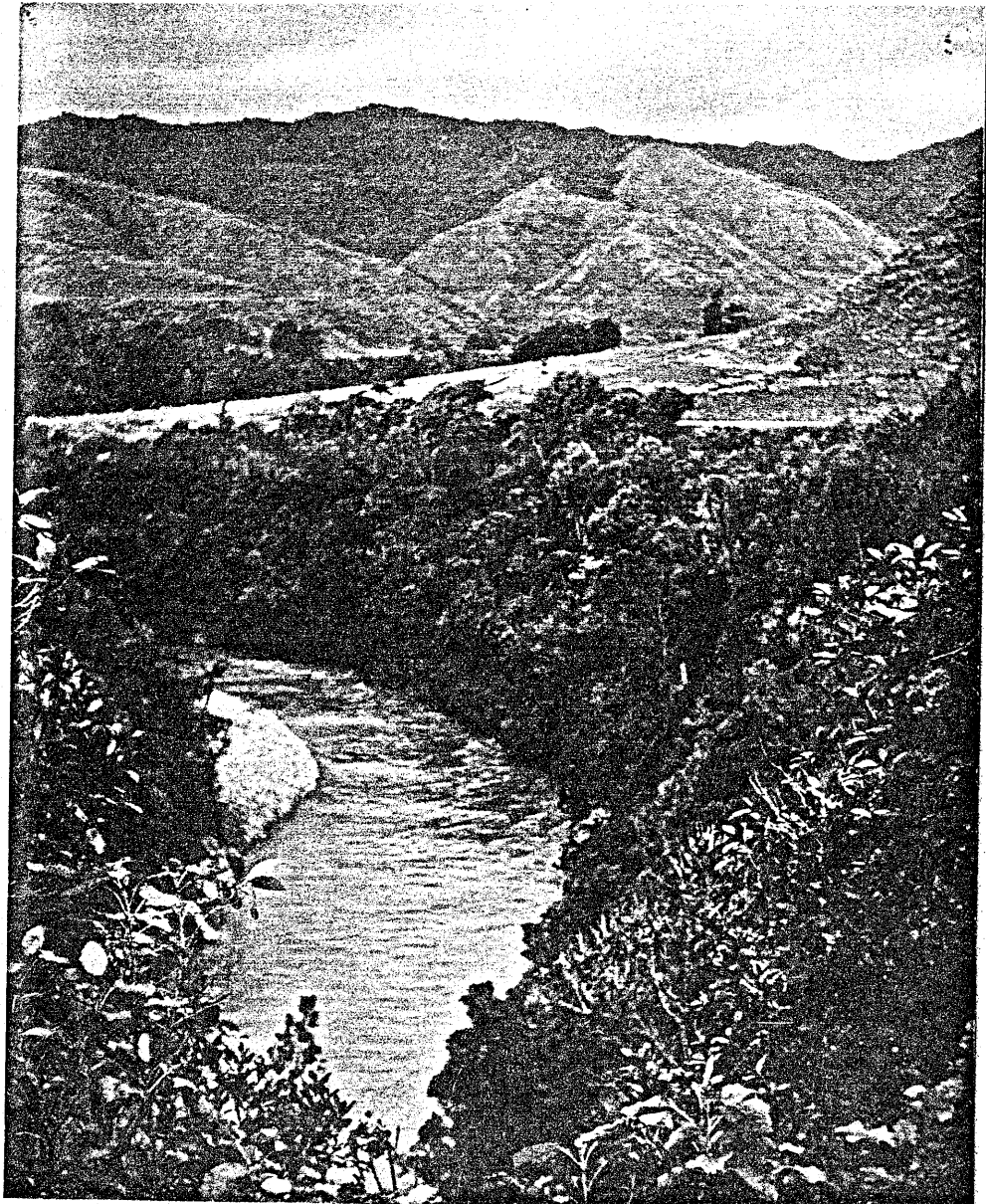
P7 Otaki River - view westwards over south bank foothills
and Canal route for schemes 3/3



P8 Otaki River - view northwards over north bank terraces and canal route for schemes 3/4

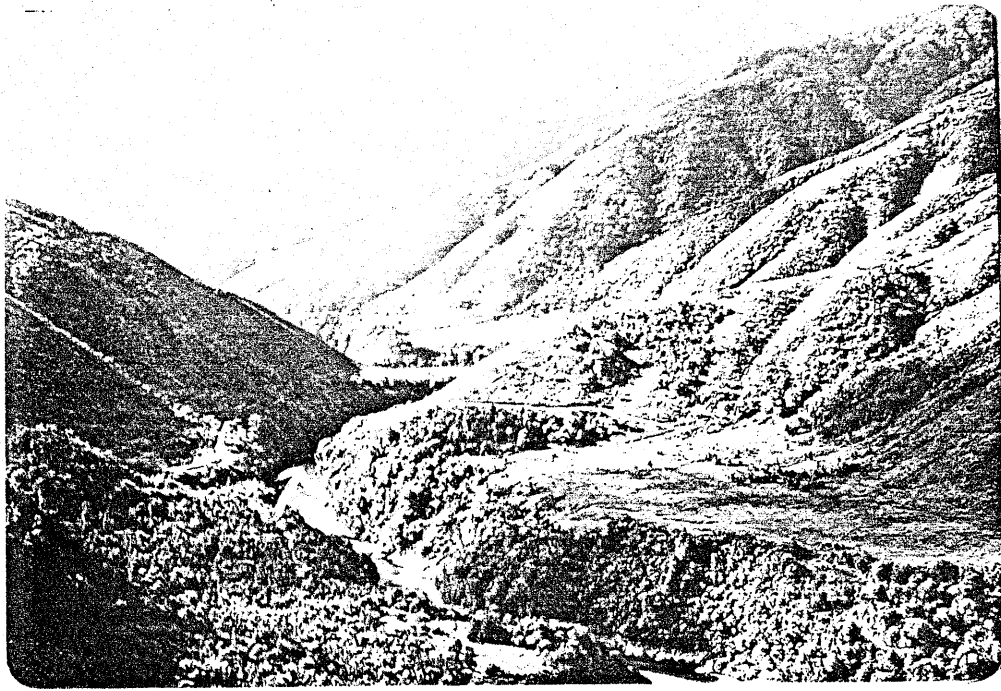


P9 Otaki river valley - view southwards
along Rahui Road to powerstation and
tailrace site 3/4A



P10 Otaki Lower Gorge - view upstream
of powerstation site for scheme 3/5

P11 Otaki Lower Gorge - view downstream to damsite 3/6



P12 Upper Otaki Catchment - view north-westwards across Waitewaewae Forks. Photo N.Z. Geological Survey

6.0 CONCLUSIONS

6.1 REGIONAL APPRAISAL OF HYDROELECTRIC SCHEME POTENTIAL

Following description of the development potential for individual hydro schemes throughout the study area it remains to review the potential on a regional basis and make outline recommendations for further investigations.

Tables 4.1 and 5.1 form the basis for this review, giving a summary of the physical parameters and 'first estimate' costs for all schemes studied. Table 6.1 summarises the power and cost of the potentially viable schemes. However, it must be recognised that with several schemes, especially those on the Otaki river involving larger dams, there are potential technical problems yet to be investigated. Therefore any regional ranking of schemes solely on the basis of these development cost estimates should be treated with caution. Table 6.1 extracts the most promising schemes on each river and ranks them according to the criteria given in section 3.4 above.

There is evidently no "very attractive" hydro potential in the region of the main western Tararua rivers; only the Otaki shows any attractive potential, which could best be realised by a combination of schemes 3/3B and 3/7D to give a total of around 37 MW.

A greater total power output at higher unit cost could be obtained from a combination of schemes 3/5A and scheme 3/7A, totalling 51 MW, to which could be added the less attractive scheme 3/1 of about 4 MW. The advantages of schemes 3/5A and 3/7A, which could possibly offset their higher power cost, would be the reservoirs formed behind each dam which could provide flow regulation for complementary water use downstream including some generation benefit for scheme 3/1.

The best apparent potential in the region is the Mangaore scheme 1/2, which could make good use of discharges from the Mangahao powerstation. It would be for debate whether this scheme would be best developed by the NZ Electricity Division, with operation tied to and covered by the Mangahao powerstation, or by the Horowhenua Electric Power Board as being of a relatively small size better suited for 'local' development and distribution.

Such questions would become clearer after further investigation, as would the optimum potential of the scheme as a function of Mangahao station upgrading, which is currently under review by the NZ Electricity Division.

The only other 'attractive' scheme in the region is the small Mangaharakiemie scheme 1/4, which would be dependant on local development interest and in particular on economic availability of smaller sizes of turbogenerator plant. The latest information on an overseas source of small hydro-generating sets with a NZ agency suggests that plant costs for effectively standardised machines up to 100 kW could be significantly less than taken for this study.

Diversion to the coast from the Maungakotukutuku tributary in the Waikanae catchment would be only marginally attractive for hydro-generation. This scheme, 4/2, would have to be considered as part of the overall supply of water to Paraparaumu and Waikanae urban areas, partly in place of the existing low level system from the Waikanae river. The scheme could save pumping costs, but could require an additional treatment plant, and could not develop the full available head if water had to be lead after discharge from a powerstation to a storage/header tank to command the water supply area. Such aspects are beyond the scope of this study, but should be worth further consideration by the Wellington Regional Water Board.

The following section outlines further investigations which we believe would be justified not only to confirm the hydroelectric potential indicated from this study but also to better define the topography and hydrology of the Otaki river in particular as fundamental to a better appreciation of the resources of the Horowhenua region.

6.2 RECOMMENDATIONS FOR FURTHER STUDIES

From Table 6.1 it is apparent that, for any regional development of hydroelectric potential, attention should be focussed on the Otaki river, and on the Mangaore stream below the Mangahao powerstation, and the following further studies are recommended:

Mangaore Scheme

- obtain from NZ Electricity their current views on uprating of Mangahao powerstation, then review economics of scheme and hence justification for a feasibility study which would include:
 - . topographic survey of intake and powerstation sites and canal route

- . optimum installation of turbines and generators to suit Mangahao output
- . geotechnical aspects of structural foundations and canal route
- . environmental aspects

Mangaharakiemie Scheme

Discuss scheme concept with local land owners, then:

- inspect and map plateau area and initiate programme of rainfall and stream flow measurements
- after 9 - 12 months of hydrological observations, reappraise hydro potential of scheme and re-estimate cost with particular attention to most economic construction/materials for races and headworks, pipeline, turbo-generator plant, and transmission facilities

Otaki Schemes

To round off earlier studies by the Horowhenua Electric Power Board, the following programme of investigations is recommended:

- maintain catchment rain and river gauge network
- obtain 1:2000 scale aerial mapping of the Otaki lower gorge between the Tuapaka gauge and the Pukehinau stream, supplemented by ground levels and dam site cross-sections obtained during ground control survey for aerial photogrammetry
- continue observation of high flood profiles in the Otaki gorge on gauges already installed by the Power Board including correlation survey of gauges
- review flood flow estimates in light of continuing hydrological data collection, including an estimate of probable maximum precipitation and consequent flood in the Otaki catchment
- derive sediment yield data from shingle extraction records and movement observations, e.g. Catchment Board cross-sections, and reintroduce sedimentation observations in Mangahao reservoirs
- then review preferred low dam/canal schemes to prefeasibility stage and overall Otaki potential in context of national energy prospects at that time.

TABLE 6.1 PRELIMINARY SCHEME RANKING

Scheme No.	River/Site	Output MW	Capital Cost \$M	Cost \$/kW	Rank
<u>Group 1 < \$1200/kW at 50% plant capacity factor</u>			NIL		
<u>Group 2 \$1200 - 1800/kW</u>					
1/2	Mangaore Stream	4.54	6.07	1340	2A
3/7D	Otaki/Waitewaewae (intake/tunnel; high head)	24.90	35.80	1400 min	2B
3/3B	Otaki/Gorge	12.0	19.63	1635	2C
1/4	Mangaharakiemie	0.11	0.18	1640	2D
3/5A	Otaki/Pukehinau	21.0	37.34	1780	2E *
3/7A	Otaki/Waitewaewae (dam)	30.0	51.00	1700 min	2F *
4/2A	Maungakotukutuku	0.70	1.26	1795	2G
<u>Group 3 \$1800 - 2400/kW</u>					
1/3	Mangahao addition	9.20	18.4	2000	3A
4/1B	Waikanae	2.20	4.44	2020	3B
3/1	Otaki/Hautere	4.30	9.04	2100	3C
2/1	Ohau	1.55	3.63	2340	3D
<u>Group 4 > \$2400/kW</u>					
1/1	Tokomaru	0.47	1.69	3600	4A

Notes: - min = cost for favourable tunnel conditions

- * = 3/5A + 3/7A alternative to 3/3B + 3/7D

- All data taken from Tables 4.1 and 5.1.

- Except for the Otaki River, only the most economic scheme on a given stretch of river is listed

- All costs in terms of MWD Construction Cost Index 1130

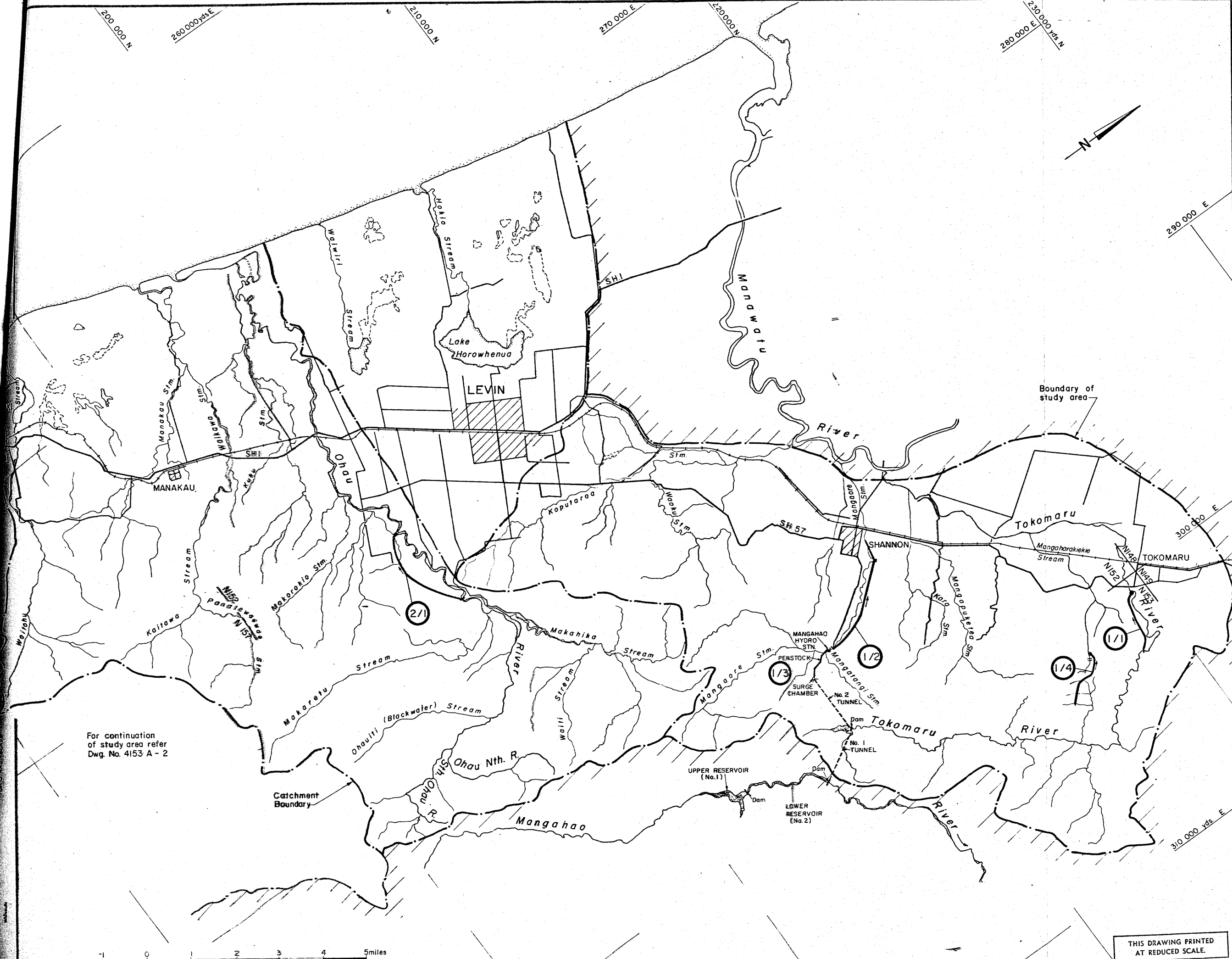
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10. "A Trampers Geology of the Tararuas": G.R. Stevens, NZ Geological Survey (1974).

11. Hydrology Report, for Assessment of Local Hydroelectric Potential:
Horowhenua, Wairarapa and Wellington Hutt Regions
Tonkin and Taylor (July 1980).
12. The Present and Potential Use of Micro-Hydroelectric Schemes in
Remote Locations
Tussock Grasslands and Mountain Lands Institute for NZ Energy Research
and Development Committee (in press).
13. Draft Water Resources Management Plan for the Otaki River Waitohu
Stream and Mangaone Stream Catchments.
Manawatu Catchment Board and Regional Water Board April 1977.
14. Proposed Hautere Plains Irrigation Scheme: Feasibility Report.
Water & Soil Division, Ministry of Works & Development, Wellington
District, December 1974.

LIST OF DRAWINGS

- 4153A - 1 Tokomaru, Mangaore and Ohau Rivers Catchments 1 and 2
- 2 Otaki and Waikanae Rivers Catchments 3 and 4
- 3 Tokomaru and Mangaharakekie Rivers Schemes 1/1 and 1/4
- 4 Mangaore Stream Scheme 1/2 and Mangahao Powerstation
- 5 Ohau River Schemes 2/1
- 6 Otaki River Sheet 1 of 4, Schemes 3/2 and 3/3
- 7 Otaki River Sheet 2 of 4, Schemes 3/4
- 8 Otaki River Sheet 3 of 4, Schemes 3/5 and 3/6
- 9 Otaki River Sheet 4 of 4, Schemes 3/7
- 10 Waikanae River Schemes 4/1 and 4/2



NOTES
 1. (1/4) depicts location of Scheme assessed.
 2. For 1:10000 scale plans of Schemes refer Dwg. Nos. 4153 A - 3, 4 & 5.

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TITLE
ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL

HOROWHENUA REGION

TOKOMARU, MANGAHOE AND OHAU RIVERS Catchments 1 & 2

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 REFERENCES
 NZMS 1 N 148, N 149, N 152, N 153, & N 157

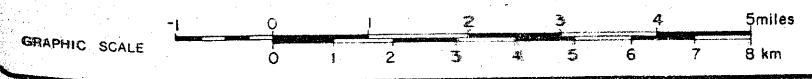
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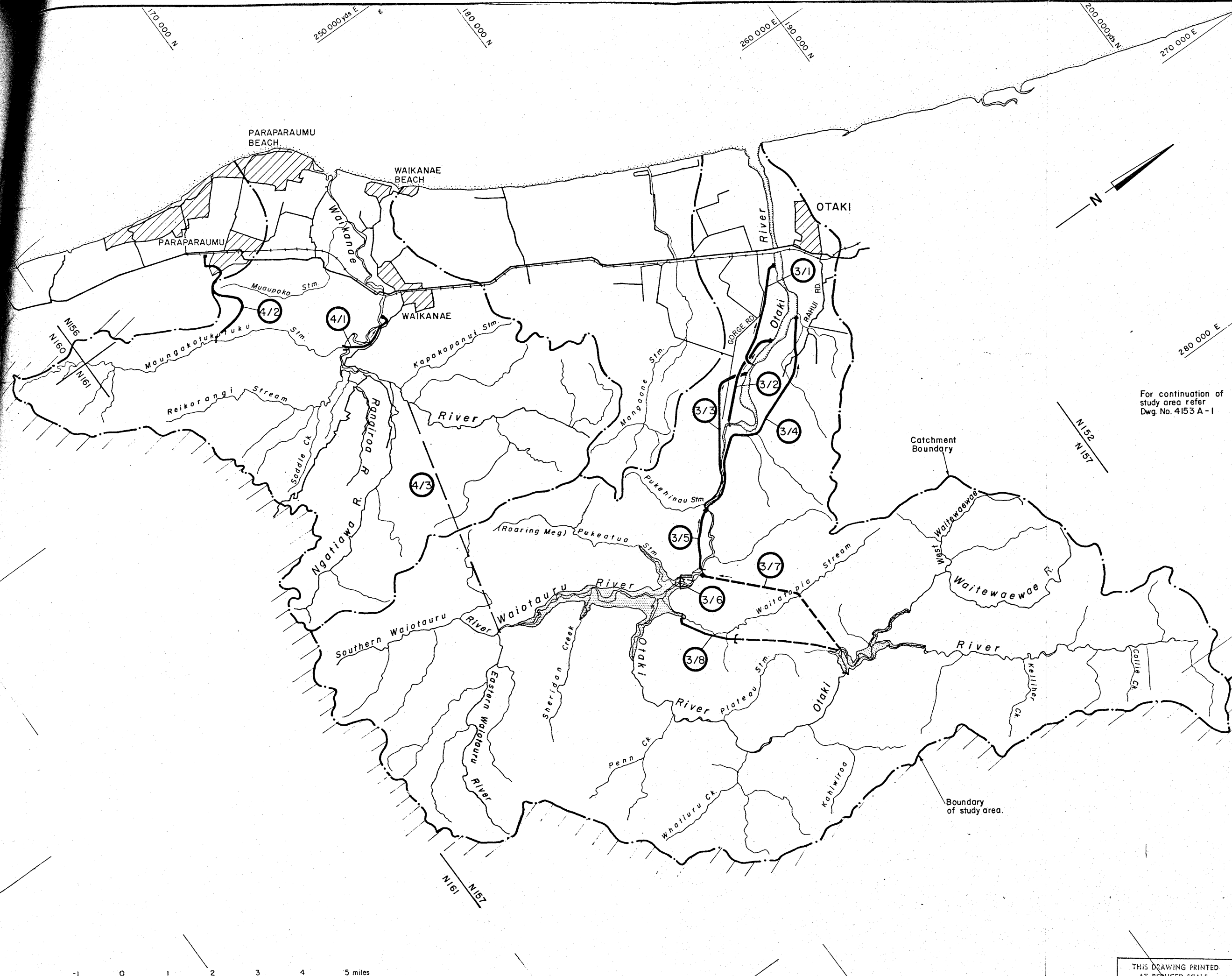
DRAWING No
4153 A - 1

DATE
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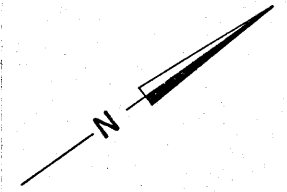
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For continuation of study area refer Dwg. No. 4153 A - 2





- NOTES
- 1 3/7 depicts general location of Schemes assessed.
 - 2 For 1:10 000 scale plans of Schemes except Scheme 4/3 refer Dwg Nos 4153 A - 6, 7, 8, 9 & 10.



For continuation of study area refer Dwg No. 4153 A - 1

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TITLE
ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL

HOROWHENUA REGION
 OTAKI AND WAIKANAЕ RIVERS
 Catchments 3 & 4

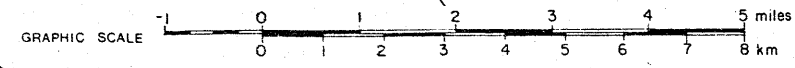
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 REFERENCES
 NZMS 1 N156, N157, N160 & N161

ORIGINAL SCALES
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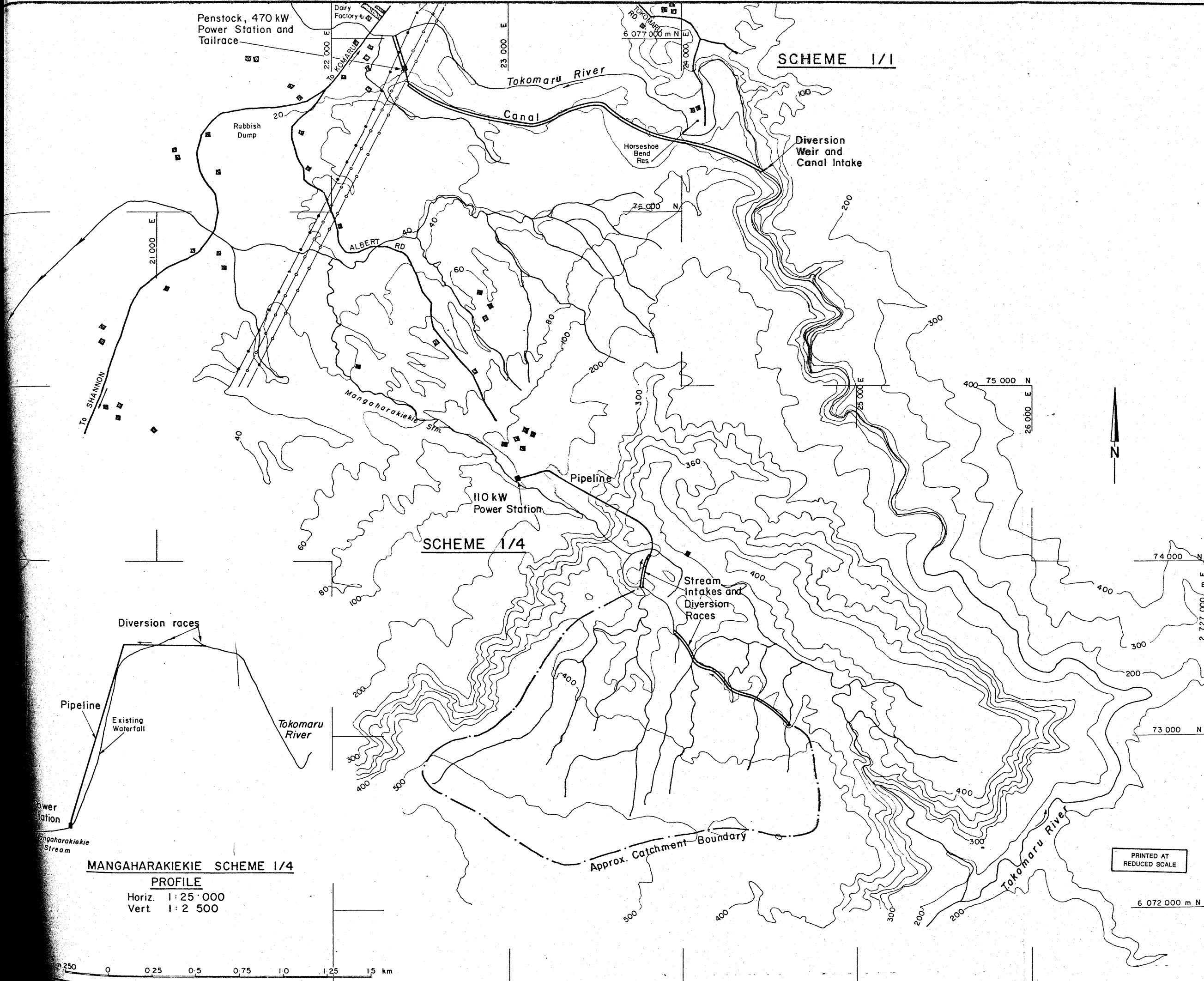
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ORIGINAL SCALE

Whitworth



NOTES

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TITLE
ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL

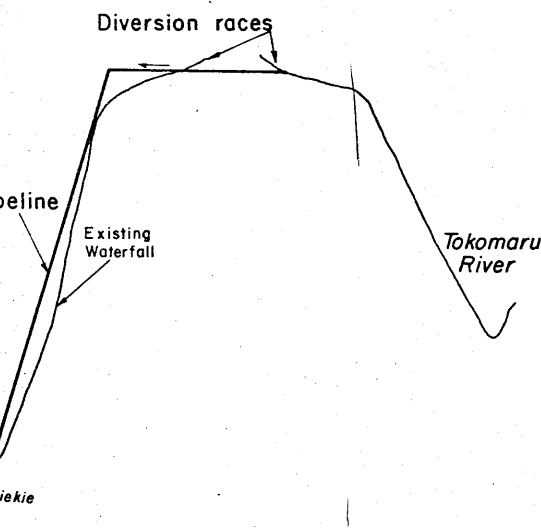
HOROWHENUA REGION

TOKOMARU & MAUNGHARAKEKE RIVERS
 Schemes 1/1 & 1/4

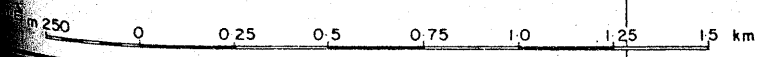
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 REFERENCES
 NZMS 270, S 24 D at 1:25 000

ORIGINAL SCALES
 1:10 000 Plan

DRAWING No. 4153 A - 3
 DATE SEPT 1980

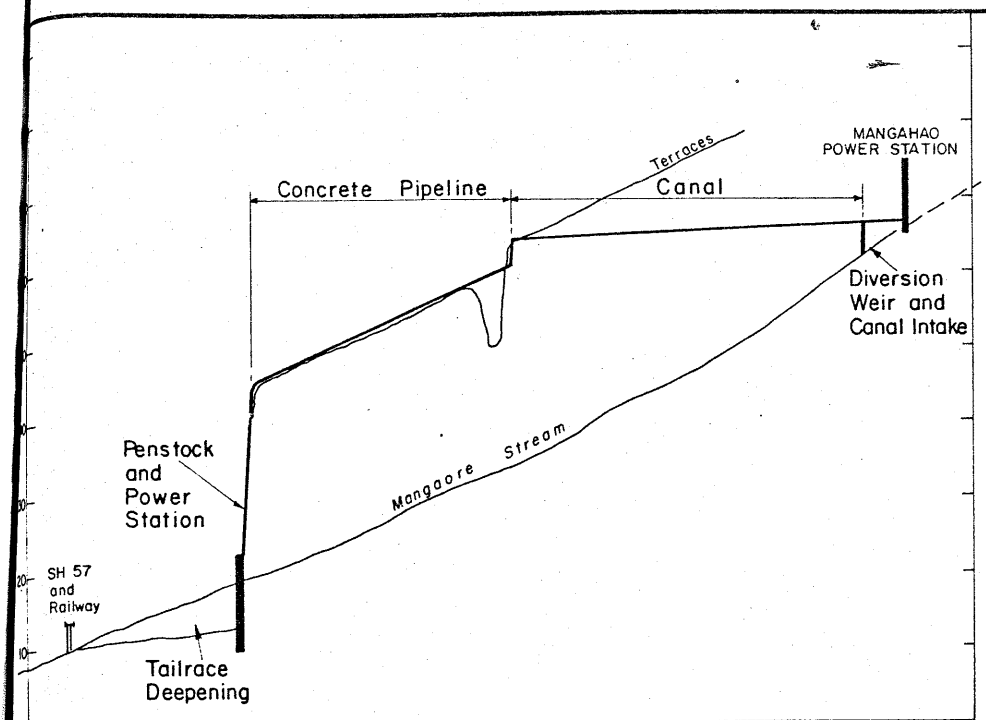


MANGAHARAKIEKIE SCHEME 1/4 PROFILE
 Horiz. 1:25 000
 Vert. 1:2 500

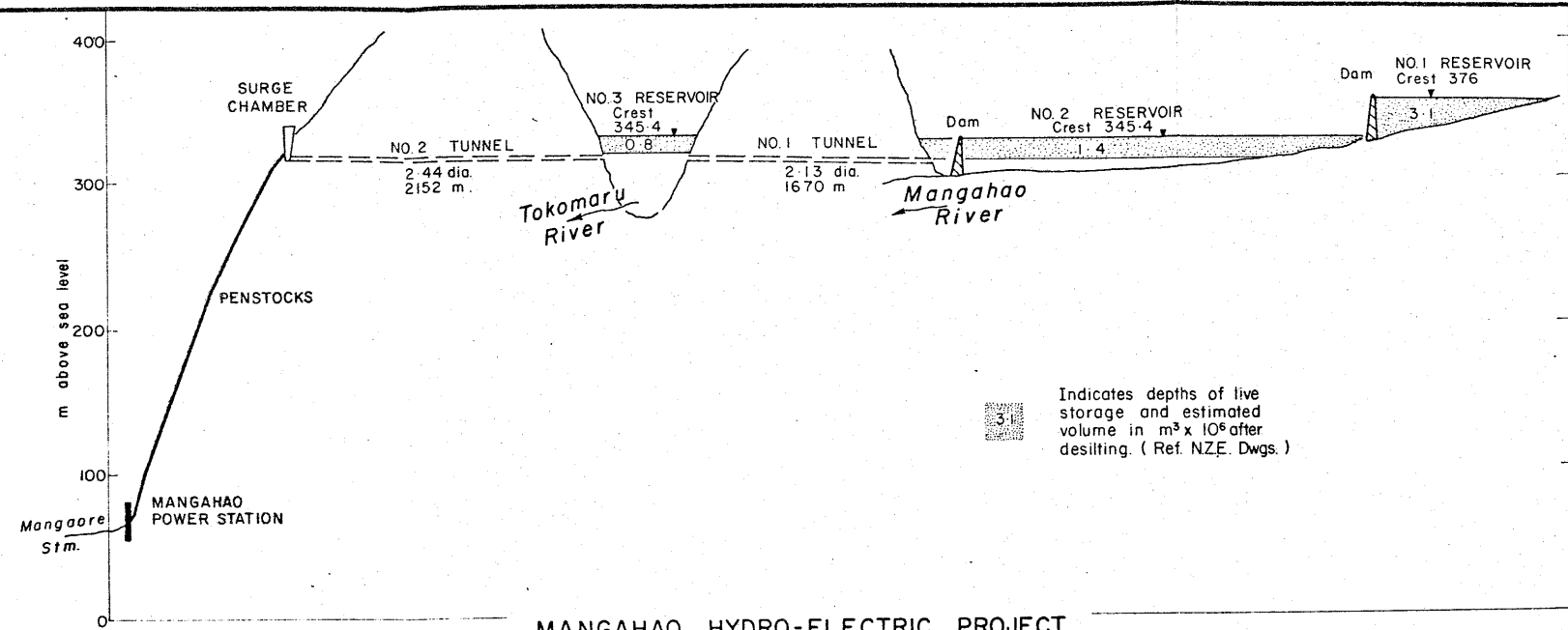


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6 072 000 m N

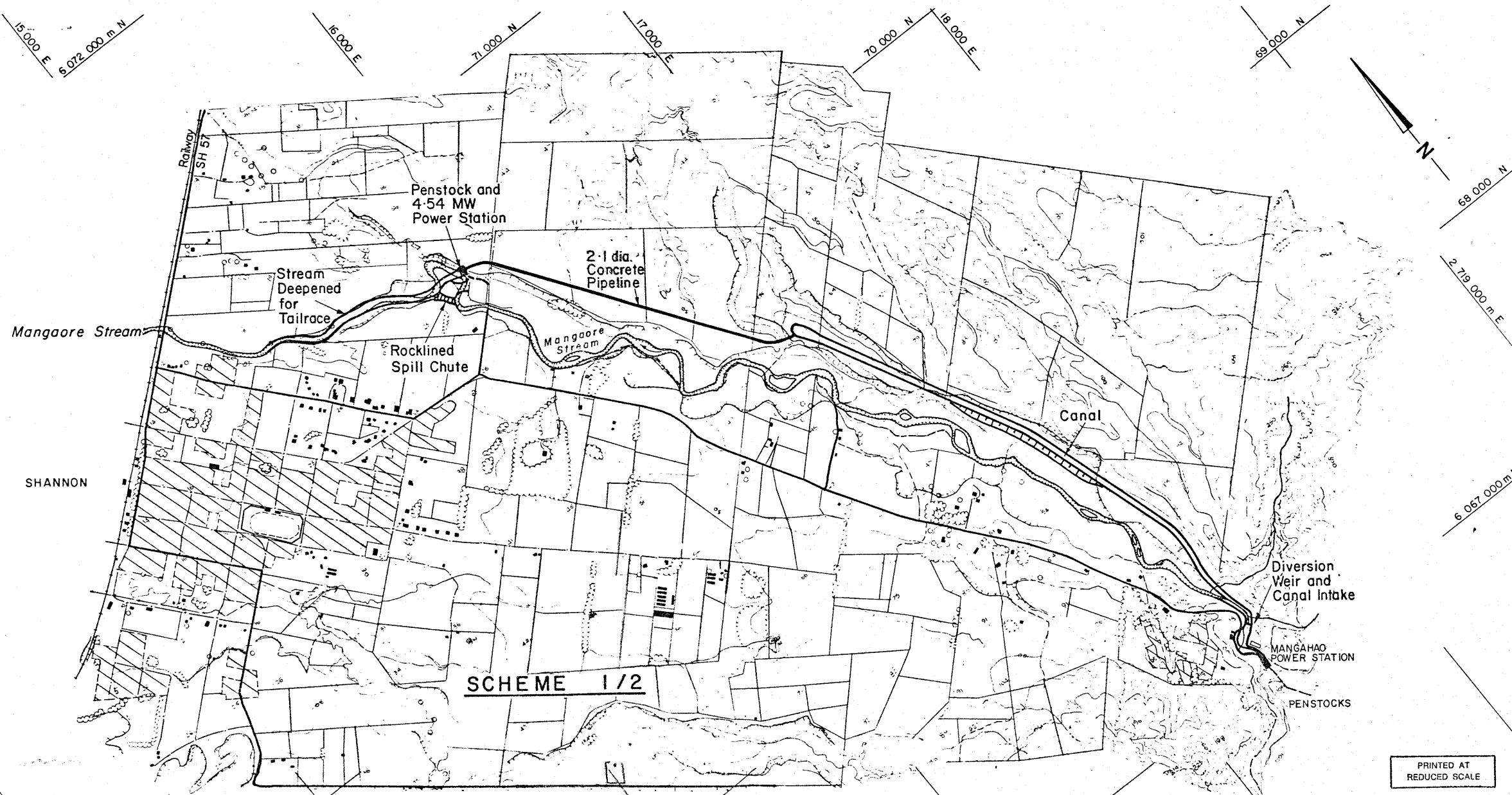


**MANGAORE SCHEME 1/2
PROFILE**
Horiz. 1: 25 000
Vert. 1: 500



**MANGAHAO HYDRO-ELECTRIC PROJECT
PROFILE**
Horiz. 1: 25 000
Vert. 1: 2 500

NOTES
For plan layout of Mangahao Hydro-electric Project see Dwg.No 4153 A-1



SCHEME 1/2

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TITLE
**ASSESSMENT OF LOCAL
HYDRO-ELECTRIC
POTENTIAL**

HOROWHENUA REGION

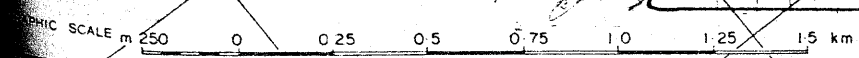
MANGAORE STREAM
Scheme 1/2 - and
MANGAHAO POWER STATION

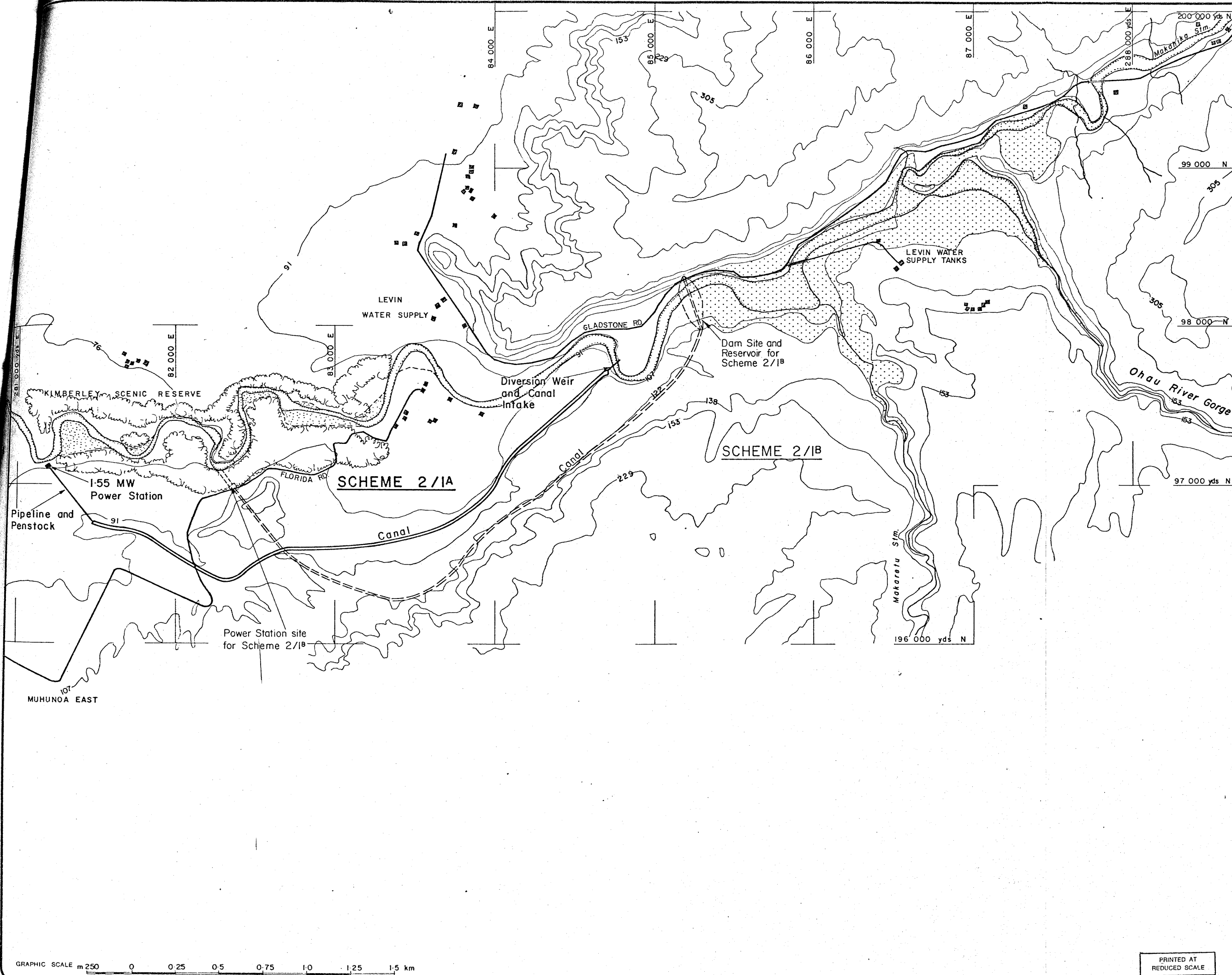
Copyright on this drawing is reserved
REFERENCES
AP 1262 Sheet 2
Run 4139/4-6
NZ Meridional Grid
Date of Photo. 5/2/68
Mapped JAN. 1980 by Photogrammetric Branch
Dept of Lands and Survey

ORIGINAL SCALES
1: 10 000 Plan

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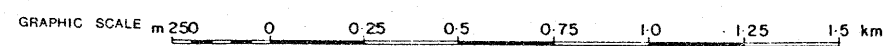
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ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL
 HOROWHENUA REGION
 OHAU RIVER
 Schemes 2/1A & 2/1B
 (alternatives)

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REFERENCES
 Photogrammetric Branch H.O.
 Dept. of Lands & Survey NZ 1974
 N 152 / N157, N158 & Pt. N159

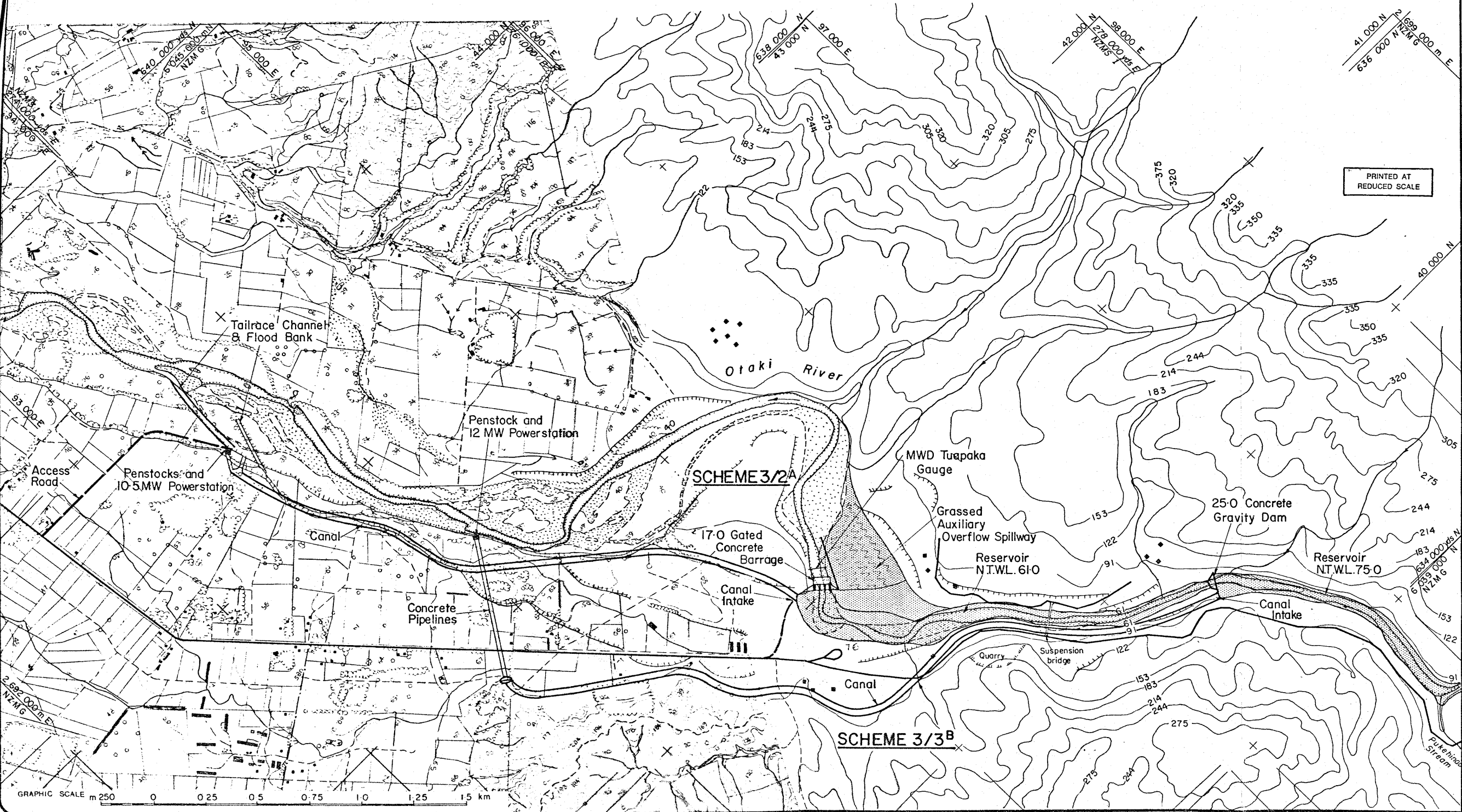
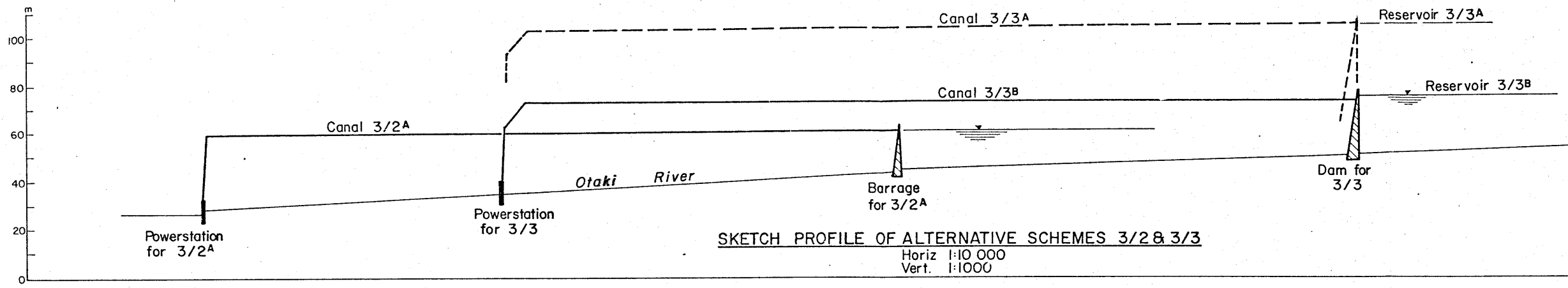
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ORIGINAL SCALE

NOTES



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TITLE
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 HOROWHENUA REGION
 OTAKI RIVER - Sheet 1 of 4 Schemes 3/2 & 3/3 (alternatives)

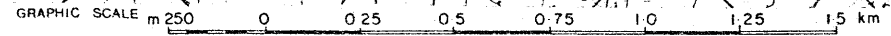
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 REFERENCES
 NZMS 1 N157
 Dep. of Lands & Survey A01262 Jan 1980
 WLD Blk sheets S25 & S26.

ORIGINAL SCALES
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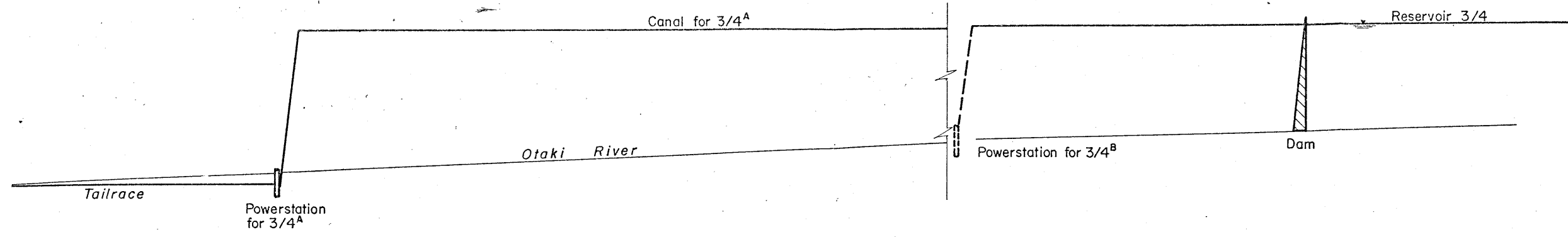


DRAWING No. **4153 A - 6** DATE **SEPT. 1980**

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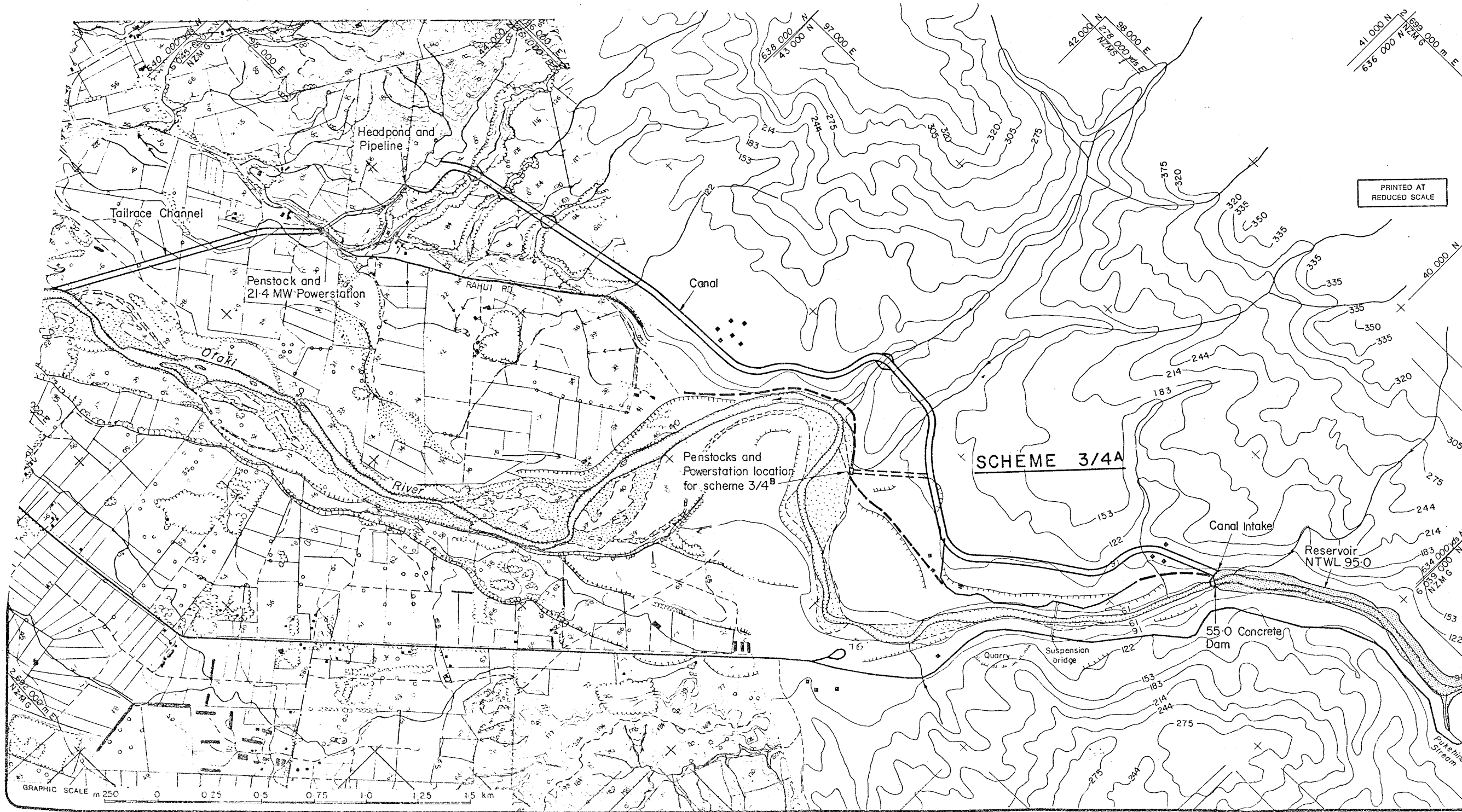


NOTES



SKETCH PROFILE OF SCHEME 3/4

Horiz. 1:10 000
Vert. 1:1000



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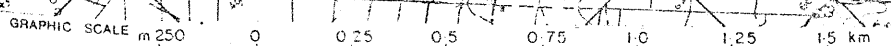
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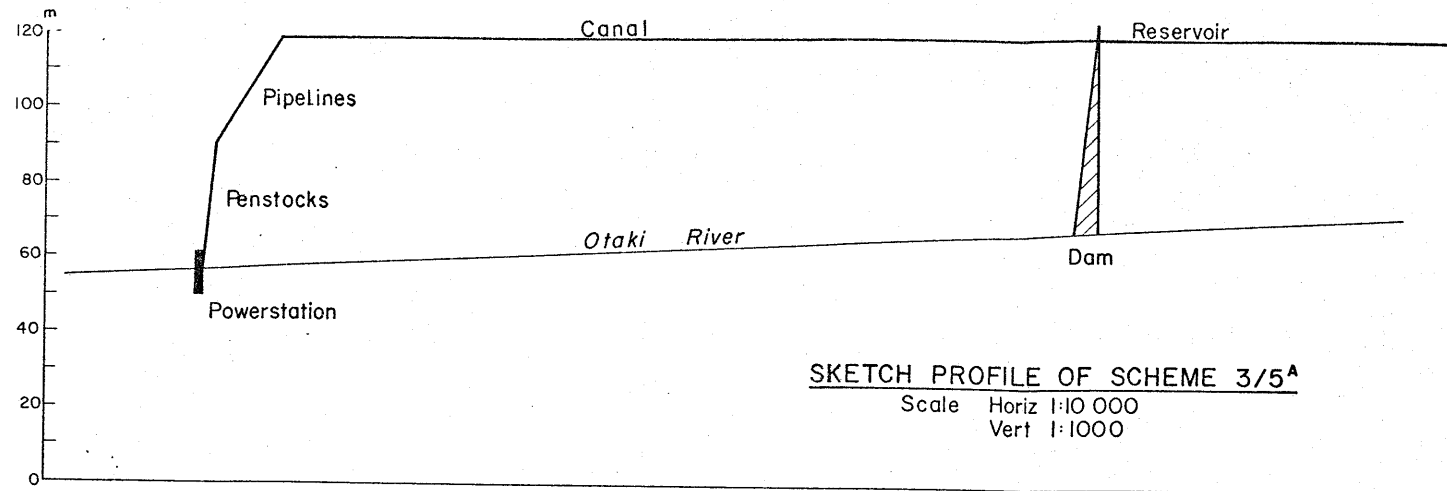
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TITLE
ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL
HOROWHENUA REGION
OTAKI RIVER
Scheme, 3/4A - Sheet 2 of 4

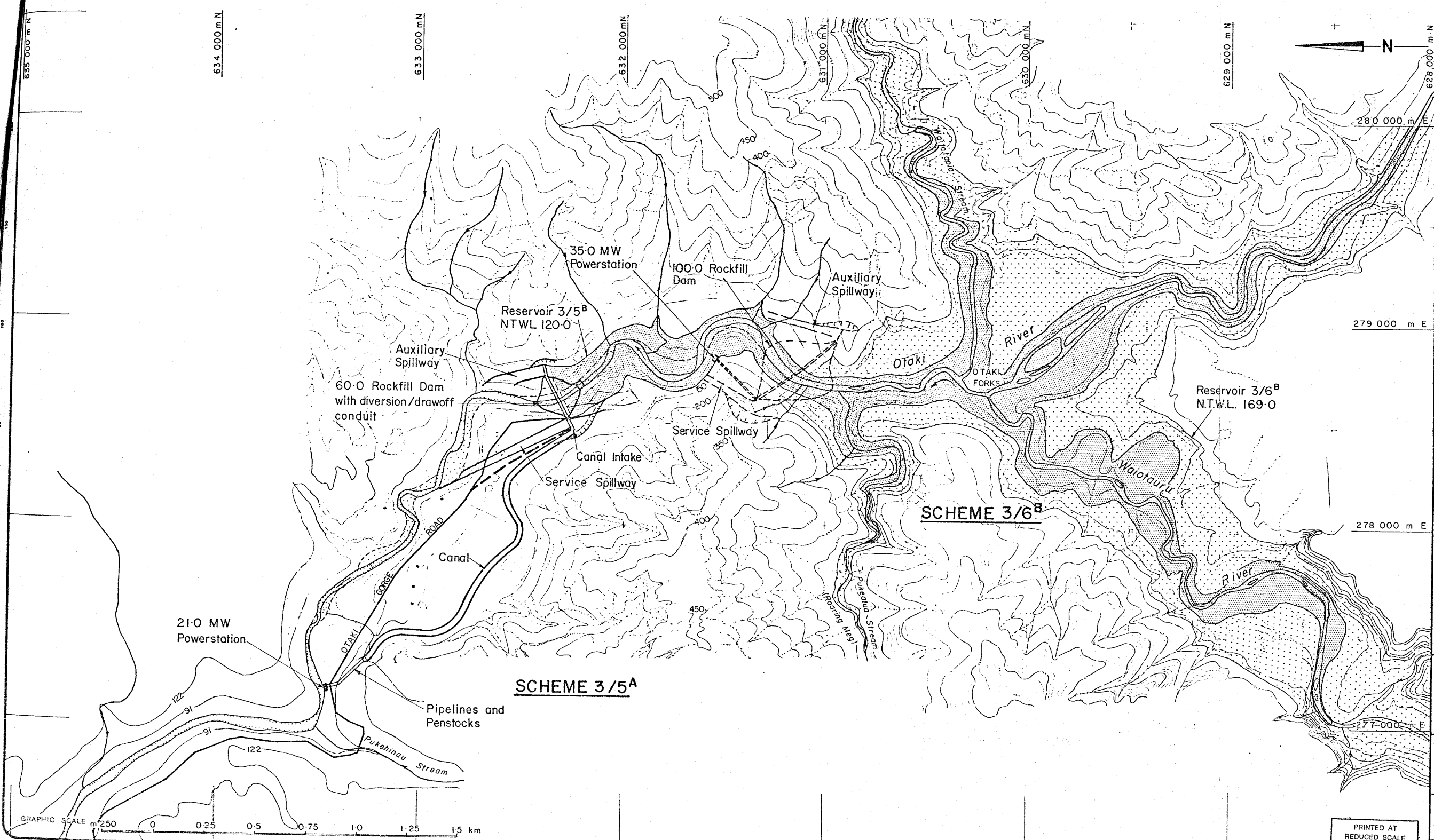
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REFERENCES
NZMS 1 N157
Dept. of Lands & Survey A01262 Jan 1980
WLD Blk sheets S25 & S26.

ORIGINAL SCALES 1:10 000	metric design
DRAWING No 4153 A - 7	
DATE SEPT. 1980	





NOTES
 1. Outline of Schemes taken from
 Tonkin Muir Energy Group
 Dwg. No. 2842-50



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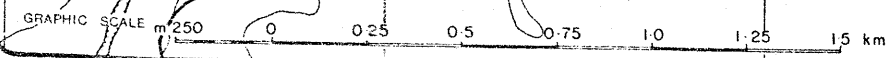
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ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL
 HOROWHENUA REGION
 OTAKI RIVER - Sheet 3 of 4
 Schemes 3/5^A & 3/6^B
 (alternatives)

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 REFERENCES
 Aerial surveys, 1:5 000, Contour Mapping
 27/3/77, Sheets 4 & 5 to
 Wanganui Meridional Grid
 NZMS 1 N 157

ORIGINAL SCALES 1:10 000	
DRAWING No. 4153 A - 8	

DATE
 SEPT. 1980

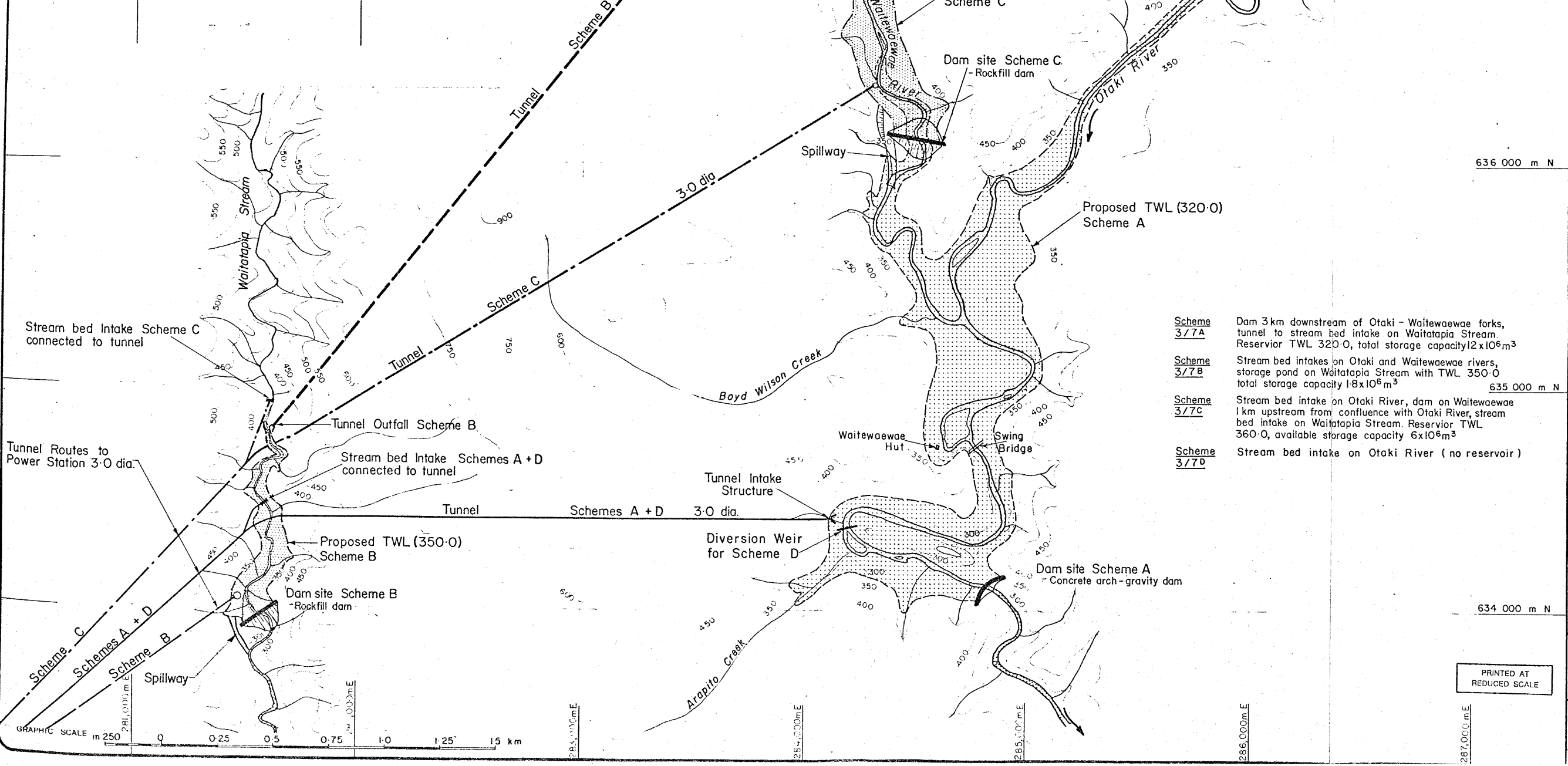
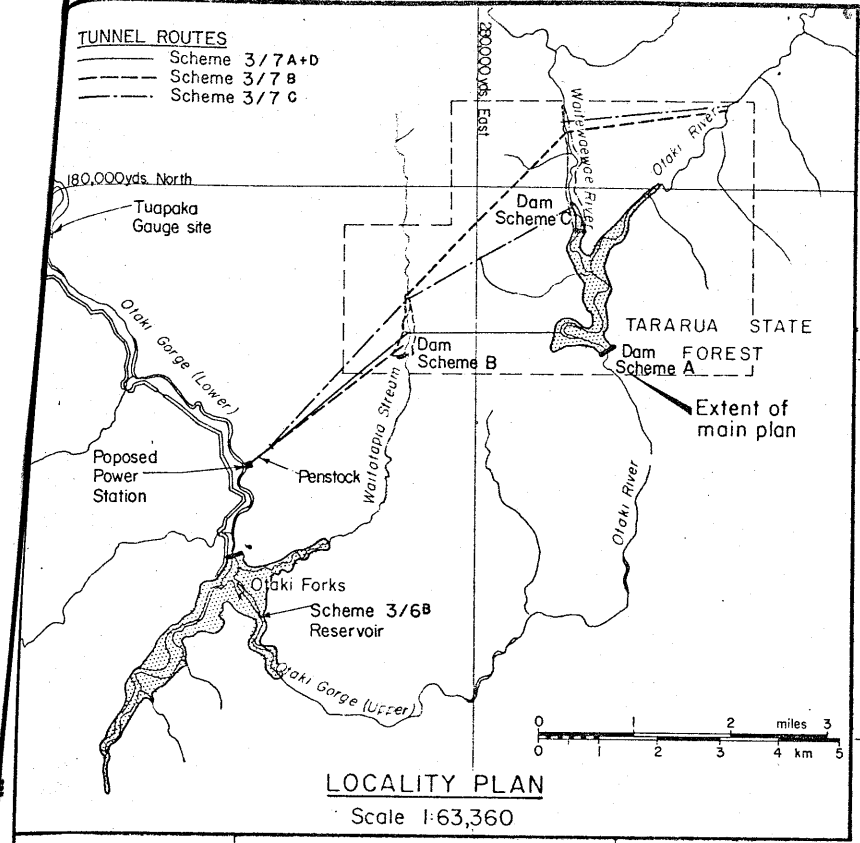
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ORIGINAL SCALE

TUNNEL ROUTES

- Scheme 3/7A+D
- - - Scheme 3/7B
- · · · · Scheme 3/7C



- Scheme 3/7A** Dam 3km downstream of Otaki - Waitawaewae forks, tunnel to stream bed intake on Waitatapia Stream. Reservoir TWL 320.0, total storage capacity $1.2 \times 10^6 m^3$
- Scheme 3/7B** Stream bed intakes on Otaki and Waitawaewae rivers, storage pond on Waitatapia Stream with TWL 350.0 total storage capacity $1.8 \times 10^6 m^3$
- Scheme 3/7C** Stream bed intake on Otaki River, dam on Waitawaewae 1km upstream from confluence with Otaki River, stream bed intake on Waitatapia Stream. Reservoir TWL 360.0, available storage capacity $6 \times 10^6 m^3$
- Scheme 3/7D** Stream bed intake on Otaki River (no reservoir)

NOTES
1. Outline of Schemes taken from Tonkin Muir Energy Group Dwg No.2842-1

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TITLE
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HOROWHENUA REGION

OTAKI RIVER - Sheet 4 of 4
Scheme 3/7
(alter natives)

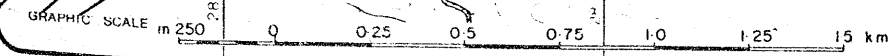
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REFERENCES
Acosurveys, 1:5 000, Contour Mapping
28/2/76 Sheets 1,2 & 3
NZMS 1 N157

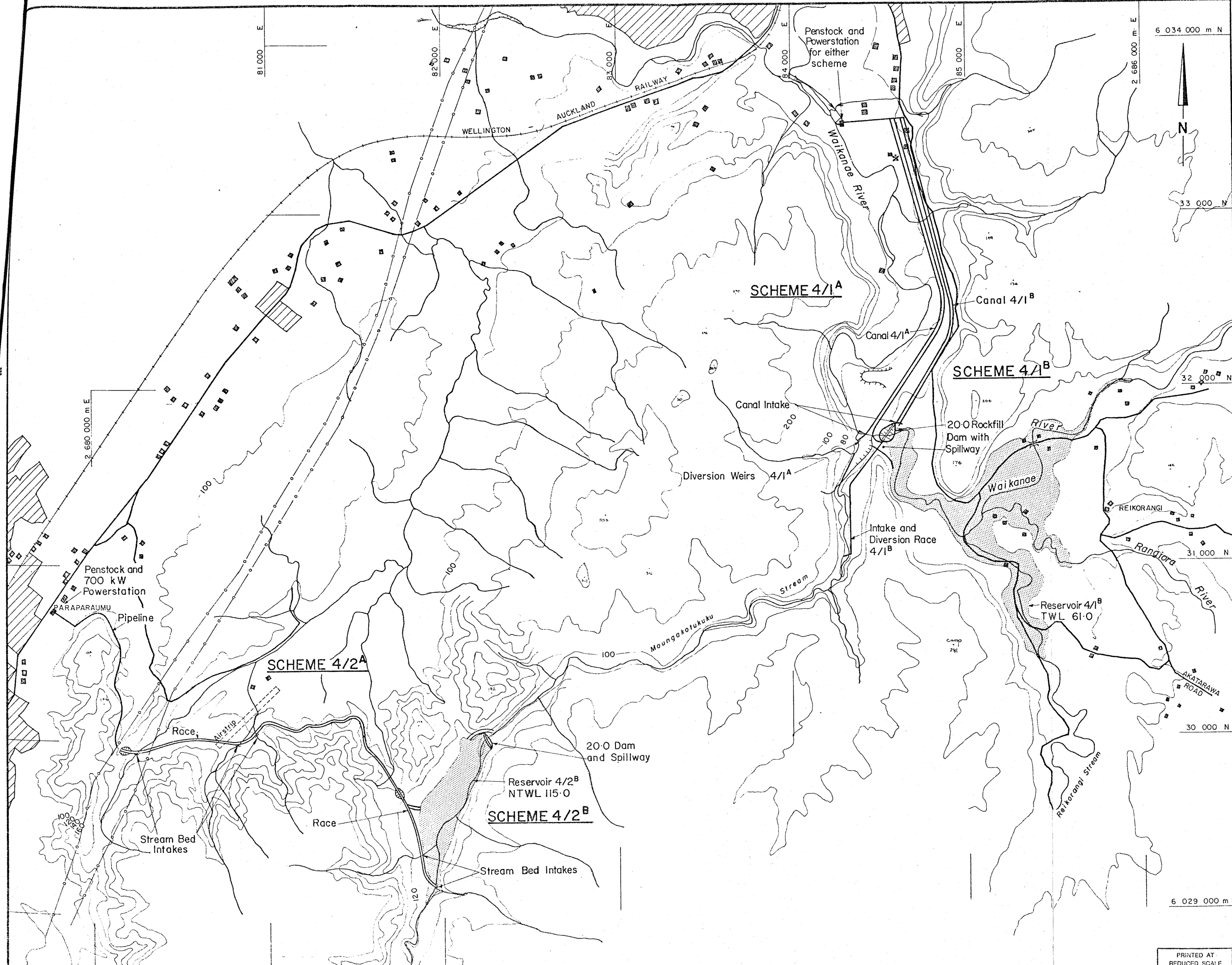
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1:10 000
metric design

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NOTES
 1. A & B Schemes are alternatives, and 4/2 is alternative to 4/1

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TITLE
ASSESSMENT OF LOCAL HYDRO-ELECTRIC POTENTIAL
 HOROWHENUA REGION
 WAIKANAË RIVER
 Schemes 4/1 & 4/2 (alternatives)

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 REFERENCES
 NZMS 270 R 26 A+B Contours
 Original Scale 1:25 000

ORIGINAL SCALES
 1:10 000

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 DATE SEPT. 1980

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 GRAPHIC SCALE m 250
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