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Otago Irrigation Dams

Dam Break

Hazard Assessment

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Chapter 1 - Introduction

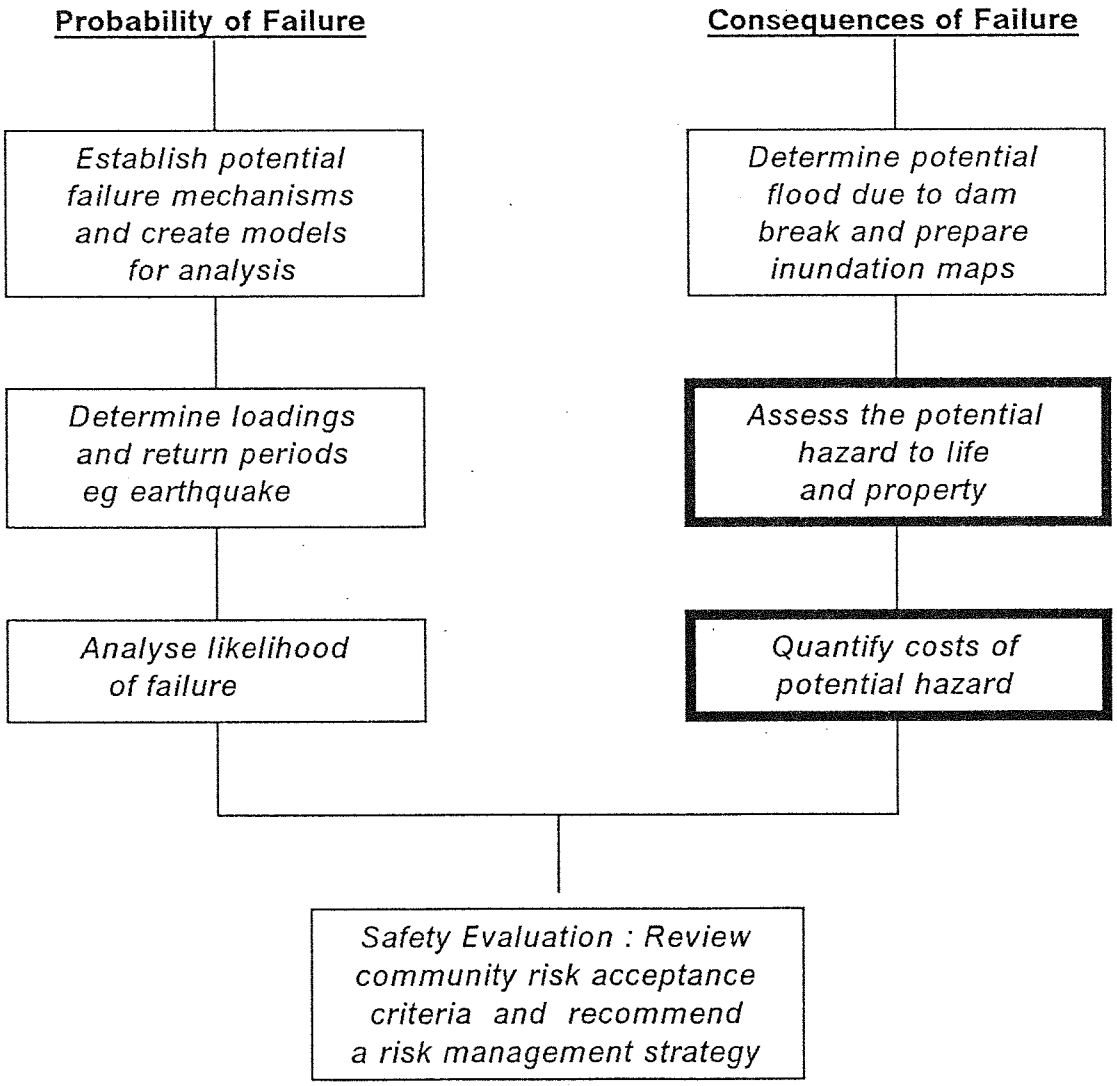
Background To SEED Investigations

MAF has commissioned WORKS Consultancy Services to investigate the irrigation dams in Central Otago as part of the SEED (Safety Evaluation of Existing Dams) programme.

This broad investigation essentially falls into two parallel streams of work which estimate:

- The probability of dam failure
- The consequence of dam failure

The final part of this process is the pulling together of each of those two streams of work into an overall safety evaluation. This total process is illustrated in the following simplified diagram with the hazard assessment items highlighted in bold line.



Objective of This Report

The objective of this report is to assess the potential hazard to life and property should the irrigation dams fail as outlined in the failure scenarios described in the Interim Report on Preliminary Dam Break Studies July 1989. The irrigation dams covered by this assessment are:

Conroys
Fraser
Lower Manorburn
Upper Manorburn
Poolburn
Falls
Idaburn
West Eweburn

The Interim Report on Preliminary Dam Break Studies contains a series of individual dam break analysis reports describing the worst case scenarios for failure of the above irrigation dams.

This hazard assessment takes these dam break analysis reports and estimates what the likely consequences would be should the hypothetical dam break events actually take place.

Sequence of Work

Using the information in the Interim Report's individual dam break analysis reports, estimated areas that could be flooded by each hypothetical dam failure were prepared and superimposed on maps of the downstream catchments. These inundation maps are included as a key part of this hazard assessment report and are included along with a location map at the end of this report.

Following preparation of the inundation maps an assessment of possible impacts and effects arising from flood routing and land inundation on people residing and using the area downstream of the dams was carried out. Included in this assessment is the possible effects on assets such as houses, farm buildings, orchards and farmland as well as impacts on public and private infrastructure such as roads, water races, bridges, dams and power supply. The results of this assessment are covered in Chapters 3 and 4 preceded by an evalution of key factors in assessing hazards in Chapter 2.

National and International Review

As part of this assessment a literature search was initiated to review hazard assessment techniques used overseas and elsewhere in New Zealand and to ensure that techniques and ratings used in this report are comparable to those used internationally.

The techniques of dam break hazard assessment internationally involve a typical process as follows:

1. Preparation of inundation maps to illustrate likely routing of the flood arising from dam break.

2. Definition of the population which would be likely to be at risk from such flood events.

3. Assessment of impacts of such floods on people and property in downstream catchments.

4. Establish a rating system to compare impacts with other dams.

The hazard assessment outlined in this report follows this process.

Considerable work has been carried out in New Zealand and overseas on establishing an agreed rating system to be applied to dam break hazard assessments. Within New Zealand dam hazard assessment was initiated in a report (referred to as the Beach Committee Report) prepared for the Commissioner of Works in 1984. This report entitled "Public Safety Review Procedures For Dam Type Structures" recommended among other things the preparation of an inventory and the classification of dam type structures "based on potential threat to life and property," ie, a hazard rating".

Acting on this recommendation a report entitled "The New Zealand Dam Inventory" was published in December 1988 by the Building and Development Directorate of the Ministry of Commerce. This report was based on work over preceding years by the Dam Surveillance Section of the Works and Development Services Corporation Ltd and its predecessor the Ministry of Works and Development.

The New Zealand Dam Inventory summarises and lists data for 402 dams throughout New Zealand that are over 1.8 metres in height and store more than 18,500 cubic metres of water. Each dam in the inventory has been assigned a hazard potential rating which has been evaluated based on the physical size of the structure, the capacity of the stored water and the downstream habitation and environment. The report notes that the hazard potential rating is independent of the actual condition of the structure, ie, it covers the consequences of failure not the probability of failure.

The New Zealand Dam Inventory uses a rating of hazard potential recommended by the Beach Committee and developed by the US Corp of Engineers. This rating illustrated below has been adopted internationally. Examples of its use other than in the US are its endorsement by the New South Wales Dam Safety Committee and its inclusion within the Alberta Environment Dam Safety Branch guidelines.

This hazard rating uses a breakdown into Low/Significant/High categories based on a combination of threat to life and threat to structures and physical environment as follows:

Category	Extent Threatened	
	Life	Development/Environment
Low	Unlikely (no Permanent structures or habitation downstream)	Minimal (undeveloped to occasional structures or agriculture)
Significant	A few lives threatened (no urban developments and no more than a small number of inhabitable structures)	Appreciable (notable agriculture industry or structures)
High	More than a few lives threatened (permanent village or urban developments)	Excessive (Extensive industry or agriculture)

This hazard rating reflects the physical size, the capacity of the reservoir of water stored by the dam, the extent of downstream population and development, and the degree to which the latter would be affected should there be a release of water. It should be noted that the rating does not give any indication of the condition or security of the dam structure, the quality of its design and construction nor the extent of control and surveillance features which have been incorporated.

Of the 402 dams listed in the New Zealand Dam Inventory 56 have been assigned a High hazard potential rating, 93 have a Significant rating and 253 have a Low rating. The eight irrigation dams studied in this hazard assessment are included in the dam inventory with all except the Idaburn dam allocated a rating in the Significant category. Idaburn dam has been included in the Low rating category.

This rating allocation was established prior to this hazard assessment exercise and prior to, and without the benefit of, the Interim Report on Preliminary Dam break studies. The re-evaluation of these ratings in the light of these further studies is discussed in the conclusions on page 23.

Chapter 2 - Key Factors in Assessing Hazards

Introduction

A number of key factors arise in assessment of hazards arising from the failure scenarios outlined in the Interim Report. These factors are:

- Routing of floods arising from dam break, ie, where the flood is likely to go as illustrated in the inundation maps.
- Timing of flood arrival, ie, how long between dam break and flood arrival.
- Flood intensity, ie, how destructive is the flood likely to be.
- Population at risk, ie, who is likely to be affected.

Routing of Floods

Estimating the routing of a flood following hypothetical dam break is a key factor in assessing potential hazards.

The inundation maps included in this report have been prepared in conjunction with the author of the individual dam break analysis reports. They are broad in format with the blue areas indicating the routing of floods arising from the worst case dam break scenarios. These areas are defined approximately only and are shown to illustrate the likely routing of the flood based on known topographical information. To obtain a precise estimate of the extent of flooding would require a more detailed evaluation than that contained in the individual dam break analysis reports together with presentation of maps at a larger scale than that contained in this report.

Accepting the limited resolution in these maps they do however illustrate the broad extent of flooding that could arise throughout the downstream catchment of each dam. One aspect of these maps which is clearly apparent is that the land that could be flooded is very large in area relative to the surface area of the dam reservoirs themselves. The reasons for this is that the flooding of land following the arrival of the initial flood wave is only temporary and that water in the catchment immediately below the dam will, within a relatively short period, move downstream to spread out on the valley flats or into the main river. In addition, and more importantly, the depth of flood waters over the larger areas on the valley flats would be very shallow relative to the depth of water within the reservoirs and would therefore spread over a much larger area before draining away into the main rivers.

Timing of Flood Arrival

The timing of arrival of the flood wave is of critical importance in hazard assessment and in implementation of a civil defence plan to give warning to the population at risk. While the brief for this report does not extend to civil defence planning it is recognised that the factor of warning time is of paramount importance. For this reason those estimates of the time lapse when the flood wave could be expected which are described in the individual dam break analysis reports are also illustrated in red on each of the maps. In the case of the Conroys, Fraser, Upper Manorburn, Poolburn and Falls dams time estimates of the arrival of the flood wave after dam

break at two or three points downstream are shown. For the Idaburn and Eweburn an estimate at one point is given while with the Lower Manorburn the estimated time before the arrival of the flood into the Manuherikia is so short that no time is shown.

Flood Intensity

The other factor which is important in relation to hazard to the population at risk is flood intensity, ie, the depth, speed and destructive capability of the flood wave. The general conclusion that can be drawn from the individual dam break analysis reports is that, as could be expected with the catastrophic scenarios envisaged, the estimated flood volumes are very large and the effect would be devastating for any residents in the areas immediately downstream.

The flood waves would in general remain devastating for all the steep downstream areas and for those areas located at points where the rivers enter out onto the valley flats. The only mitigating effect for these latter areas is the time lapse between dam break and arrival of the flood wave.

However much of the flooded areas indicated on the inundation maps for Conroys, Fraser, Poolburn and West Eweburn in particular cover wide areas of the valley flats. Within these areas, particularly those parts remote from the exit of the river onto the flats, the level of hazard in terms of threat to life and damage to property would be very much less. The reason for this is that the size of the flood wave, the depth of the flood itself and the scouring effect of the water would reduce as the wave extended outwards across the flats.

So in general terms there would be likely to be a grading of potential hazard effects and impacts. Impact and hazards would tend to lessen where the attenuation effect of the topography is such as to slow the flood wave down and gradually disperse it over wider areas. While the effects in these areas more remote from the dam would in some cases be comparable to a very major flood (an example is the likely effect of a Lower Manorburn dam break on the Manuherikia River) in most cases the flow of water and the speed at which it would arrive is likely to be such that the effects are very much greater than any known or potential natural flood event.

The flow of flood water estimated in the individual dam break analysis reports illustrates this latter point. These estimate flows are huge both in relation to the downstream rivers themselves and also in relation to the rivers that they flow into, ie, Manuherikia (Upper Manorburn, Lower Manorburn, Falls, Idaburn and Poolburn) the Taieri (West Eweburn) and the Clutha (Conroys, Fraser). To illustrate this point the following table summarises the estimated range of maximum flow of water following dam break at each dam site respectively.

Conroys 1550-1850 cubic metres per second
Fraser 7750-11300 cubic metres per second
Lower Manorburn 1000-1300 cubic metres per second
Upper Manorburn 3900-4400 cubic metres per second
Poolburn 6700-11700 cubic metres per second

Falls 3200-7800 cubic metres per second
Idaburn 630 cubic metres per second
West Eweburn 1400-3500 cubic metres per second

For comparison purposes the mean flow and estimated 500 year return period flood flow of the Clutha River at Clyde are:

	Mean	500 year flood
Clutha main stem	470 m^3/s	3,200 m^3/s

It will be noted that the estimated range of water flows released at each of the dam sites following dam break vary considerably. Fraser and Poolburn estimates are the largest, both in flow volume and range. The Upper Manorburn and Falls are next largest. The range for Falls is particularly wide because it, along with West Eweburn, are rockfill dams (all the others are concrete arch dams) and the failure scenarios are based on more prolonged erosion failure not total collapse. Conroys, West Eweburn and Lower Manorburn come next with Idaburn having the lowest estimate dam break flow.

It also must be emphasised that these flows are based on failure scenarios assuming full reservoirs. For much of the year the reservoirs will not be full and at particular times during long dry periods some reservoir levels drop very considerably.

Should the hypothetical dam break events coincide with these times of low reservoir levels the inundation would be much less than estimated and the impacts and effects would be considerably reduced.

Population at Risk

The size of the population at risk is a key factor in any dam break hazard assessment. Clearly hazard is directly related to the population size which is placed at risk.

The population at risk comprises those people who would be present within the inundated areas and, on, or adjacent to the dam reservoirs at the time of dam break. This population is likely to vary depending on the time of day and the time of year that the hypothetical event would happen. Also the level of risk would be likely to vary depending on the warning time available and the success of evacuation of the area prior to flood wave arrival.

Although there is no built up urban land within the inundation areas of the eight dams studied, and although much of the downstream areas are sparsely settled, there is a small resident population at risk in most cases. The issues related to defining the population at risk and the likely impact on these population for each of the eight dams are discussed further in the following chapters.

Chapter 3 - Explanation of Inundation Maps

General Explanation of Maps

The routing of floods are illustrated in the eight inundation maps contained in the Appendix. The Location Map illustrates the coverage of inundation maps for each dam and its downstream catchment areas. The inundation maps have all been compiled at the same scale of 1:50,000 and are based on a combination of the published 1:50,000 Infomap 260 Series and the older 1:63,360 (one inch - 1 mile) NZMS 1 Series. The older mapping has been used for locations such as Conroys and Fraser dams and parts of the Manorburn and Poolburn catchments where the 260 Series is not yet available.

In interpreting these maps a number of matters should be taken into account as follows:

- The maps show by way of blue colour overlays the probable maximum extent of inundation in the valley downstream arising from hypothetical dam failure. In view of the sparseness of the topographic data available and the simplifying assumptions on which the dam break analysis was based, the extent of inundation shown must be treated as indicative only.
- The flood routing and estimated extent of inundation is based on worst case scenario events occurring at times when reservoirs are full.
- The Otago Irrigation Dams Interim Report assumptions are conservative regarding the breach dimensions and dam break analysis. In the unlikely event of an actual dam failure the breach dimensions and initial hydrological conditions may differ from those assumed giving rise to differing consequences in the downstream valley.
- The times shown on the maps refer to times of occurrence of peak flood level after dam break and represent the maximum possible warning time available for evacuation.

Conroys

The dam break report for Conroys reveals the following scenario:

- Earthquake induced failure resulting in a peak outflow of 1550-1850 cubic metres of water per second at the dam site
- The initial flooding of a substantial part of the upper ponding area immediately downstream of the dam
- The ponding of the flood within this upper area followed by overflow some 12/13 minutes after dam break into the lower basin area
- The ponding of the lower area followed some 24/27 minutes after dam break by overflow through to exit onto the Earnscleugh flats some 25/28 minutes after dam break
- The spreading out of the flood wave across the south east corner of the Earnscleugh flats in a shallow flooded area

Map 1 illustrates this scenario and the approximate extent of flooding through the upper and lower ponding areas and the possible extent of shallow flooding across the Earnscleugh flats.

In assessing impacts and effects it is apparent that the severest effects would apply to the upper and lower ponding areas. Two houses and orchard buildings in the upper area would be engulfed with little time lapse for warning. The flood wave would also devastate the orchard in this area together with associated orchard buildings.

The effect on the lower ponding area would be equally devastating with the only mitigation being a 12/13 minute time lapse for warning. Within the lower area are two houses, an orchard and associated orchard buildings which would be devastated.

The estimated flooded area on the Earnscleugh flats contains some 9 houses and associated orchard and farm buildings. The water velocity and depth of flow would lessen as the flood spreads out from the exit onto the flats. There is unlikely to be any danger to life within this area although damage to houses and buildings could be substantial.

The flood would be likely to drain away relatively quickly from the flats. This combined with the low velocity and water depth, should not result in irreparable damage to orchards and farmland.

Fraser

The dam break report for the Fraser dam poses the following scenario:

- Earthquake induced failure of the dam with a peak water volume outflow of 7750-11300 cubic metres per second at the dam site
- The movement of the flood wave over steep gorge conditions with only one ponding area until it would reach the exit to the north western corner of the Earnscleugh flats at Fraser Domain - some 15/20 minutes after dam break
- The extension of the flood wave out into the flats and along the flood corridor of the Fraser River to the Clutha

Map 2 illustrates the possible extent of the flooding across the flats and down the flood corridor of the Fraser river.

Within the uninhabited downstream area from the dam to the Fraser domain the main impact would be the destruction of the Fraser power station headworks located within the gorge area. The power station itself located at the exit of the gorge would also be devasted at a time some 15/20 minutes after dam break.

The Fraser dam break scenario would create risk to life and property within the inundated area of Earnscleugh particularly the area adjacent to the exit at the

Fraser Domain. Flood velocities at the Fraser Domain would be such that the few houses in this vicinity which would be in the direct line of the flood would be likely to be devastated. As the flood would spread out downstream as indicated on map 2 the effect would lessen. However there are additional houses downstream which would be likely to be inundated and damaged together with substantial areas of orchards, water races, storage dams and associated facilities. The effect in this area would be flooding on a scale somewhat greater than the 1978 flood in the Fraser River. The main difference in this case in the speed at which the flood would arrive. Overall some 20 houses would be flooded with this scenario to a greater or lesser degree.

Lower Manorburn

The dam break report for the Lower Manorburn puts forward the following scenario:

- Earthquake induced collapse of the arch section of the dam with a peak outflow of 1000-1300 cubic metres of water per second.
- The flooding of the area downstream of the dam, extending across the railway embankment and into the low lying Manuherikia riverbed and adjacent land.

Map 3 illustrates this area of flooding extending down the Manuherikia to Alexandra and backing up toward the Galloway bridge. Overall the effects would be limited to possible damage to the railway and some flood damage to orchards and farmland particularly on the west bank of the Manuherikia. Flooding is not likely however to extend as far as State Highway 85 and no houses are likely to be affected.

Upper Manorburn

The dam break analysis report for the Upper Manorburn is based on an instantaneous earthquake induced collapse scenario with:

- A peak outflow of 3900-4400 cubic metres of water per second at the dam
- The routing of the flood wave down the long steep winding gorge of the Manorburn until some 30-40 minutes after dam break the wave would reach the Lower Manorburn reservoir
- The swamping and collapse of the Lower Manorburn dam and the flooding of downstream areas along the Manuherikia to a higher level than the flooding which would arise from the Lower Manorburn dam break alone.

The impacts within the section between the Upper and Lower Manorburn would not be great because there are no houses or settlement within this steep gorged area. Some sections of irrigation race downstream of the dam however would be destroyed.

The main impact as illustrated in Map 5 would arise at and below the Lower Manorburn where the railway embankment would be likely to be destroyed by the flood wave. Flooding of the Manuherikia would be extensive extending up to and across State Highway 85 in the vicinity of the Letts Gully road junction. Overall it is likely that up to 15 houses and extensive areas of orchards and associated buildings would be flooded. The lower part of the Alexandra camping ground would also be likely to be inundated although serious effects on Alexandra below the railway bridge are not likely.

Poolburn

The hypothetical earthquake induced collapse of the Poolburn dam described in the Poolburn dam break analysis report would create a peak outflow of 6700-11700 cubic metres of water per second at the dam site This scenario would result in a flood wave descending the steep channel of the Poolburn reaching the exit onto the Ida Valley flats some 17/20 minutes after dam break.

Map 5 illustrates the likely extent of flooding across the Ida Valley draining out via the Idaburn to the Manuherikia. The severest impact would be in the Bonspiel Station area at the exit onto the valley flats. An irrigation dam close to the exit would be destroyed followed by the devastation of the station homestead and buildings together with the adjacent old Moa Creek hotel.

The impact further downsteam would be less severe with the flood wave spreading out over the flat valley reaching a width of up to three kilometres and slowing in velocity and depth. Further houses would be affected by inundation in addition to the Poolburn School buildings and grounds. Overall approximately 12 houses could be flooded within the valley.

Some 55/70 minutes after dam break the flood would reach the Idaburn and exit the valley through the gorge. Some flooding may occur where the Idaburn joins the Manuherikia with subsequent high flows for a time in the Manuherikia River itself.

Falls

The dam break analysis report for Falls is based on a dam failure scenario having a peak outflow of approximately 3200-7800 cubic metres of water per second at the dam site. The analysis estimates that this peak would only be likely to develop after a considerable period of erosion through the dam resulting in abnormally high water levels in the Manuherikia river for some time prior to dam break.

Map 6 illustrates approximately the likely flood routing. The flood wave would descend the enclosed valley downstream of the dam and widen out into two ponding areas in the vicinity of Fiddlers Flat before exiting into the open valley and washing out the Loop Road bridge across the Manuherikia.

The flood routing down the Manuherikia would be likely to be confined to the lower river terraces as illustrated in Map 6. This confined routing of the flood wave would

ensure that impact is minimised. However at one point downstream of where Coal Pit Road joins State Highway 85 the flood would cross the highway and probably flood a house and farm buildings in this lower lying area.

While further threat to life and property downstream would be limited, there would be some impact including potential damage to the highway bridge at Blackstone Hill and to the water race intake in this vicinity. The flood would extend downstream off Map 6 and would potentially result in some damage to the highway bridge at Becks and the irrigation syphon pipeline immediately downstream as well as the Lauder railway bridge.

The two gorges in the middle section of the Manuherikia river, the Lauder gorge and Ophir gorge respectively, would assist in mitigating the impact of the flood in the lower reaches towards Alexandra. High river flows in the Manuherikia would however continue for some time.

Idaburn

The hypothetical dam break scenario for the Idaburn dam indicates an earthquake induced instantaneous collapse with a peak outflow of some 630 cubic metres of water per second at the dam site. Map 7 illustrates the likely extent of the floodable area arising from this scenario.

The flood wave would initially inundate the confined area downstream of the dam and probably destroy the Ida Valley - Omakau road bridge. Two smaller bridges downstream may also be washed out while one house may be at risk from the flooded area which would spread out along the flower river flats. The flood wave would reach the gorge at 55-75 minutes and flooding beyond that would be limited to some flooding at the Manuherikia junction, and high flows in the Manuherikia River for some time.

West Eweburn

The dam break analysis report for West Eweburn assumes an erosion failure of the dam with a peak outflow within the wide range of 1400-3500 cubic metres of water per second at the dam site.

Based on this scenario Map 8 illustrates the routing of a flood wave. Downstream of the dam the flooded areas comprising part of the Naseby Forest plantations would be confined by river terrace topography of the West Branch of the Eweburn but further downstream towards and beyond State Highway 85 the topography is very flat and the extent of inundation would widen.

Map 8 illustrates an estimate 750 metres maximum width of inundated corridor in the vicinity of the state highway at a time about 30-40 minutes after dam break. Downstream of the highway there are two houses and related farm buildings which lie within the inundated area. However at these locations the depth of water would be small and while damage would be extensive, threat to life would be low.

Further downstream towards the railway crossing the flood would be ponded back by the railway embankment at a point where the East Branch joins the West to form the Eweburn.

Chapter 4 - Summary of Hazard Assessment

Summary of Hazard to Life

An assessment of hazard to life arising from each of the dam break scenarios raises a number of variables which make it difficult to make any estimate of loss of life potential.

These variables are:

- Variables in defining the size of the population at risk.
- Variables in assessing the success or otherwise of systems of warning for downstream residents

The population at risk from any of these events are primarily those people resident within the inundated areas downstream of the dam. The numbers of houses within these inundated areas give an indication of numbers of people. These numbers of houses which may be at risk are estimated as follows:

Conroys	13 houses
Fraser	20 houses
Lower Manorburn	-
Upper Manorburn	15 houses
Poolburn	12 houses
Falls	1 houses
Idaburn	1 house
West Eweburn	2 houses

The resident population in these houses is likely to vary during the year. Some of these houses are not permanently occupied. Equally some within the Conroys, Fraser and Upper Manorburn inundation areas may be fully occupied to a high level during the fruit picking season only and remain vacant for the remainder of the year.

In addition to the uncertainty of numbers resident within the inundation areas at any time there is the difficulty in assessing the level of risk that these residents would face. The difference between residents living immediately downstream of the dam and those resident out on the flat remote from the dam is very great. While the former are likely to be greatly at risk in terms of threat to life those more distant where warning time is much greater and the flooding much shallower and less destructive the threat to life is not likely to be great.

A further complication in assessing the population at risk and the impact on that population is the likely variation in numbers of non residents who may move into the inundation area and onto or around the edges of the dam reservoirs for both work and recreation. This inflow of people would occur for instance during the fruit picking season for the areas downstream of Conroys, Fraser, Upper and Lower Manorburn reservoirs. Should the dam failure events coincide with these peaks then the hazard to life would be much greater than at other times.

The recreation users at risk would include anglers using the rivers downstream of the dams and any boat users on the reservoirs at the time of failure. At most times these numbers would be very low or nil. However all reservoirs are actively used during summer and the risk would be greater at high use periods. The greatest concentration of people by far occurs for winter skating on the Lower Manorburn and Idaburn. At those times the population at risk for both the Upper and Lower Manorburn and Idaburn dam break scenarios would occasionally reach many hundreds. The very short duration of this very high use however needs to be borne in mind in any overall assessment.

With all these variables precise estimates of lives threatened are not practical to achieve. However some estimate is necessary in order to evaluate hazard to life even though it invariably will be broad in range and subjective in nature. The following comments attempts to estimate and summarise the relative threats to life should the dam break scenarios eventuate.

- Fraser and Conroys: These two dam failure scenarios exhibit the greatest threat to life within the group of dams studied. It must be expected that these failure scenarios would result in some loss of life. With a great deal of luck and an effective warning system in place it is possible that loss of life may be avoided with Fraser. This however would only happen if residents in the vicinity of Fraser Domain were able to clear the area very quickly and there were no other people in the downstream catchment close to the river. If warning was not effective, loss of life could be within the 0-10 range or greater for Fraser. With Conroys because of a shorter warning time loss of life is even more likely than with Fraser although the numbers may be lower because of less extensive flooding.

- Upper Manorburn and Poolburn: These two failure scenarios are the next greatest in terms of threat to life of the eight dams studied. The numbers threatened would be greater in the case of the Upper Manorburn than Poolburn but there are several mitigating factors with Upper Manorburn which potentially reduce the threat. These are firstly the warning time potential to vacate both the Lower Manorburn reservoir area and the Manuherikia area and secondly the fact that houses within the inundation areas adjacent to the Manuherikia would not be likely to be in the direct line of the flood and are generally on the periphery of the flooded area. With Poolburn the numbers of houses are less and the likely population of the downstream catchment at time of dam break is likely also to be less. However the buildings close to the exit onto the Ida Valley would be likely to be in the direct line of the flood and hence the threat is greater to the few residents in this area. Overall loss of life could be within the 0-5 range should these dam break scenarios eventuate. This disregards the potentially large but extremely remote chance of the Upper Manorburn scenario eventuating at times of high recreation use of the lower reservoir.

- With the Lower Manorburn, Idaburn, Falls and West Eweburn dams it should be possible to sustain a dam break without loss of life. Those houses that may be flooded would not be likely to be devastated and adequate warning signs and warning time would be likely. However the coinciding of these scenarios with

high recreation use of the dam reservoirs or with inadequate or ineffective warning, then loss of life could potentially occur.

Summary of Hazard to Property

The hazard to buildings would arise mainly to the houses that would be flooded as previously outlined. Some of these would be completely devastated and financially would be written off while others would be flood damaged, some seriously.

In addition to houses there will be some damage to orchard and farm buildings. As with houses this is likely to be greatest with Fraser and Conroys. The scouring and flooding of farmland and orchards is also likely to be a major contributor to financial loss to property. In this respect the following listing of estimated total areas of land flooded and the areas of orchard inundated are relevant.

	Total area of land likely to be inundated (Ha)	Estimate area of orchard (Ha)
Conroys	280	60
Fraser	570	130
Lower Manorburn	200	30
Upper Manorburn	940	50
Poolburn	3000	-
Falls	580	-
Idaburn	500	-
West Eweburn	700	-

The following cost estimates illustrate very approximate costs of property reinstatement. The costs include rebuilding of devastated houses, repair and refurbishment of flooded houses, replacement of orchards devastated, loss of income, reinstatement of damage to irrigation and power facilities, reinstatement of bridges and roads, reinstatement of scoured and flooded farmland and fences and general clean up.

Conroys	$1.75 million
Fraser	$9.0 million
Lower Manorburn	$0.5 million
Upper Manorburn	$1.75 million
Poolburn	$1.5 million
Falls	$1.0 million
Idaburn	$0.3 million
West Eweburn	$0.5 million

These approximate cost estimates do not include estimates for the cost of rebuilding the dams following dam failure. The very high cost for Fraser relative to the others reflects not only the greater impact on houses and orchards in particular but also the reinstatement costs for the Fraser power station and headworks.

Conclusions

This hazard assessment provides an insight into the likely effects of the dam break scenarios on people and property. In view of all the variables involved in this assessment and the broad scope of the scenarios themselves with their inherent lack of precision, this assessment should only be considered as providing an indication, not a clear picture, of likely effects.

For all these inherent imprecisions the assessment does however reveal a number of important conclusions:

- The dam break scenarios reveal potential catastrophic events for downstream residents and properties in all cases.
- The flood volumes released in the dam break scenarios are huge relative to naturally occuring flood events.
- The populations at risk are small with no built-up areas threatened.
- There are small permanent resident populations at risk in all cases except perhaps for Idaburn and Lower Manorburn.
- Conroys and Fraser scenarios are the most threatening to downstream populations with Upper Manorburn and Poolburn next in order and Lower Manorburn, Falls, Eweburn and Idaburn the least threatening.
- Timing of the scenario events would be critical to threat to life. The very remote prospect of dam break coinciding with peak recreation use should be considered with a view to mitigation measures.

- The main mitigation measures which could substantially reduce risk to life are firstly measures to make the dams more secure against the threat of dam failure and secondly the establishment of a civil defence warning system to evacuate potentially flood areas. The main factor working against effective warning systems is the relatively short times in some cases between dam break and flood arrival.

- All dam break scenarios would result in a considerable financial cost for reinstatement of flooded and destroyed buildings facilities and infrastructure. The Fraser dam break scenario with its impact on the downstream power facilities, numerous houses and large areas of orchard is likely to be by far the greatest in terms of reinstatement cost.

Finally it is appropriate to review this hazard assessment in relation to the national and international rating system described on page 7 and 8.

The first point to make in this regard is that because no urban areas are threatened none of the eight dams should be included in the High threat category. This leaves the Significant and Low categories for consideration. The NZ Dam Inventory includes all except Idaburn in the Significant category. Clearly Fraser, Conroys Upper Manorburn and Poolburn should be in the Significant category because there is a definite threat to life in each of these and also appreciable threat to buildings and development. Although threat to life is not great with Falls and West Eweburn damage potential with these scenarios is sufficient for them to also be in the Significant rating. With Lower Manorburn the justification is less clear and there would appear to be a reasonable case to include this along with Idaburn in the Low category.

These ratings may assist in putting the effects of dam break scenarios in the context of other dams in New Zealand and overseas. However of more importance in comparing the effects locally is the following suggested listing of the eight dam break scenarios in decreasing order of hazard. This listing is based on an overall balancing of the impacts and effects which are likely to arise should dam failures occur as described in the 1989 Interim Report on Preliminary Dam Break Studies.

1. Fraser
2. Conroys
3. Upper Manorburn
4. Poolburn
5. Falls
6. West Eweburn
7. Lower Manorburn
8. Idaburn

Appendix - Inundation Maps

FALLS

map 3

IDABURN

map 7

WEST EWEBURN

map 8

map 5b

FRASER

map 2

CONROYS

LOWER
MANORBURN

map 1

map 3

map 4b

POOLBURN

map 5a

UPPER MANORBURN

map 4a

0 5 10km

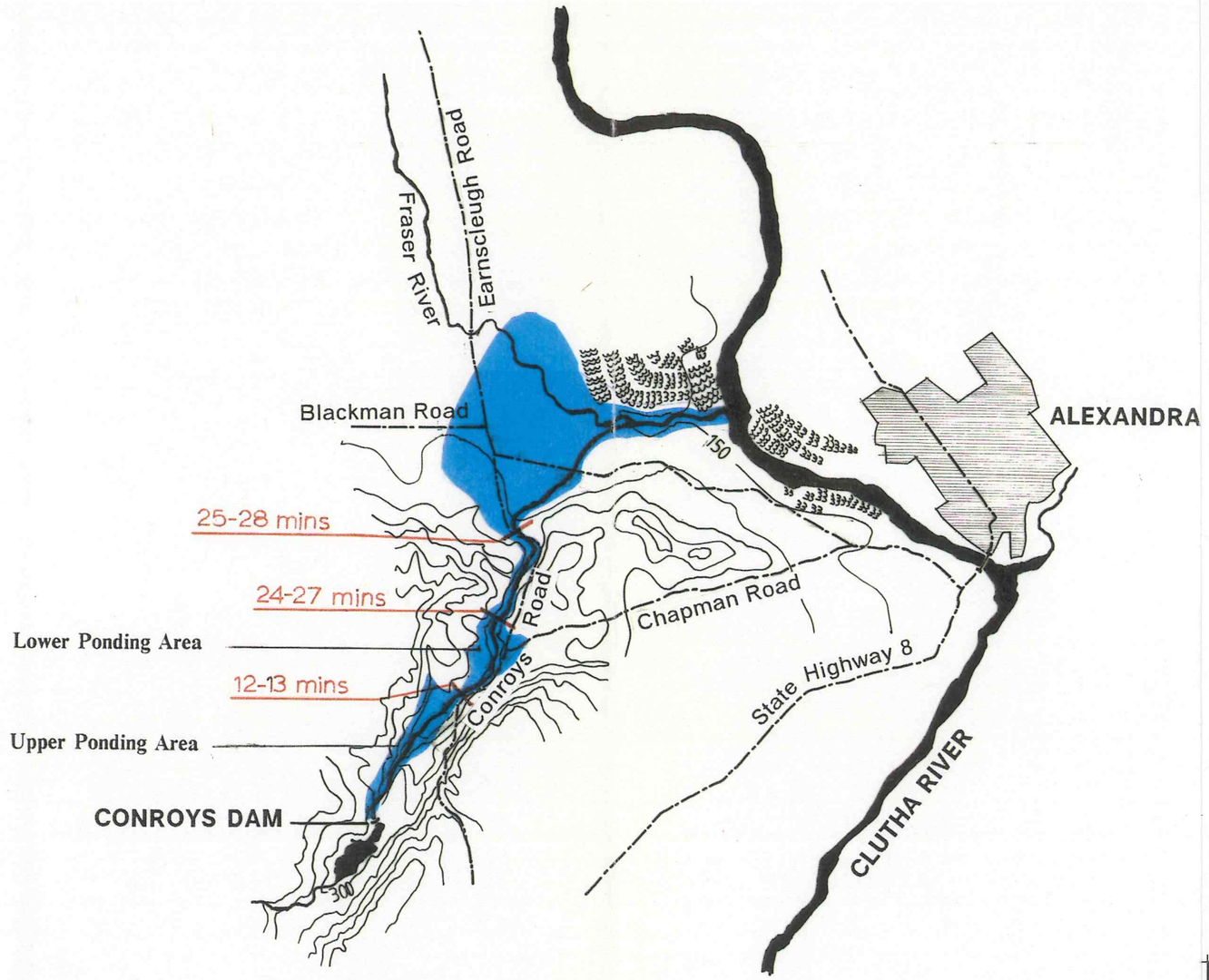
SCALE 1: 250 000

N

OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAPS

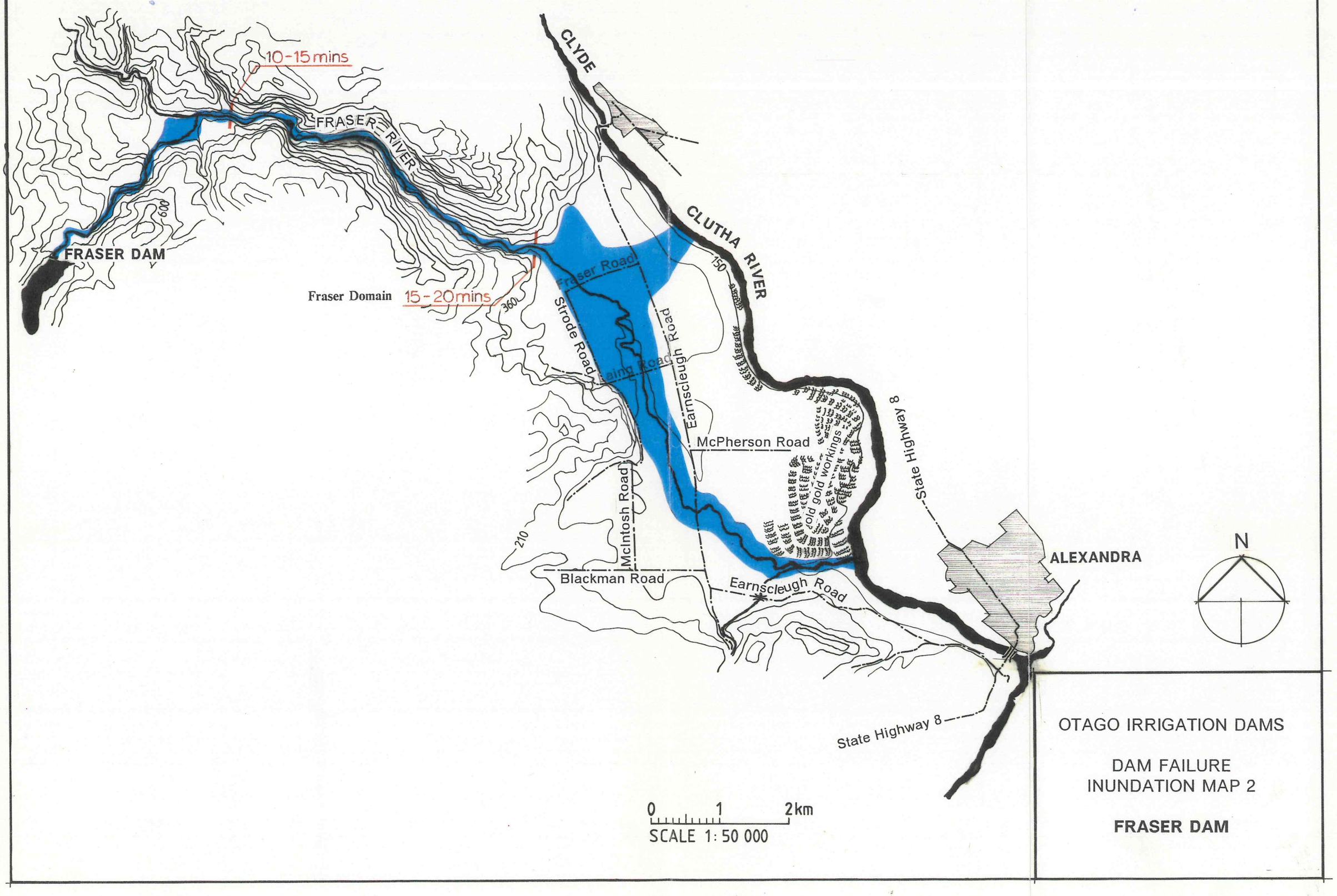
LOCATION PLAN

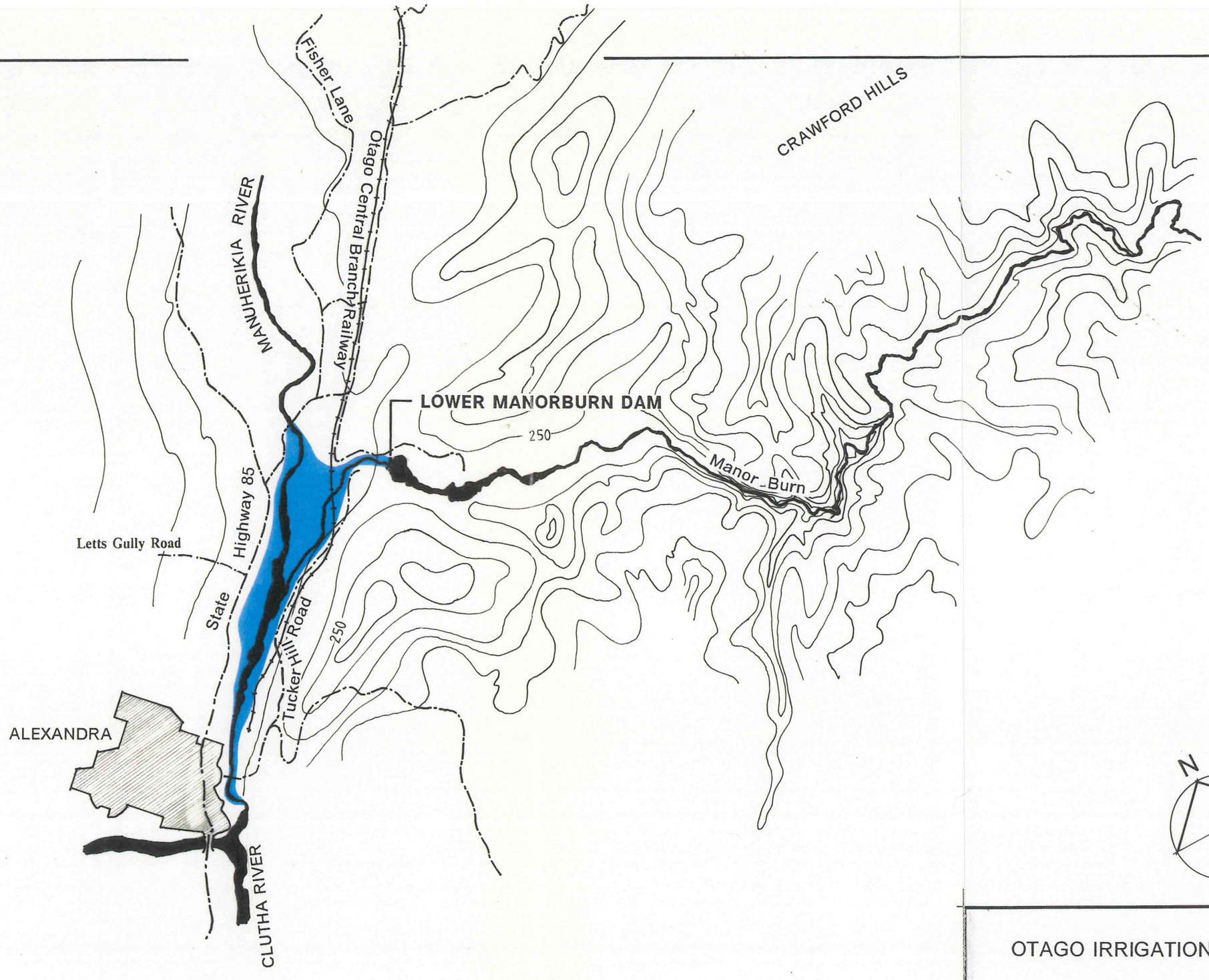


OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 1

CONROYS DAM

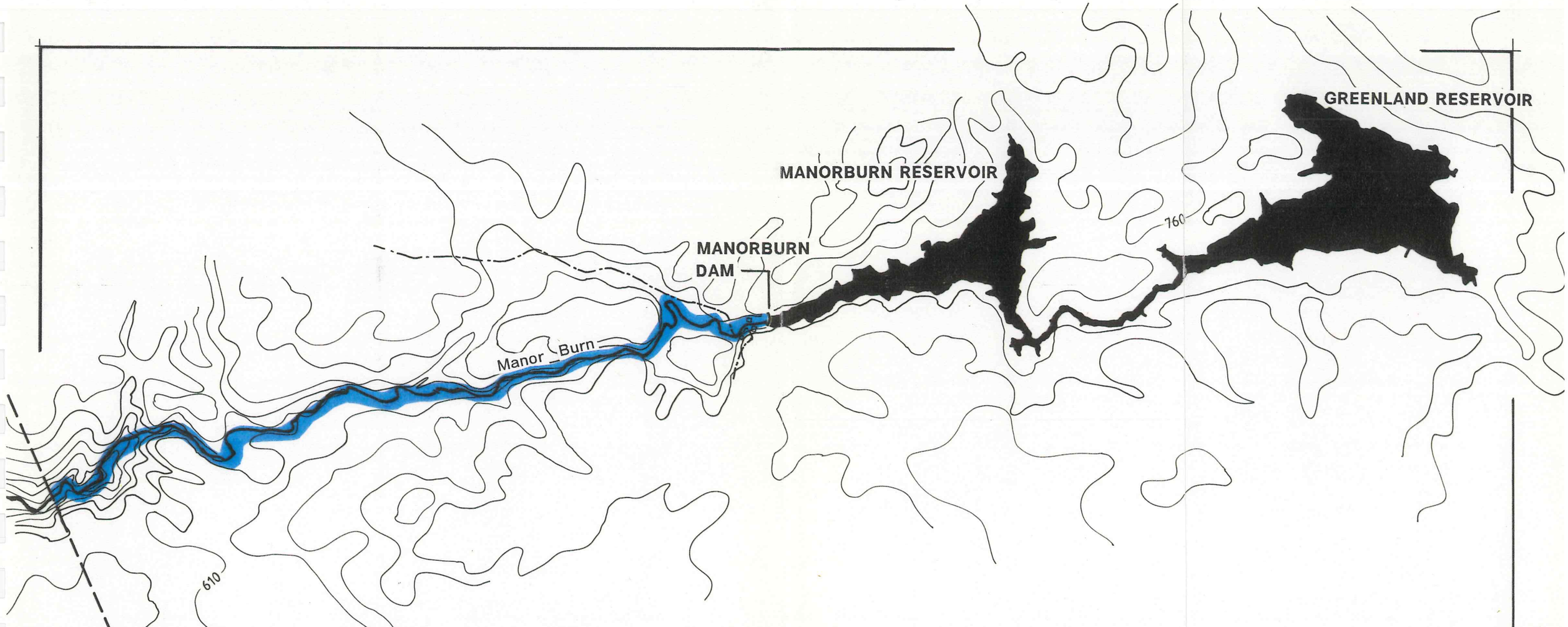

10-15 mins
FRASER RIVER
FRASER DAM
600
Fraser Domain
15-20mins
360
CLYDE
CLUTHA RIVER
150
Fraser Road
Strode Road
Earnsclough Road
McPherson Road
McIntosh Road
210
Blackman Road
Earnscleugh Road
State Highway 8
cold gold workings
ALEXANDRA
N
0 1 2km
SCALE 1:50 000
OTAGO IRRIGATION DAMS
DAM FAILURE
INUNDATION MAP 2
FRASER DAM

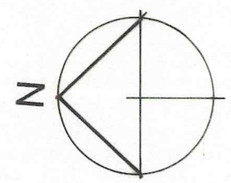


OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 3

LOWER MANORBURN DAM





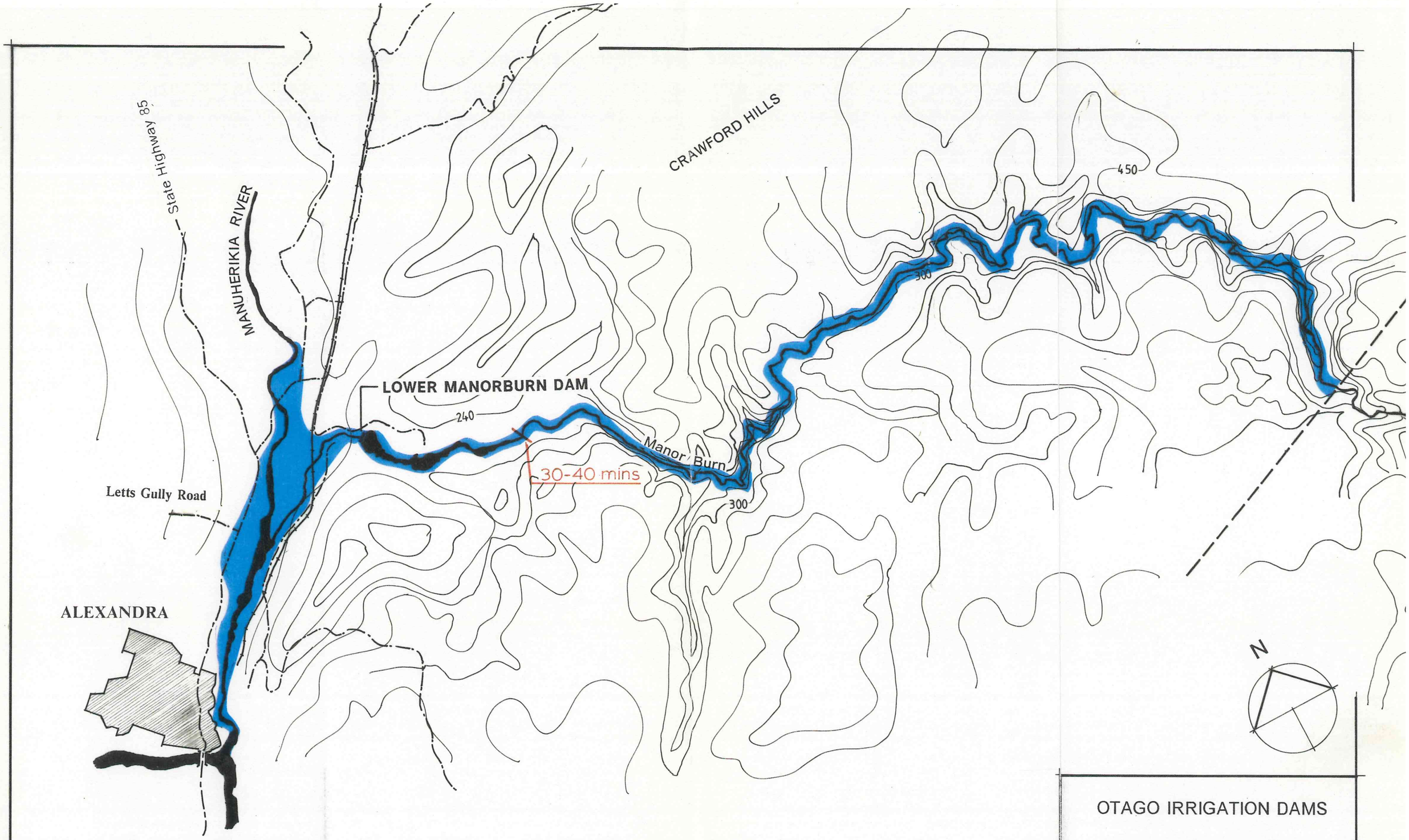
0 1 2 km

SCALE 1: 50 000

OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 4a

UPPER MANORBURN DAM



OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 4b

UPPER MANORBURN DAM

POOLBURN DAM

Long Valley Cre

POOL - BURN

800

600

Old Dunstan Road

Smalls Road

Moa Creek Road

Sullivan Road

17-20 mins

Nevill Lane

Webster Lane

Poolburn Moa Creek Road

N

0 1 2km

SCALE 1:50 000

OTAGO IRRIGATION DAMS

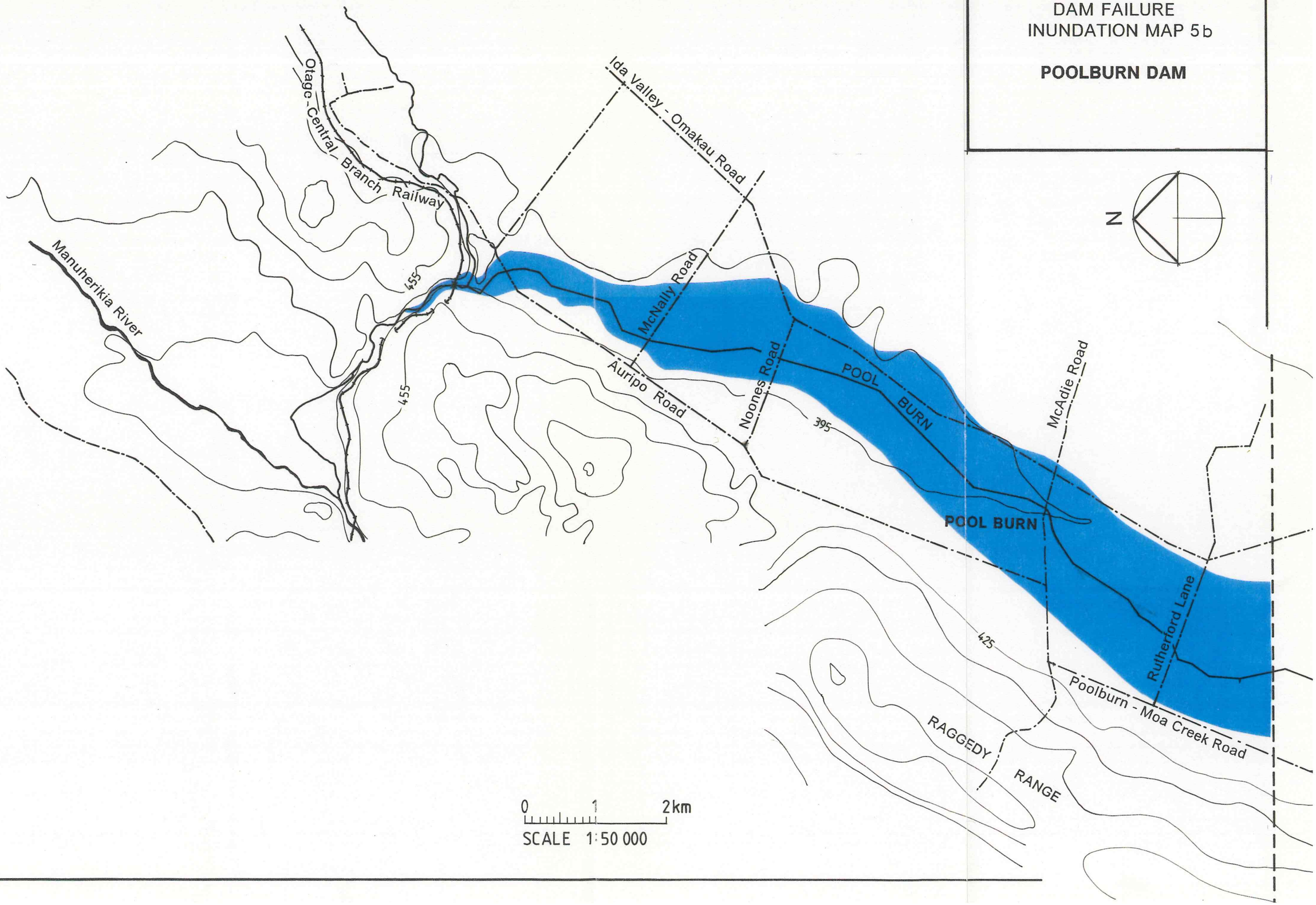
DAM FAILURE
INUNDATION MAP 5a

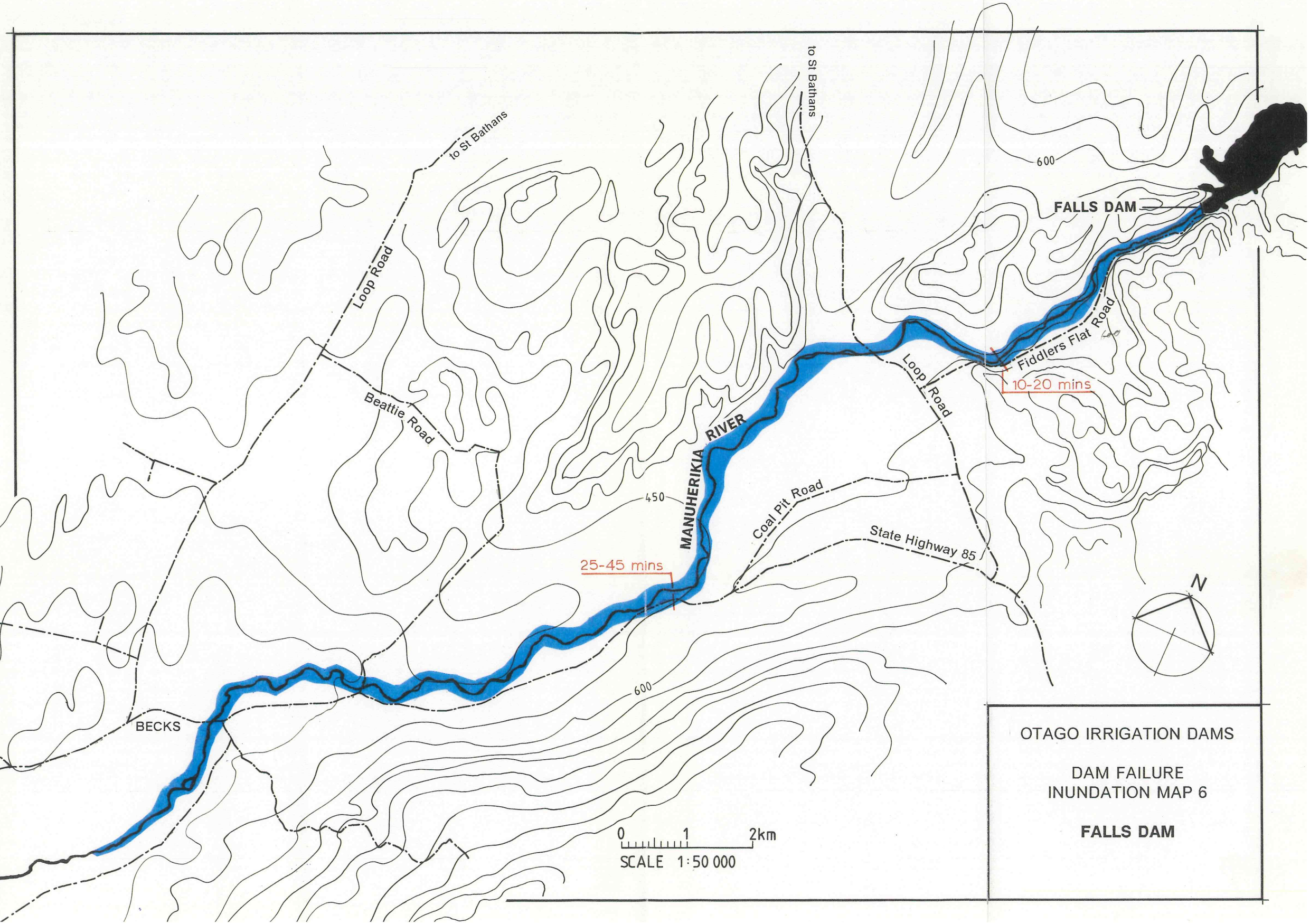
POOLBURN DAM

OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 5b

POOLBURN DAM

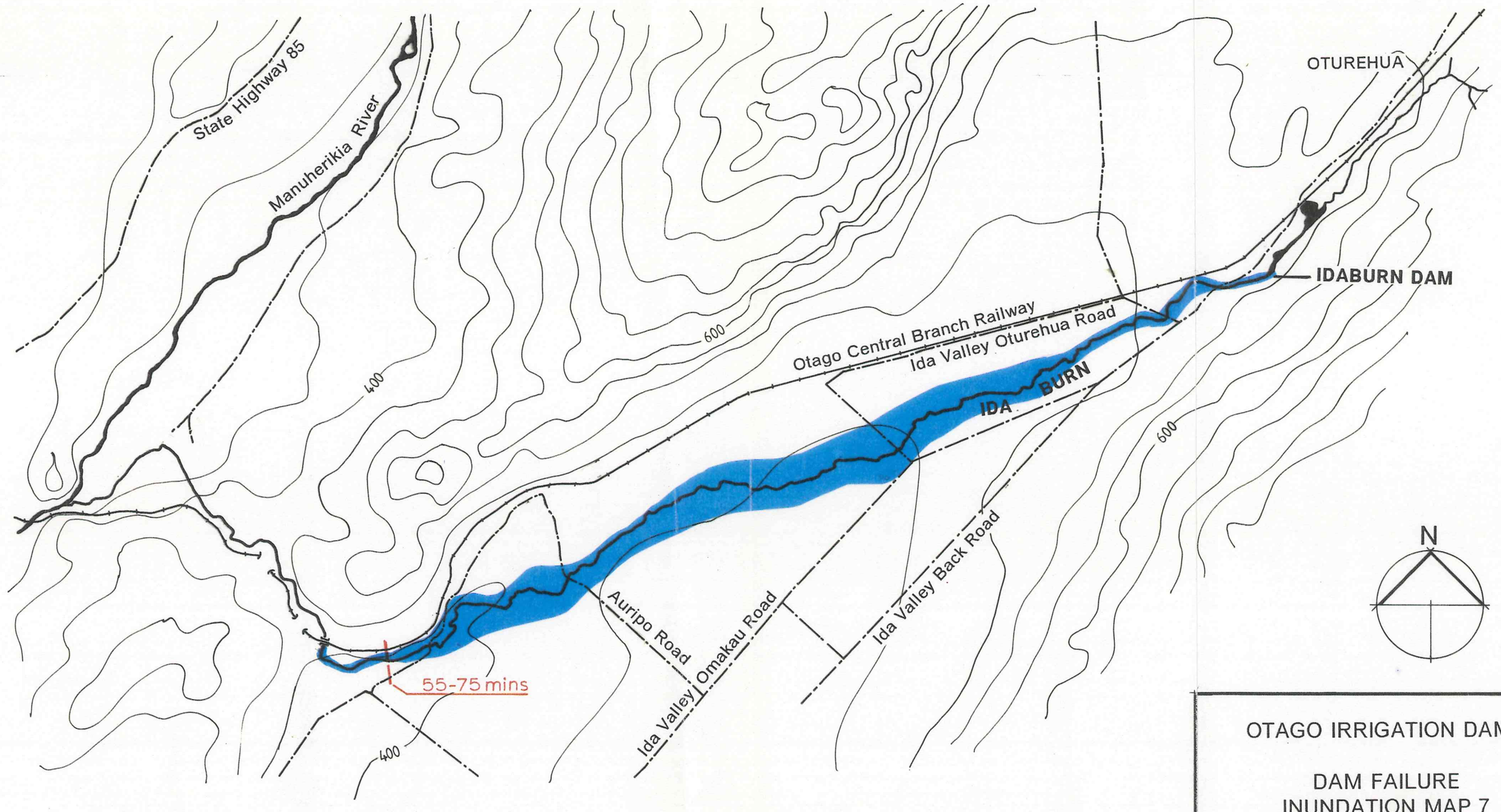




OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 6

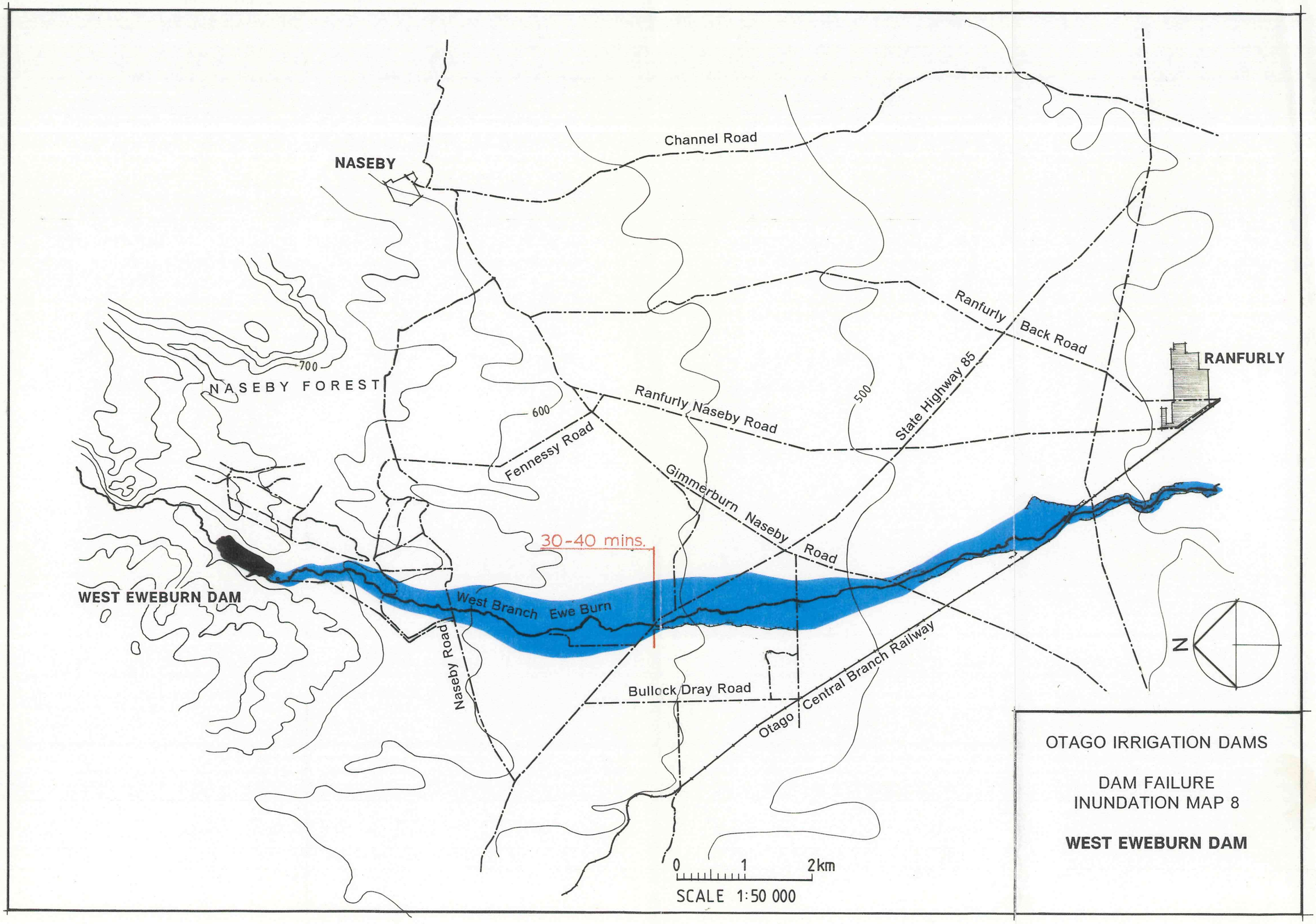
FALLS DAM



OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 7

IDABURN DAM

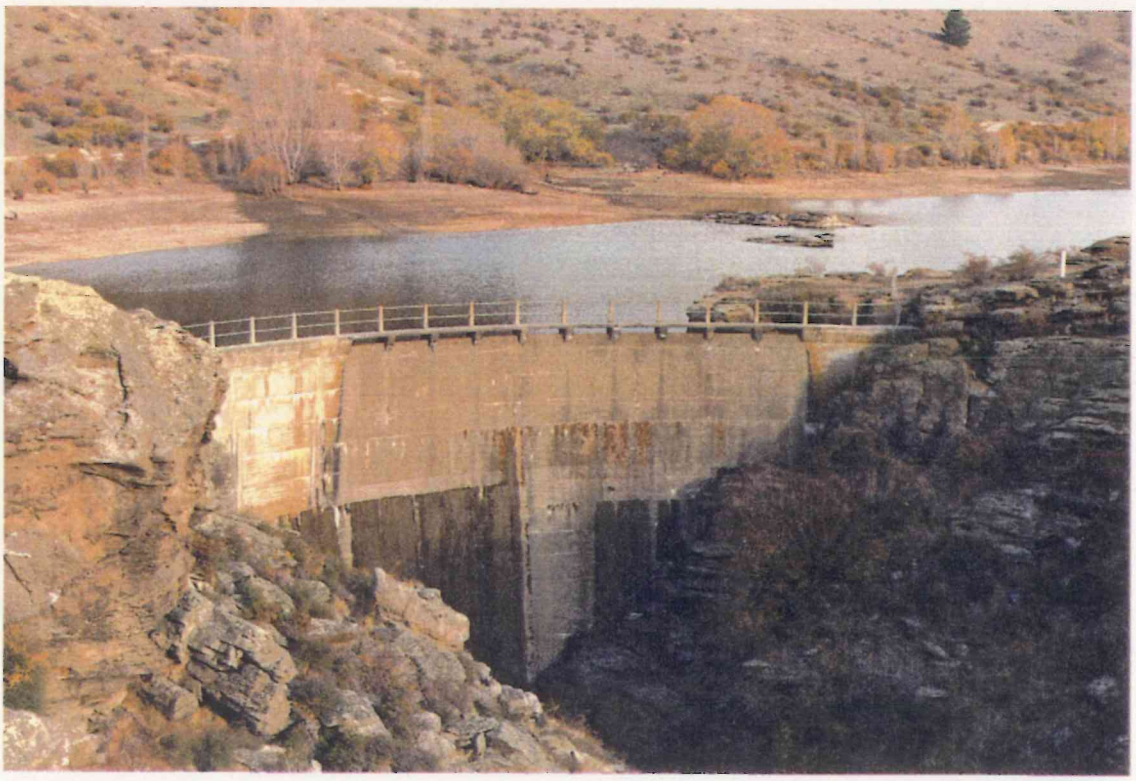


OTAGO IRRIGATION DAMS

DAM FAILURE
INUNDATION MAP 8

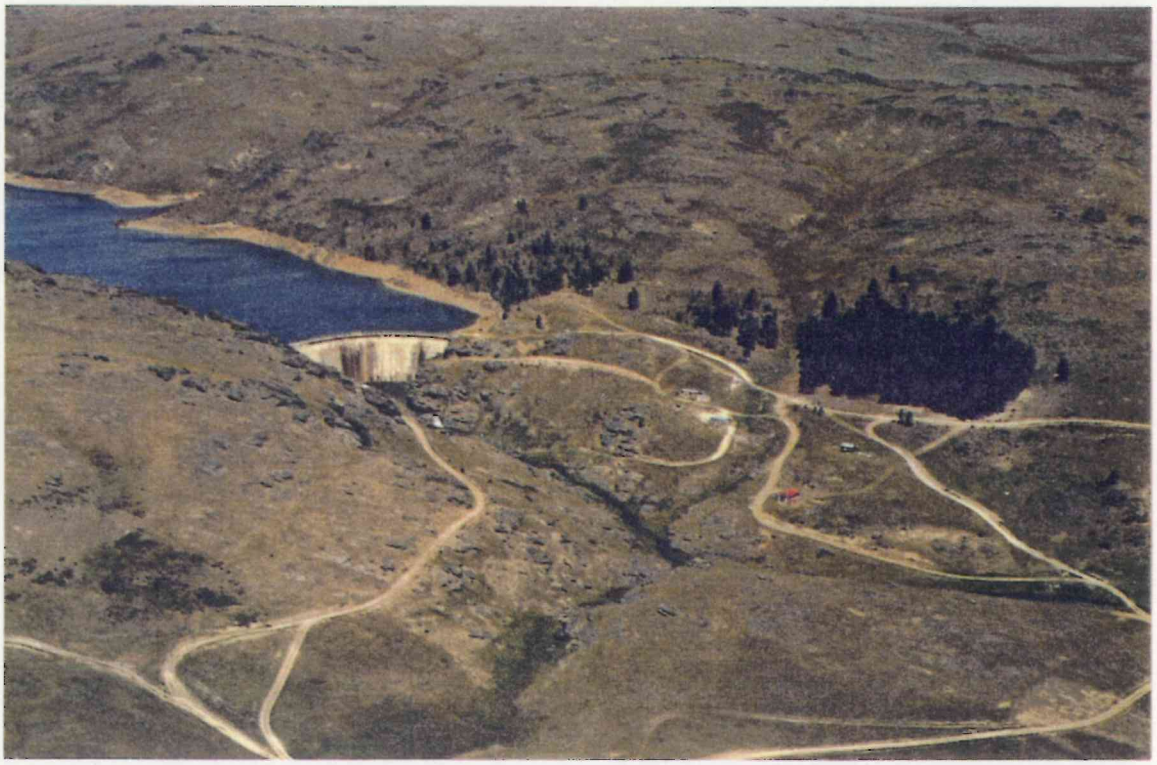
WEST EWEBURN DAM

Appendix Photographs

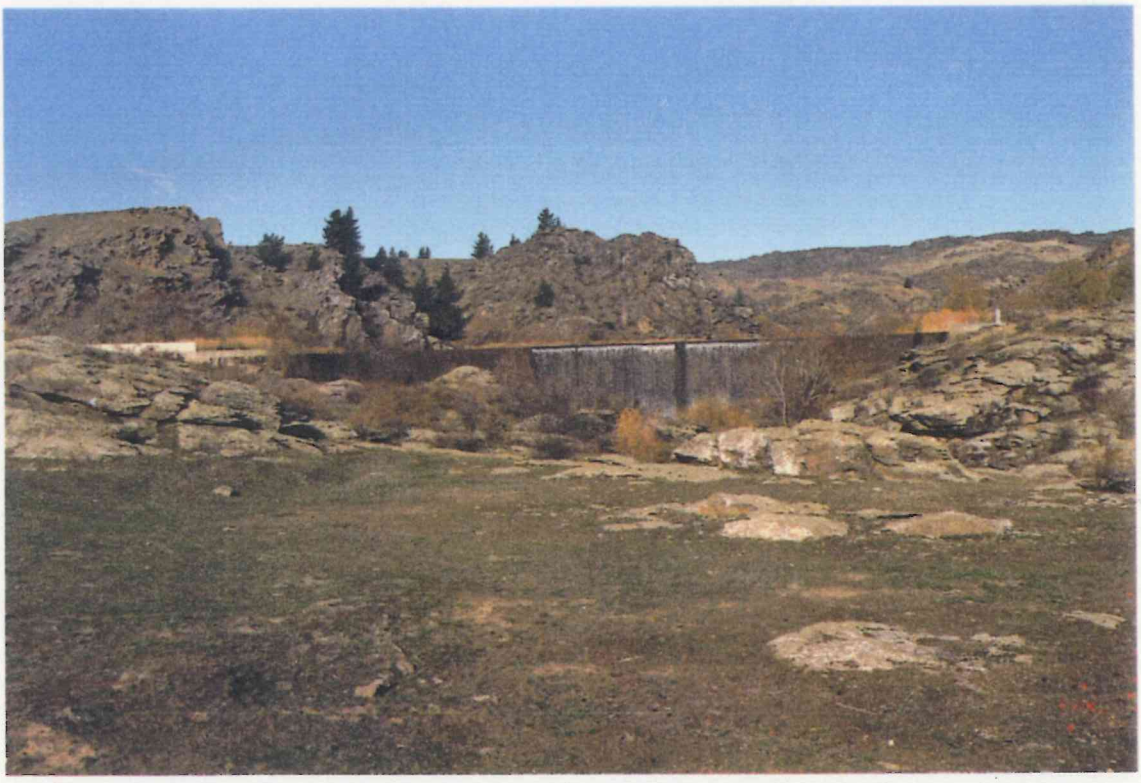


Conroys Dam May 1990

Fraser Dam May 1990



Upper Manorburn Dam January 1990



Lower Manorburn Dam May 1990

Poolburn Dam January 1990

Falls Dam
January 1990

West Eweburn Dam January 1990

Idaburn Dam May 1990