National Highways Linking Sydney, Melbourne and Canberra Third Report: Canberra Connections, 1979

Report

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BUREAU OF TRANSPORT ECONOMICS

NATIONAL HIGHWAYS LINKING SYDNEY, MELBOURNE AND CANBERRA, THIRD REPORT : CANBERRA CONNECTIONS, 1979

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FOREWORD

The former Commonwealth Bureau of Roads was requested by the Minister for Transport, Mr. P. J. Nixon, to examine the National Highways connections to Canberra including a possible bypass of Yass. Mr. Nixon also arranged for assistance by the N.S.W. Department of Main Roads in this study.

The Bureau of Roads and the Bureau of Transport Economics have previously submitted two reports to the Minister dealing with the route location of sections of the Hume Highway between Sydney and Albury. This Third Report, like the Second Report, was based on a study carried out largely by the former Bureau of Roads. The study was completed and documented by the Bureau of Transport Economics after the amalgamation of the two Bureaux in mid-1977.

I would like to thank the Department of Main Roads, the National Capital Development Commission and other organisations and persons referred to in the Report, for their assistance and advice in the conduct of this study.

(C. A. Gannon)
Director

Bureau of Transport Economics,
CANBERRA
March, 1979.

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CONCLUSIONS

The results of the study indicate that:-

- The future connections between Canberra and the Hume Highway, and the bypass of Yass, should be constructed on the routes shown in Figure A.

- The connection between Canberra and Goulburn should follow the general alignment of the present Federal Highway with two qualifications:

  - the route should bypass Collector to the south; and

  - part of the road along the western shore of Lake George may need to be designed to a reduced standard to enhance environmental conditions.

- Construction of the Federal Highway on the recommended route has an overall benefit/cost ratio (BCR) of about 0.9 which indicates that construction of the whole length (outside the A.C.T.) is not yet economically warranted.

- The connection between Canberra and Yass should follow the general alignment of the existing Barton Highway, except that Hall and Murrumbateman should be bypassed to the west. Construction of this route (outside the A.C.T.) has a BCR of about 0.8, indicating a slightly lower priority than construction of the Federal Highway.

- The Hume Highway bypass of Yass should follow the line of the N.S.W. Department of Main Roads proposal to the north of Yass (Z_2BC on Figure A). Consideration should be given to providing direct access between the bypass and the road-houses in North Yass. Construction of the Yass bypass on the recommended route has a BCR of about 2.0 and is thus currently economically warranted. Construction of the connection from the bypass to the Barton Highway has a BCR of about 1.6 and if delayed for several years after completion of the bypass, a reduced impact of the bypass on the economy of Yass would result.

- The estimated costs of construction in 1976/77 prices are as follows:

  - Federal Highway from the A.C.T. border to the Hume Highway at Yarra - $53.2 m.

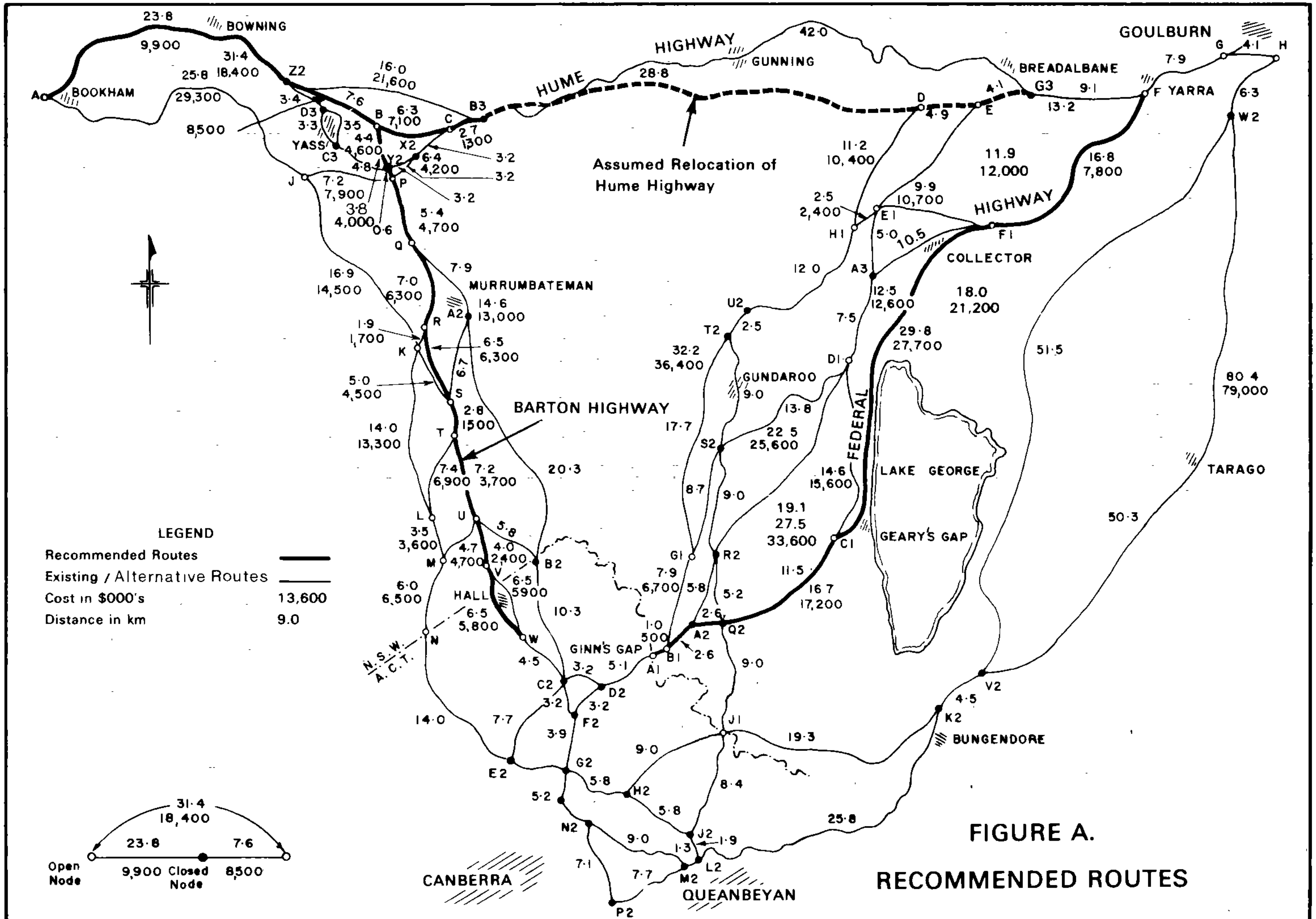

FIGURE A.

RECOMMENDED ROUTES

- Barton Highway from the ACT border to the existing Hume Highway east of Yass (excluding the bypass of Hall) - \$25.5 m.
- Yass bypass - \$15.6 m.
- Barton Highway connection to the Yass bypass - \$4.0 m.

. As the design of these routes proceeds and the precise locations are determined, further environmental study will be required to assess in detail the full impact of the construction on drainage, aquatic environment, water quality, wild life and landscape aesthetics. Similarly, further study will also be needed to determine the location of sites of historic importance along the routes where the existing alignment has been varied.

. After finalisation of the location of the routes, a survey should be conducted to determine whether any aboriginal archaeological deposits would be affected by the proposed construction. This will facilitate the salvage of aboriginal relics before, or during, construction. Also, if deposits of significant interest are found, minor deviations to the road alignment may be arranged.

CHAPTER 1 - INTRODUCTION

1.1 ORIGIN OF THE STUDY

The Commonwealth Bureau of Roads (CBR) "Report on Roads in Australia, 1973" recommended that the Australian Government legislate to declare a system of National Highways throuthout Australia and to provide grants of financial assistance to the States for the construction and maintenance of these highways. The Commonwealth Government accepted this recommendation and the National Roads Act, 1974, was passed, and a system of National Highways was declared. Grants for the National Highway System are currently provided under the States Grants (Roads) Act, 1977. The System is shown in Figure 1.1.

The National Highways System includes the Federal Highway between Yarra and Canberra and the Barton Highway between Yass and Canberra, as the routes connecting Canberra to the National Highway between Sydney and Melbourne. The location of these two routes was given some consideration in a study of the ultimate location for the Hume Highway between Goulburn and Albury.(1) However, a more detailed examination of alternative locations for the connections to Canberra was considered necessary.

On 30th November, 1976, the Commonwealth Minister for Transport Mr. P.J. Nixon requested that the CBR investigate and report on the most suitable routes for the National Highway between Canberra and the Hume Highway, including the possibility of a bypass of Yass (for the Hume Highway). The Minister also arranged for the co-operation of the N.S.W. Department of Main Roads (DMR) and of the National Capital Development Commission (NCDC) in this study. The Bureau of Transport Economics (BTE) maintained all of the arrangements made by the CBR for the conduct of the study after the amalgamation of the two Bureaux.

1.2 TERMS OF REFERENCE

The study was carried out according to the following terms of reference:

(a) Develop alternative feasible routes for the National Highway connections to Canberra from the Hume Highway, including the possibility of a bypass of Yass;

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(1) Commonwealth Bureau of Roads, National Highways Linking Sydney, Melbourne and Canberra, 1975 (First Report), Melbourne, 1975.

FIGURE 1.1

NATIONAL HIGHWAY SYSTEM IN AUSTRALIA

(b) estimate the costs of constructing the alternative routes;

(c) discuss the impacts on the biophysical environment which might be expected from each alternative route;

(d) identify the social implications of alternative routes;

(e) evaluate the road user effects of alternative routes; and

(f) report on the alternatives and their expected effects, and on the possibility of a bypass of Yass by the Hume Highway.

The study was not required to consider the location of the Hume Highway between Goulburn and Yass except in so far as it influenced the location of the connections to Canberra or the bypass of Yass. The study was intended to determine appropriate locations at the "approximate route" level, the responsibility for detailed location and design remaining with the construction authorities, DMR and NCDC.

1.3 OUTLINE OF STUDY AND REPORT

Four parallel investigations were undertaken:

(i) road user effects;

(ii) construction costs and engineering considerations;

(iii) environmental impact; and

(iv) social impact.

In examining possible route locations in each corridor the four investigations were progressively carried out in more detail as alternatives were eliminated, until the best alternative became apparent. At this stage road user effects were quantified and a benefit-cost ratio was used to assess the economic warrant for construction of the preferred alternative. The investigations identified various aspects requiring further and more detailed study during selection of the precise location and the design and the construction stages.

This report describes the investigations carried out for each corridor and presents the results and the conclusions. The report includes the principal information used as a basis for the conclusions as to the most appropriate route in each corridor, and also provides details of the assessment of the economic justification for construction of the preferred route.

Since the majority of the work for this study was carried out in the first half of 1977, some of the descriptions of existing conditions could now be out of date. However this does not restrict the reasoning or conclusions of the study.

1.4 ACKNOWLEDGEMENTS

A number of organisations and persons contributed to the study and details of this assistance are given in Appendix 1.

CHAPTER 2 - THE STUDY AREA

2.1 SCOPE

In this chapter the study area is defined and the features of principal relevance to the study outlined. Major land uses, settlements and transport links are described and an outline of the available information on traffic flows provided.

2.2 DEFINITION OF THE STUDY AREA

The principal function of connections between Canberra and the Hume Highway is to facilitate travel between Canberra and both Sydney and Melbourne. The area outlined by dashed lines within Figure 2.1 was selected as the study area after consideration of the geographical location of Canberra with respect to the Hume Highway. The study area is shown in detail in Figure 2.2. In terms of local geographical features, the study area is bounded by:

- the Main Southern Railway between Yarra and Bowning;
- the Hume Highway between Bowning and the Burrinjuck turnoff near Bookham;
- the Burrinjuck road;
- Burrinjuck Dam and the Murrumbidgee River upstream to the ACT border;
- the ACT border to the Cooma-Goulburn railway; and
- the Cooma-Goulburn railway to Yarra.

The ACT border was chosen as the approximate southern boundary of the study area rather than (say) Canberra GPO to avoid detailed consideration of urban arterial issues near the city which would be well outside the terms of reference of the study. This did not affect the alternatives considered, the evaluation, or the conclusions.

2.3 PHYSICAL CHARACTERISTICS

The study area is generally undulating with occasional broad river valleys interspersed with steeper ranges and rugged river gorges. This is typical of the southern table lands of NSW. The average rainfall for the area ranges from 550 mm to 620 mm per year.

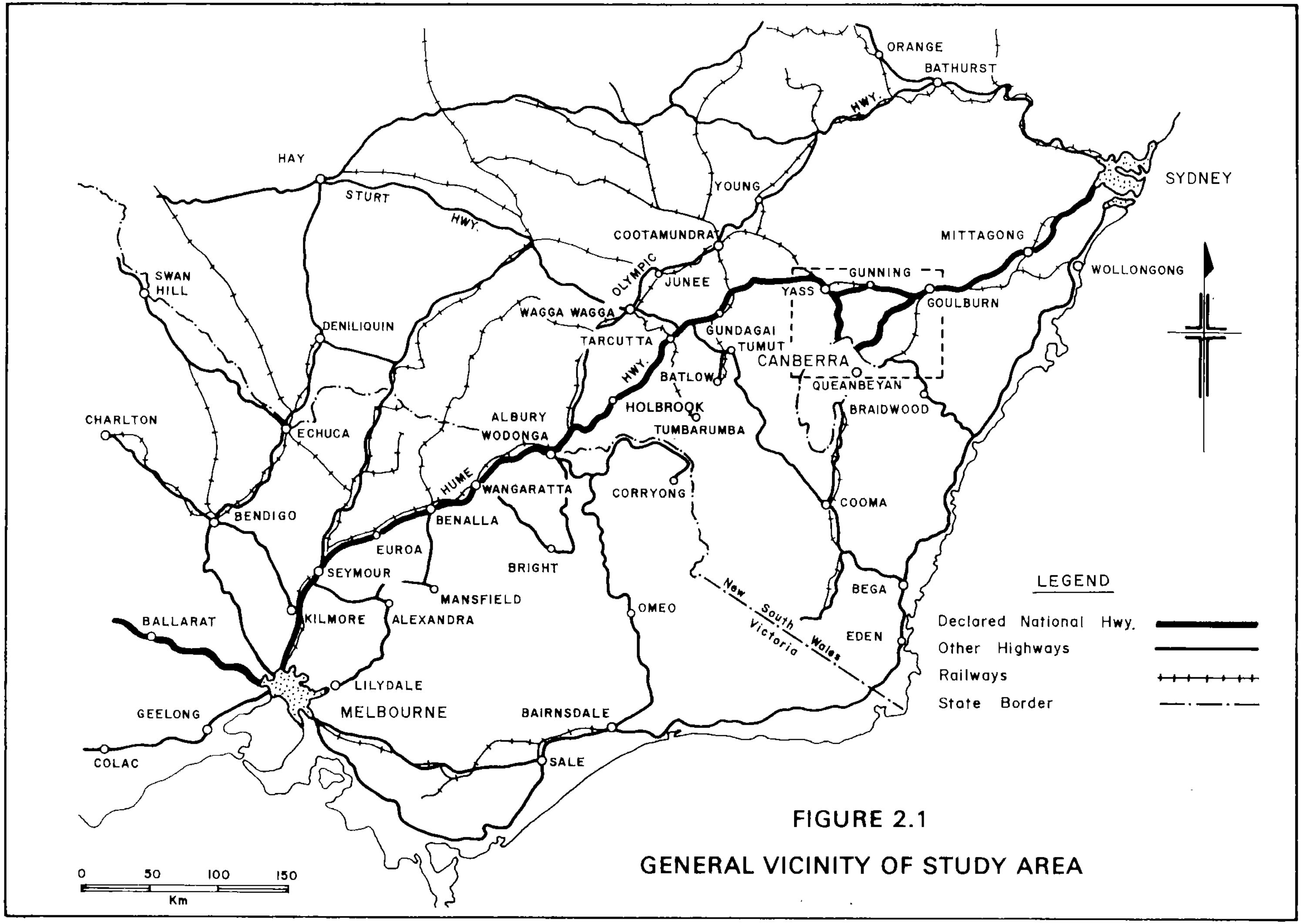

FIGURE 2.1

GENERAL VICINITY OF STUDY AREA

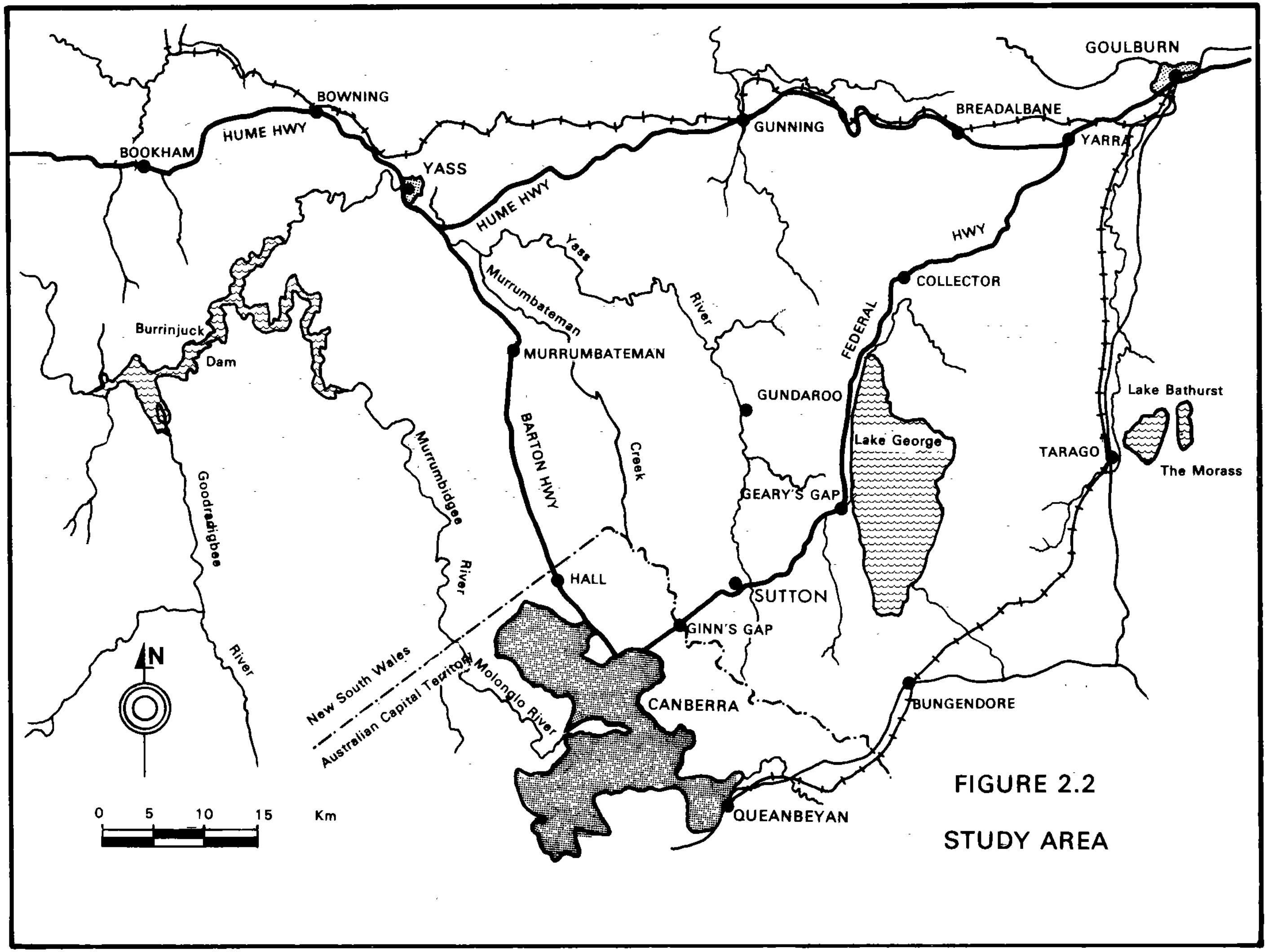

FIGURE 2.2

STUDY AREA

In the east an elongated internal drainage basin extends from south of Bungendore to north of Breadalbane. The floor of the basin is generally flat and poorly drained and the lowest part holds the waters of Lake George. The western edge of the basin is marked by an often steep escarpment called the Cullerin Range in the north and the Lake George Range in the south.

West of the range the Yass River valley, comprising predominantly undulating country, extends westward to the Barton Highway from where the country slowly falls away towards the Murrumbidgee River Gorge. The Yass River and its tributary, Murrumbateman Creek, flow approximately north-west to join near Yass after which they turn abruptly southwest to descent into a deep gorge before their confluence with the Murrumbidgee River at Burrinjuck Dam.

Towards the north of the study area the undulating country gives way to more rugged timbered ranges. Further north the gorges of the Lachlan and Wollondilly Rivers are encountered.

The Molonglo River flows across the southern boundary of the study area. The Molonglo is dammed upstream from its junction with the Murrumbidgee River to form Lake Burley Griffin.

2.4 LAND USE AND SETTLEMENTS

The national capital, Canberra, with a population of 200,000 lies by the Molonglo River and Lake Burley Griffin south of the study area. To the east, also on the Molonglo, is Queanbeyan (population 19,000), which was originally an industrial and service centre for the region but increasingly has become a dormitory suburb for Canberra.

Yass is located some 60 km north west of Canberra where the Hume Highway crosses the Yass River and has a population of about 4,000. It is connected to the Main Southern Railway by a spur line between it and Yass Junction. The historic roles of Yass have been as a staging point on the Sydney to Melbourne road, and as an administrative and service centre for its wool-growing hinterland. In recent times the former role has increased in importance relative to the latter as commercial and tourist road traffic has increased relative to rural activities. Since about the mid-1960's ties between Yass and Canberra have strengthened with Canberra providing jobs and specialized services for Yass people, and the Yass area providing alternative residential opportunities for Canberra workers. During this time the Yass population has remained roughly stable with fairly steady housing construction mostly south of the Yass River.

The only settlement on the Federal Highway between Yarra and Canberra is Collector, a town with population of less than 150. This population has declined slightly in recent years and the 90 adults in the present population represent a mixture of retired people, local service employees (police, hotel proprietor, teacher, etc.) farm workers and several who commute the 60 km to Canberra. There are 30 or so houses in the town and 26 children attend the local school. The Federal Highway passes through Collector on the northern edge of the original town subdivision. Three businesses are located on the highway : a general store with an attached petrol station, the Collector Hotel, and a service station/restaurant.

On the Barton Highway there are two townships. Hall, 2 km inside the ACT with a population of about 250 is in effect a suburb of Canberra. Murrumbateman, 36 km from Canberra and 22 km from Yass, is an expanding rural residential area.

The population of the Murrumbateman area is less than 200. It has a post office agency and a general store on the western side of the Barton Highway, and a recreation area (including oval and small hall) on the east. Since the mid 1960's there has been renewed interest in land in or near Murrumbateman as an alternative to the Canberra suburbs. Very recently the Goodradigbee Shire Council zoned an area west of the Barton Highway, and immediately to the south, for rural-residential subdivision (0.8 - 2 ha blocks) and a somewhat larger area east of the Highway for development at a minimum size of 16 ha. Subdivision and sale of these lots has proceeded rapidly but little building has taken place. In 1977, there were fifteen occupied dwellings in the new subdivisions, and sixteen under construction. There are about thirteen dwellings occupied in the town and several under construction.

Several small towns are spread across the north of the study area along the Hume Highway. These include Gunning with a population of 460 and Bowning, Bookham and Breadalbane, all of whose populations are less than 200.

The other towns in the study area are Bungendore and Tarago on the Cooma-Goulburn railway line; and Sutton and Gundaroo on the Canberra-Gunning road. The latter, containing many old buildings and cottages, is developing as an arts and craft centre and as a rural retreat for Canberra workers.

Very little of the study area (see Figure 2.2) remains unchanged from its natural state. Most of the area is used for farming on relatively large holdings, with sheep grazing being predominant, although in recent times horse and cattle studs have been established. The more rugged areas, parts of which are covered by regrown timber is used for range grazing. Scattered pine planting has taken place in the south of the area.

The only major mining development likely in the study area is at Woodlawn, south west of Tarago where mining of a large copper mineralisation is due to begin in 1978. There are numerous other scattered quarries and pits in the study area, particularly near Canberra.

2.5 EXISTING TRANSPORT SYSTEM

The existing transport system within the study area (see Figure 2.2) is dominated by the three National Highway routes forming the Goulburn-Yass-Canberra triangle, together with the main Melbourne-Sydney rail line passing through Goulburn and Yass Junction. In addition trunk and main roads link Goulburn with Queanbeyan via Bungendore (running parallel to the Goulburn-Canberra Railway), and Gunning with both Collector and Sutton. These routes are described in more detail in the following sections. Canberra is served by air links with Sydney, Melbourne and Albury. There are express bus services between Canberra and Melbourne, Sydney and Yass respectively.

2.6 NATIONAL HIGHWAY ROUTES

2.6.1 Hume Highway

The Hume Highway is a divided highway with 7.4 m carriageways for the 12 km from shortly outside the Goulburn city boundary to the grade-separated junction between the Federal and Hume Highways at Yarra. From there until Yass the Hume is a single carriageway, mainly between 6.7 m and 7.4 m wide although there are short sections 11 m wide. The highway constitutes the main street of Yass, crossing the Yass River by a new concrete structure. Between Yass and Bookham about 12 km of divided highway have been constructed (the Bowning bypass). The condition of the road and road surface on older sections of the Hume Highway is generally poor. Despite this, vehicle speeds outside urban areas are not unduly restricted; although there are some slow sections, particularly in the Cullerin Ranges.

2.6.2 Federal Highway

The Federal Highway is divided for at least 3 km from its intersection with the Hume Highway at Yarra, with a further short section under construction. In general the remainder of the existing road is narrow (6.0 to 6.6 m) with poor alignment. South of Collector the highway follows the western shore of Lake George, at the base of a 150 m scarp, and is subject to flooding by streams which enter the lake at its northern end. The highway climbs the scarp at Geary's Gap and from there it traverses rolling country, entering the ACT at Ginn's Gap. The structural and surface condition of the road for most of its length is poor.

2.6.3 Barton Highway

The Barton Highway is a single carriageway road through undulating country, between 5.5 m and 7.4 m in width. As with the Federal and Hume Highways a good deal of the road is in poor structural and surface condition.

2.7 OTHER ROADS

2.7.1 Goulburn-Bungendore-Queanbeyan

This route, using TR79, MR268 and TR51, passes through undulating country to the east of Lake George, running parallel to the Goulburn-Cooma railway. The route is sealed except for a section on MR268 between Tarago and Bungendore.

2.7.2 Gunning-Sutton

This route, MR249, connects Gunning with Sutton via Gundaroo. From Gunning to Gundaroo the road passes through undulating country and has a gravel surface. Between Gundaroo and Sutton the route lies in the valley and is a sealed road with generally good alignment.

2.7.3 Minor Roads

A network of minor roads connects Gunning with Collector, and Gundaroo with Murrumbateman and Collector. Dog Trap Road, running west of and parallel to the Barton Highway between Yass and Murrumbateman provides access for properties.

2.8 TRAFFIC PATTERNS

The major road traffic flows within the study area occur on the three National Highway links. The nature of traffic flows on the Federal and Barton Highways, and on the Hume Highway near Yass, is examined in Appendix 2. In particular the origins and destinations of travel are considered, and short and long distance trips are identified. The traffic patterns support the view that intermodal effects are only a secondary consideration in the evaluation of upgrading of the Federal and Barton Highways. This is probably also the case with the Yass bypass but further consideration should be given to the long term implications of a possible shift from road to rail for long-distance freight in the Hume Corridor.

Traffic growth over the last ten years at points on the three National Highways is shown in Table 2.1.

TABLE 2.1 - TRAFFIC GROWTH 1966-76 [a]

Highway [b]	AADT [c]			Average Growth % Per Annum From 1966 To 1976
	1966	1971	1976	
Federal	2260	3110	4410	6.9
Barton	1560	2270	3540	8.5
Hume - west of Yass	3370	4830	6550	6.9
Hume - east of Yass	2370	3740	4310	6.2

(a) Source : Department of Main Roads, New South Wales.

(b) Locations of counts are respectively : 1.6 km South of the Hume, South of the junction with the Hume, 7.2 km West of Tumut Road, 3.2 km East of the Barton.

(c) AADT : annual average daily traffic (i.e. average number of vehicles per day).

The growth rates in Table 2.1 are high by comparison with rural arterial roads in NSW, reflecting in the case of the Hume Highway the strong growth over the period of long distance freight and passenger traffic and, in the case of the Federal and Barton Highways, the rapid population growth of Canberra (7.5% p.a. between 1966 and 1976). These growth rates cannot be expected to continue and substantially more conservative forecasts were used in this study for the calculation of road user benefits, as given in Appendix 2.

CHAPTER 3 - NATIONAL HIGHWAY ALTERNATIVES

3.1 GENERAL COMMENTS

This Chapter describes the various alternative routes assessed in the study. These alternatives are illustrated in Figure 3.1.

In a limited road budget situation major deviations from existing routes are at a disadvantage in evaluation when compared with existing routes or upgrading of existing roads (see Sub-section 4.1.6). In view of this, the majority of alternatives considered in this study were developed from the existing Federal, Barton and Hume Highways to overcome recognisable deficiencies or inadequacies. Such alternatives facilitate construction in stages along the route. In some cases the alternatives were based on potential opportunities offered by radical new locations, as indicated later in the descriptions of the alternatives concerned.

Except where otherwise noted, the alternatives were based on ultimate development to the National Highway design standard of a four-lane divided road of 130 kph design speed.

3.2 BASE CASE FOR HUME HIGHWAY

A previous report[(1)] included a recommendation which was accepted by both the previous and present Governments, to the effect that the National Highway between Sydney and Melbourne should be retained in the vicinity of the existing Hume Highway. Therefore in this Study it was assumed, as a base case, that the Hume Highway between Goulburn and Yass will be upgraded in the general vicinity of the existing route. The route assumed (B_3DEF in Figure 3.1) follows the existing Hume Highway east of Yass, with deviations through the Mundoonen Range, as far as Jerrawa Creek. It then runs parallel to, and some 3-5 km south of, the existing alignment, bypassing the small town of Gunning. After crossing Cullerin Range it rejoins the existing alignment about 2 km east of Breadalbane.

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(1) Commonwealth Bureau of Roads, National Highways Linking Sydney, Melbourne and Canberra, 1975 (First Report), Melbourne, 1975.

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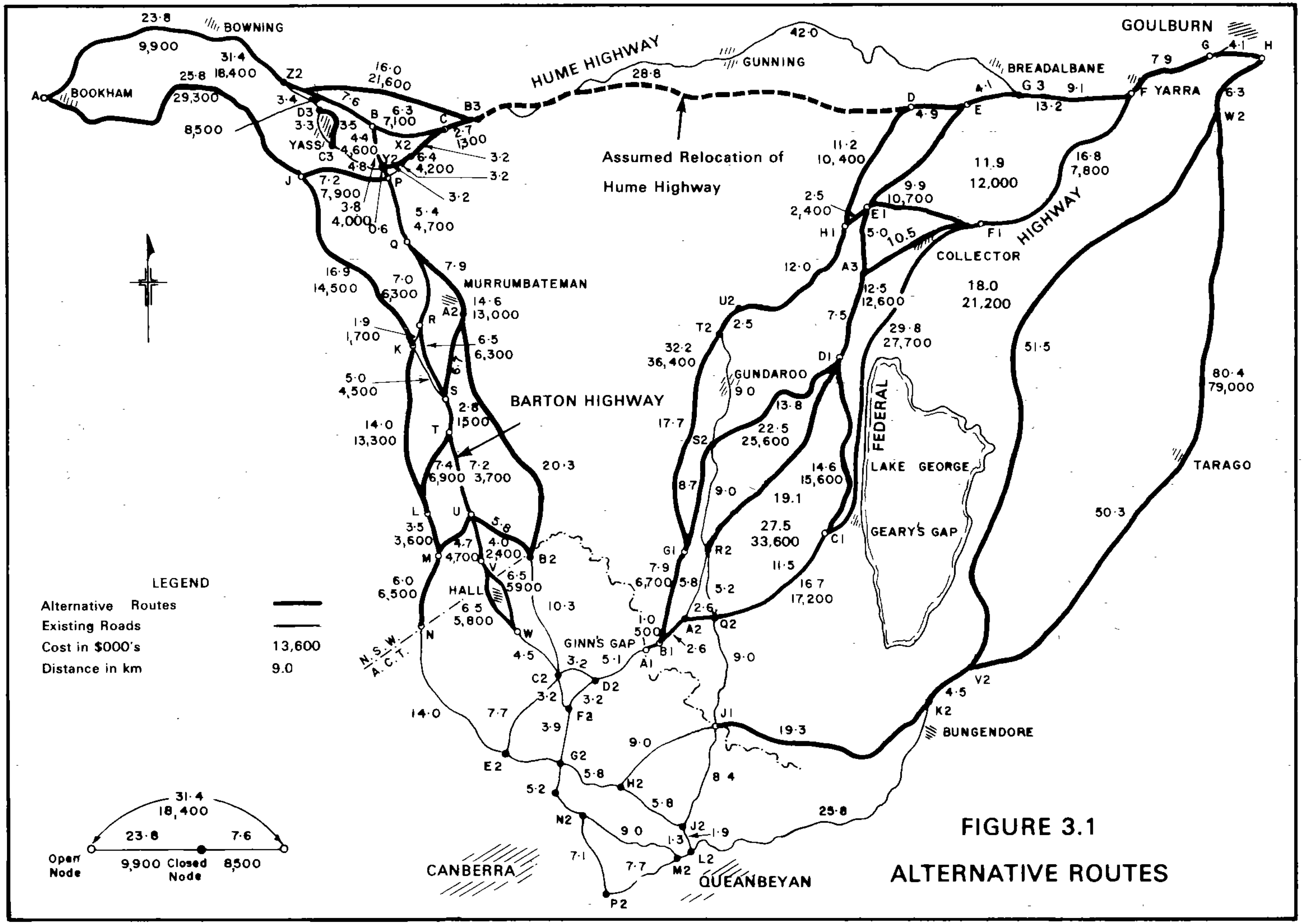

FIGURE 3.1

ALTERNATIVE ROUTES

3.3 CLASSIFICATION OF ROUTES

The alternatives developed fall into three groups:

- those related to the existing Federal Highway, between Goulburn and the ACT;
- those related to the existing Barton Highway, between Yass and the ACT; and
- those related to the town of Yass, including bypasses to the north and south.

3.4 ALTERNATIVES BETWEEN GOULBURN AND THE ACT

The existing Federal Highway leaves the Hume Highway at Yarra and crosses a flat upland plain with occasional higher points before passing through the small settlement of Collector. South of Collector the Highway crosses Collector Creek and its flood plain which drains into the inland basin, Lake George. The Federal Highway follows a line west of Lake George at the foot of the steep scarp of the Lake George Range. After following the lake for nearly half its length the Highway leaves the lake shore turning west over the range at Geary's Gap. Undulating country is traversed between there and the boundary of the ACT at Ginn's Gap. The lake water level has reached the level of the road on a number of occasions in the past.

The alternative routes between Goulburn and the ACT as shown in Figure 3.1 were developed from the existing Highway to avoid the two areas of Collector and Lake George. They fall into two broad subgroups: those to the east of Lake George and those to the west.

The two alternatives to the east of Lake George enter Canberra via Bungendore. The first alternative, which follows the existing Goulburn - Bungendore route (TR79 and MR268) and the line of the Goulburn - Cooma railway, passes the proposed Woodlawn copper mine at Tarago. It strikes due west from Bungendore through undulating country, meeting the Sutton-Queanbeyan road at the ACT border. The second alternative passes closer to the east shore of Lake George before rejoining the first alternative about 6 km east of Bungendore. Both alternatives are around 7 km longer than the existing Federal Highway between Goulburn and the centre of Canberra.

As the existing route passes along the western shore of Lake George, alternative routes are further west, either close to the Lake George Range or predominantly within the Yass River Valley.

Collector may be bypassed either to the north or the south. If it is bypassed to the south, it is only possible to climb the scarp at the existing Federal Highway pass at Geary's Gap 21.6 km south of Collector along Lake George. Thus all routes on the scarp or in the Gundaroo valley rely on a northern bypass of Collector. Two such northern bypasses were considered, a gentle rise (F_1E_1) and a more direct route closer to the existing Collector-Gundaroo road (F_1A_3). If the existing Federal Highway were upgraded, it was assumed that Collector would be bypassed to the south, as this is the most direct route.

From the top of the scarp onwards, three principal alternatives were considered. One alternative involves crossing the Yass River about 7 km north of Gundaroo and following the west side of the valley 2-3 km west of the river as far as Ginn's Gap on the ACT border. A second alternative follows the scarp as far as the head of Lake George and then passes south of Gundaroo village. $D_1R_2B_1$ offers a more direct route but crosses more difficult country. The third alternative (D_1C_1) runs the length of the scarp before rejoining the existing Federal Highway 3 km west of Geary's Gap.

The scarp routes offer the opportunity to link direct into the Hume Highway by cutting directly across ($H_1D;E_1E$) to join the related Hume Highway east of the Cullerin Ranges, thus reducing the length of new construction on the Federal Highway route, and maximising the use of the new Hume Highway construction west of Yarra. Such routes would, however result in increases in the cost of construction compared with reconstructing the existing Federal Highway and increases in route lengths and hence user costs.

3.5 ALTERNATIVES BETWEEN YASS AND THE ACT

The Barton Highway leaves the Hume Highway 3 km east of Yass and crosses undulating country to the township of Murrumbateman. It then runs directly to the ACT border at Hall. The principal alternatives to reconstruction along the existing route are associated with entering the ACT either to the east of Hall at B_2, or to the West at N.

The route to the east (A_2B_2) minimises the distance between Murrumbateman and Canberra, but only saves 1 km compared to the existing highway. The more indirect connection (UB_2) gives a route 1 km longer than at present.

The route to the west (MN) links into the Molonglo Parkway (NG_2), the first stage of which has already been constructed near the Australian National University. It is, however, expected to be many years before construction reaches the ACT/NSW border. One alternative (NLKB) is to continue north from the border, running along the edge of the scarp above the Murrumbidgee Valley, before rejoining the Barton Highway north of Murrumbateman, having bypassed it to the west. Sub-options are to rejoin the Barton Highway at varying points along its length (MU,LT). The two urban settlements along the existing line of the Barton Highway, Murrumbateman and Hall, may each be bypassed to either the west or the east. There is little difference in route length between the options at Hall, although that to the west is marginally shorter and does not affect existing and projected urban development to the same extent as that to the east. The western bypass of Murrumbateman, however, is over 1 km shorter than that to the east, besides creating fewer acquisition and severance problems. An inner western bypass has also been proposed, but this passes very close to the village area and could restrict future development.

If a southern bypass of Yass (see following Section 3.6) were to be constructed, an opportunity exists to considerably shorten the journey from Canberra to west of Yass by constructing a cut-off (JK) saving over 4 km compared with the route along the existing Barton Highway. Traffic to and from Yass would receive few benefits from such a route and the Yass- Burrinjuck road would probably need to be upgraded to provide for such traffic.

3.6 ALTERNATIVES FOR A YASS BYPASS

Possible bypasses of Yass fall into two groups: those to the north and one to the south.

Three bypasses have been proposed to the north; DMR have for several years proposed a bypass(CBZ_2) leaving the Hume Highway just over 6 km to the east of the Hume/Barton intersection, passing over a saddle to the north of Mount Manton and keeping generally close to but north of the Yass River. It passes about 1.5 km to the north of Yass, keeping to the south of the main rail line and rejoins the Hume Highway 2 km west of the town.

An addition to this route involves a connection near its western end to take advantage of the existing service centre on the Hume Highway on the western edge of Yass, just south of the former Yass rail branch. These service stations would be bypassed under the DMR scheme as it now stands.

The second major alternative for a northern bypass of Yass follows a line about 2 km north of the DMR route, (B_3Z_2) leaving the Hume Highway about 9 km east of the Hume/Barton intersection and rejoining it 2 km west of Yass. This alternative provides the shortest route for through traffic on the Hume Highway but requires more new construction than the DMR bypass where it crosses the ridge extending north of Mt. Manton.

The third alternative for a northern route is an inner bypass of Yass (D_3C_3) as suggested by Yass Council. This passes along the northern edge of the existing urban area, after leaving the Hume Highway near the saleyards just before its intersection with the Burrinjuck Road. It crosses the Yass River at or adjacent to the western end of the town water storage and then heads due west, passing along Reddall Street at the northern edge of the urban area to rejoin the existing highway just east of the railway level-crossing in West Yass. Although this route would not be particularly attractive to private motorists, the Council envisage that it could be developed as a truck relief route and thus remove through semi-trailers from the main street. There are, however, major problems in crossing the Yass River, particularly so close to the town's water supply.

The southern bypass of Yass (AJC) represents by far the greatest deviation from the existing Hume Highway leaving the Hume Highway near its intersection with the Yass-Gundaroo road and rejoining it about 4 km east of Bookham. The route passes through very much more rugged country than the northern bypasses.

CHAPTER 4 - ASSESSMENT OF ALTERNATIVES

4.1 ASSESSMENT FRAMEWORK

4.1.1 General

Each set of alternative routes described in Chapter 3 was assessed taking into consideration:

- construction costs;
- road user costs;
- social implications; and
- environmental impact.

The alternatives in the set were compared and a particular route was selected. Further analysis of the selected route was made to estimate the benefit-cost ratio of the construction involved. The benefit-cost analysis was consistant with the general approach used by the CBR in the past [(1)].

4.1.2 Construction Cost and Engineering Aspects

The construction costs of the alternative routes were based on unit costs per kilometre, taking into account the type of country through which the route passes and also the extent to which existing carriageways could continue to be used. Major structures (e.g. the bridge over the Yass River in the Yass Council bypass proposal) were costed individually.

For the purposes of estimating the benefit-cost ratios of the selected routes, the costs of maintenance and reconstruction were also assessed.

The engineering appraisal also included consideration of unusual and sensitive engineering aspects of the improvement alternatives, such as those involved in upgrading the existing Federal Highway along the shore of Lake George. A a route close to the lake must be planned and constructed firstly at levels which are unlikely to be flooded, and also with sensitivity to the environmental constraints of the lake shore at the base of the steep scarp.

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(1) See, for example, G.J. Both, C. Bayley, Evaluation Procedures for Rural Road and Structure Projects, 8th ARRB Conference, 1976.

4.1.3 Road User Costs

Road user costs are comprised almost exclusively of:-

- vehicle operating costs, which vary with road characteristics and operating speeds;
- journey time costs for persons and freight; and
- accident costs, which vary with the distance travelled and the standard of the road.

The difference in route length between alternatives was considered to be an effective index for estimation of differences in user costs, since user costs after construction are dependent predominantly on the distance travelled where road characteristics affecting travel costs, e.g. grades and alignment, are similar for the alternatives. Where the comparison of alternatives was affected by differences in any such characteristics this factor was then taken into consideration. It was not generally necessary therefore to quantify road user costs for the comparison of alternatives. However in some instances user costs were calculated to assist in the comparison as shown in Section 4.2. Road user costs were quantified to calculate the BCR of the recommended routes in each corridor as discussed in Section 4.3.

User costs are increased slightly where construction works interfere with traffic flow. This applies more to the construction of routes close to the existing road alignment. This increase is difficult to quantify and no allowance was made for this in either the comparison of alternative routes or in the benefit-cost calculations.

4.1.4 Social Consequences

The social advantages and disadvantages of the existing road and highway system and potential alterations to it were analysed both within towns along the existing highways and also in rural areas likely to have future highways located in them.

Within towns the economic dependence of various land uses on highway traffic has to be balanced against the effect of traffic on the general environment of the town (e.g. danger, noise, pedestrian difficulties). In rural areas the most significant social issues raised by new highway locations are property severance and access changes. The matter of severance is discussed generally in sub-section 4.4.1.

4.1.5 Environmental Consequences

As indicated in Chapter 3 environmental factors were considered in the selection of the alternatives to ensure that existing or potential problems were avoided, and that every opportunity to enhance the environment was taken. Following this principle, the assessment of the environmental impact of individual routes concentrated on the larger scale and more significant features and impacts of road upgrading and relocation.

Thus, impacts on drainage, aquatic environment, water quality, landscape aesthetics and wildlife were considered in respect of identifiable areas where conflicts might occur. Consideration of the myriad of minor impacts, usually dealt with by amelioratory measures during detailed design, was not attempted. At some time in the future, as design of a chosen route proceeds from the general locations discussed in this report, much further detailed work will be required.

4.1.6 Overall Evaluation

The overall evaluation drew together the four assessments discussed above to enable comparison of the various alternatives. The preferred route in each corridor was established by seeking out a dominant route for each set of alternatives i.e. a route which is best in at least one criterion and which compares well overall in the other criteria.

The alternatives in each set fall into two groups:

- those involving upgrading along existing alignments; and
- those involving long lengths of completely new alignment.

For the foreseeable future, construction is expected to amount to about 10 km each year for any project in the study area and part of the benefits from some alternative routes will begin to accrue up to four years later than those from upgrading along the existing alignment.[1] This is an important factor in the evaluation which favours routes close to the existing alignment.

(1) The discounted benefits of two such routes with identical streams of costs and benefits will differ by over 10% if one route takes five years to build and the other is used as each section is completed, and by over 20% if the new alignment takes ten years to complete.

4.2 COMPARISON OF ALTERNATIVE ROUTES

4.2.1 Canberra-Goulburn Routes

The links shown in Figure 3.1 can be combined to form routes in a large number of ways. Of these, eight representative routes were chosen covering the main opportunities. The eight routes are listed in Table 4.1, together with their length, construction cost and the relative change in overall route travel distance for long distance travel. All costs are in 1976/77 prices.

In terms of construction cost and user benefits, Route 1, the existing Federal highway, dominates all others(1) with the exception of Route 5, the direct Sutton-Collector route, which is 1.0 km shorter but costs an additional \$9.9 m to construct. However, unlike Route 1, user benefits would not flow from the majority of Route 5 for at least four years during the construction period. Allowing for a four-year delay in the flow of benefits, the saving in travel distance on Route 5 would result in benefits over the life of the road having a present value of about \$2½ m.(2) Furthermore, user benefits on Route 5, for the large part of its length which is not common with Route 1 (between F_1 and A_2), would be somewhat lower than user benefits per km for construction of the equivalent part of Route 1; this is due to the significantly greater rise and fall of road level which would be required in the rugged terrain of Route 5 compared with the relatively flat conditions along the equivalent part of Route 1. Accordingly, Route 1, the existing highway, is the preferred route on construction cost and user benefit considerations.

Westerly alternatives for the Federal Highway have a number of engineering and environmental problems. Both the ascent of the Cullerin escarpment west of Collector, and the extremely difficult terrain between this point and Gundaroo would require expensive construction work to meet National Highways standards and the road would have a high proportion of curves and maximum grades. The environmental problems concern both water pollution and adverse affects on wildlife and natural bushland. A major road across the headwaters of the Yass River would facilitate pollution of the upstream sections. The introduction of a new road through largely undeveloped country

(1) i.e. has both a shorter length and a lower construction cost.

(2) For all present value calculations this study used a discount rate of 10%, an analysis period of 30 years, and the base year of 1976.

TABLE 4.1 - COSTS AND LENGTHS OF ALTERNATIVES

Route		Details of Links[a] Requiring Construction to NHS Standard			Change in Overall Route Travel Distance km
No.	Description	Figure 3.1 References	Cost 1976/77 prices $m	Construction Length km	
	CANBERRA-GOULBURN				
1.	Existing Federal Highway	$A_1B_1C_1F_1F$	53.2	64.3	0
2.	Existing Federal Highway and scarp	$A_1B_1C_1D_1E_1F_1F$	64.4	71.5	+7.2
3.	As 2 but more direct descent from scarp	$A_1B_1C_1D_1A_3F_1F$	62.0	66.9	+2.6
4.	Gundaroo valley to Collector	$A_1B_1G_1D_1E_1F_1F$	63.9	70.6	+6.3
5.	Direct route : Sutton-Collector	$A_1B_1A_2R_2D_1A_3F_1F$	63.1	63.3	-1.0
6.	Via Ruthfield to Collector	$A_1B_1G_1H_1E_1F_1F$	64.5	70.3	+6.0
7.	Via Ruthfield to Hume	$A_1B_1G_1H_1D$	54.0	52.3	+6.1[b]
8.	Via Tarago	$J_1K_2V_2W_2H$	79.0	80.4	+6.7[b]
	CANBERRA-YASS				
9.	Existing Barton Highway[c]	$VTRPY_2$	25.5	33.5	0
10.	Molonglo Parkway Connection	$NLKRPY_2$	36.7	38.4	+4.7[b]
11.	One Tree Hill route	$B_2A_2QPY_2$	38.6	34.2	0[b]
	YASS BYPASS				
12.	DMR route - north of Yass[d]	B_3CBZ_2A	26.8	40.4	0

13.	Outer north route	B_3Z_2A	31.5	39.8	-0.6
14.	Yass council route	$B_3CY_2C_3D_3Z_2A$	26.7	44.6	+4.2
15.	Southern route	B_3CPJA	42.7	42.1	+1.7

(a) Excludes roads within the A.C.T., and also the Hume Highway east of B_3 which will be constructed to NHS standard irrespective of the alternative selected;

(b) Due to the need to consider route length between common end points which were beyond the length considered for construction this change in distance is not equal to the difference between construction lengths.

(c) Assumes bypass of Murrumbateman to the West.

(d) The portion of this route which deviates from the existing Hume Highway route is estimated to cost \$15.6m and is 13.9 km in length. (see section CBZ_2 in Figure 3.1).

and natural bushland can be expected to have serious effects on the conservation of remaining wildlife habitats. The bushland west of the scarp complements the lake environment in encouraging use of the area by migratory water birds. Some freehold agricultural land of high quality, particularly south of Gundaroo, could also be adversely affected by some alternative routes to the west.

Some Gundaroo residents fear that a highway near the town could destroy the seclusion and peaceful atmosphere which they value. More generally, a complete new route of this sort is likely to have important implications for the value and use of surrounding land: with much improved accessibility, property values are likely to rise - but so too are rates, which can be a major problem for farm owners.

The engineering and environmental problems associated with Route 1 are considerably less formidable. A significant engineering consideration for Route 1 is the level of the existing Federal Highway which is prone to flooding if the level of Lake George rises. The lake has no outlet and has risen to and remained at high levels before. The highest recorded lake level is the 1874 flood level of about 7.3m above datum. Costing of Route 1 was based on a minimum design road level of 2 m above the 1874 level, which includes an allowance of one metre for wave action. The lowest point on the existing highway in the vicinity of Lake George is about 5.8 m. Analysis of available data is recorded in Appendix 4. Table A4.5 shows that a road level of 8.3 m has less than a 1 in 7 chance of flooding in the next 100 years, and a road level of 9.3 m has a chance of less than 1 in 25 of being flooded disregarding wave action. The proposed minimum design road level of 9.3 m is considered an adequate precaution against future rises in the Lake level.

The main environmental consideration with development of the existing highway alongside Lake George arises because of the narrowness of the strip of land available for upgrading the highway. Construction of the highway would require some cuts into the scarp and its alluvial fans. Some of the highway would need to be located on fill along the edge of the lake, and some of the trees on the foreshore would need to be removed. To minimise such environmental effects, DMR would plant new trees well in advance of construction.

The design verge width on the lake side would be, on average, at least equal to the average verge width existing. Environmental disturbance could also be reduced by some relaxation of the National Highways design standards - in particular the alignment and median width standards. If the design speed is reduced for several horizontal curves and if the two carriageways are considered essentially as two somewhat independent roadways for design purposes (i.e. without fixed median width), less trees would need to be removed and cutting into the scarp would be reduced. Such a reduction in standards would have a negligible affect on road user costs. Environmental investigations indicated that a highway on the lake shore which is designed and constructed to optimise the recreational scenic and ecological aspects of the lake, may improve on the overall environmental conditions along the existing road.

On the advice of the National Parks and Wildlife Service, which emphasises the value of the Lake as a bird habitat, the New South Wales Lands Department plans to incorporate the Lake, including the western shore as far as the top of the neighbouring escarpment, in a future nature reserve under the Crown Lands Act. It is understood that Parliamentary approval will then be required for any new roadworks. The presence of a four-lane highway should be quite compatible with such a nature reserve. Nevertheless some State Government agencies which support the nature reserve plan to oppose construction of a dual-carriageway National Highway along the Lake shore on environmental grounds. One alternative which has been proposed is to use a route at the top of the escarpment for the northbound carriageway of an upgraded Highway. There has not been a detailed investigation of this scheme but some significant disadvantages are apparent. Cross connections between the two carriageways would not be practicable between Geary's Gap and somewhere beyond the north end of the lake - i.e. for a distance of at least 14 km. Thus motorists undertaking return journeys to points along the lake foreshore would have to travel at least 14 km additional distance to do so (and up to say 28 km additional distance to gain access to parts of the foreshore currently accessible to all traffic). Further, the wide separation between carriageways would be conducive to "wrong way" traffic even if full access control were applied to the two carriageways. The carriageway at the top of the scarp would generate disbenefits to road users with a present value of about \$5 m due to the extra distance of some 2½ km which northbound traffic would need to travel. As previously indicated, construction at the top of the scarp would also have environmental disadvantages.

The settlement most affected by upgrading the Federal Highway is Collector. Route 1 includes a bypass of Collector to the south, as indicated on page 20. A bypass would shorten travel distances and travel times for through traffic, and would improve the town's overall environment including traffic safety conditions. Various bypass proposals have been under discussion for some years. The Gunning Shire Council accepts the notion of a bypass but seeks direct access at both ends of the town in order to retain as much passing trade as possible.(1) Uncertainty as to the bypass location has delayed Council decisions on local rural-residential subdivisions.

The town at present has three businesses - a service station/cafe, a hotel, and a general store. While these would be directly affected by a bypass, their employees are generally from outside and thus the effect on resident's jobs would be minimal. The service station and hotel would probably not survive a by-pass, but the general store could well survive and prosper as the only village business.

In summary, construction and road user considerations clearly favour Route 1, the existing highway route, and the environment and engineering studies also favour this route. If some of the design standards for parts of the road along the lake shoreline were reduced, environmental conditions could be optimised. The highway should bypass Collector to the south. This would directly affect the three town businesses, but impact on the town itself will be comparatively mild economically, and would include certain environmental benefits.

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(1) These matters were discussed at a meeting of a representative of the study team with the members of the Gunning Shire Council in March 1977.

4.2.2 Canberra-Yass Routes

As with the Canberra-Goulburn corridor a large number of alternative routes can be constructed from the links in Figure 3.1. Three typical routes, given in Table 4.1 were assessed : these correspond to the three possible entry points into the ACT. The Murrumbateman and Hall bypasses are considered later.

Table 4.1 shows that option 9 along the existing Barton Highway dominates the other routes, as it is cheaper to construct and has the shorter overall route travel distance.

In contrast to the Canberra-Goulburn corridor there are few environmental considerations for or against any of the routes, except that Route 10, the Molonglo Parkway Connection, crosses more tributaries of the Murrumbidgee than the other routes.

The major social considerations concern the Hall and Murrumbateman bypasses. Both schemes for a Hall bypass shown on Figure 3.1 are of equal length and of approximately equal cost. However, the route to the west, which has been reserved for some time by NCDC, does not affect the future urban development of Hall to the same extent as does the one to the east.

Three distinct schemes for bypassing Murrumbateman have been proposed:

- the DMR route (QRS on Figure 3.1);
- the inner western; and
- the eastern.

The Highway is the source of some dissatisfaction in the town at the present time, on account of noise, dirt and danger. The Shire Council is in favour of a bypass and would like a clear decision on the subject. Local opinion regards the Barton in general as a "bad road", in need of some widening and straightening.

Upgrading the Highway through the town, as proposed a few years ago by the Department of Main Roads, would split or destroy several small holdings and the local recreation area, though relocating or redeveloping these should not present major difficulties. With extensive subdivision approved on both sides of the Highway, however, the prospect arises of a growing village severed by the National Highway. This is in general terms undesirable, although the Goodradigbee Shire Council has designed the future local road system to be largely independent of the Barton Highway.

The western bypasses are preferable to the eastern bypass on both construction and road user cost grounds, with the DMR route being the best in these terms. There are no particular arguments in favour of the inner western route as the existing town has no highway-dependent businesses, and there is thus no pressure to keep the bypass close to the town. Thus the DMR route should be adopted.

In summary, option 9, the existing Barton Highway, should be adopted for upgrading within the Canberra-Yass corridor, together with western bypasses of Hall and Murrumbateman. Such a route does not preclude the possibility of a connection to the Molonglo Parkway (e.g. NU) at a future date, should it become warranted.

4.2.3 Yass Bypass

In contrast to the two previous corridors, there are relatively few routes available for a Yass bypass. Table 4.1 lists the four considered in detail in this study.

Only option 15, the southern route, can be immediately rejected on construction and user benefit grounds. The Yass Council route option 14, costs almost the same as option 12, the DMR route, while being over 4 km longer. Option 13 costs about $4.7 m more than the DMR route, for a saving of 0.6 km in travel distance. The present value of road user benefits for a new bypass, over the life of the road, is around $3 m per km of journey distance saved. Thus option 13 would reap less than $2.0 m in user benefits for this additional cost of $4.7 m. The DMR route, option 12, is thus the preferred route in terms of user and construction costs.

The main environmental and social effects of the bypass options are on the urban area of Yass, both in terms of the impact on the town's economy and also the improvement a bypass would bring to the general environment of the town. The only significant impacts outside the town are that the Yass council route, option 14, would pass over or adjacent to the town water storage and that the southern bypass, option 15, would have a significant impact on the country south-west of Yass.

The Hume Highway runs through the commercial heart of Yass; no alternative heavy vehicle route is available. The Highway traffic and the business it brings - the provision of food, petrol and accommodation for travellers, and road-related retail sales in various fields - generate many jobs. On the other hand, heavy traffic through the heart of Yass detracts from the town's amenity and convenience: noise, particularly at night from large articulated vehicles, is a problem to many residents. Drivers often experience delay or inconvenience in travelling or crossing Comur Street (the Highway), and there are parking problems. Shopping in Comur Street - where commercial facilities are concentrated - is made unpleasant by continuous through traffic, and crossing the Highway is a danger, especially for young children. These problems have led to some local support for DMR in constructing a dual carriageway bypass of the town. From the viewpoint of commercial drivers, an appropriate bypass is highly desirable. The Yass Municipal Council has expressed its preference for a bypass that runs as close as possible to the town, in order to minimise the likely loss of business. Among the town's residents, and business people in particular, there are, however, some who fear that any diversion of traffic will spell major economic loss for Yass.

The town's economic health at present depends substantially but by no means exclusively on the Highway. The Electricity Commission and the Department of Main Roads employ 15% of a total workforce (which was about 1650 in 1971). About 23% of the workforce belong to the "Wholesale and Retail Sales" sector, and a further 10% to "Entertainment etc.", but neither of these reflects purely Highway-related business. The impact on business of a bypass will not be evenly distributed. Some undertakings in Yass - notably those servicing essentially rural needs - would scarcely notice it, while at the other extreme there are businesses which could suffer greatly because most of their services or goods are used directly or indirectly by the traveller. Service stations typically get a good deal of driveway trade from travellers (but little workshop business). The importance of Yass to the traveller is highlighted in Table 4.2. Over 20% of private vehicles and over 30% of trucks on through trips stop in Yass, and it attracts more business from travellers than any other centre on the Hume Highway between Melbourne and Sydney.

TABLE 4.2 - STOPOVERS AT URBAN CENTRES - HUME HIGHWAY 1974 [a]

Centre	Vehicles Stopping/Day [b]			
	Private Car		Truck	
	Overnight	Fuel, Food	Overnight	Fuel, Food
Albury/Wodonga	80	340	30	410
Holbrook	20	90	-	10
Tarcutta	10	30	-	60
Gundagai	30	300	-	70
Bowning	-	10	-	-
Yass	40	760	-	450
Gunning	-	40	-	10
Goulburn	20	380	-	50

(a) Source : Travel survey by CBR, in conjunction with DMR, conducted in 1974

(b) Average of weekday and weekend

Loss of highway trade will be a major problem for some Yass businesses, and thus will cause the loss of some jobs. There are reasons, however, for believing that a Hume bypass is not likely to cause a severe economic loss to the town. These include its proximity to and growing relationships with Canberra, its strategic location in relation to certain recreational resources (notably the Burrinjuck Dam), and the potential environmental and historical attractions of the town itself (which can obviously be enhanced by a reduction in through traffic). Provided that the future bypass route is designed to maximise access to businesses, and provided that local authorities take positive steps to minimise continuing dependence on road-related business, the social and economic strains of adjusting to a bypass should not be excessively severe for the town as a whole, though the position of some individuals may well be difficult.

Attention is drawn to the roadhouses on the outskirts in North Yass. These thriving businesses are the town's chief source of truck trade, which it is considered important to retain. In designing the northern bypass route it should be feasible to incorporate a connection to this service area which would involve little deviation from the main route.

It is clear that, if Yass is to preserve its role of a major stopover on the Hume Highway, any bypass should provide good access to Yass in both directions. The southern bypass would provide poor access to Yass; of the northern bypasses the Yass council route naturally offers the best access to Yass. However, the DMR bypass has the potential for a low-cost connection to the roadhouse area of North Yass. This would remove heavy traffic from the central area of Yass whilst still offering reasonable access to the existing service centre.

In summary, the DMR route, option 12, offers considerable advantages in construction and user costs. Any bypass will have a significant impact on the Yass economy but the DMR bypass offers the opportunity to keep this to a minimum by linking the route to the roadhouse area of North Yass.

4.3 WARRANT FOR CONSTRUCTION

Although in practice, other factors besides economics influence the priority of a project, it is considered that the BCR of the project is a valuable guide to its priority and a reasonable indication of the economic warrant for construction.

The benefit-cost analysis considered the road user and supply (construction and maintenance) costs, both with the proposed improvements and without the improvements, over the evaluation period of 30 years.

The BCR's which were calculated for this study are the present value of the future road user and road maintenance benefits, divided by the cost of construction. Appendix 3 gives details of the assessment of benefits. The BCR for each route is the average for the route and the BCR of a particular section will vary from this average, e.g. due to high construction costs in a section.

Construction of the Federal and Barton Highways along their present routes can be carried out progressively in sections which can be opened to traffic on completion, because of the ease of connection between the existing road and the newly constructed sections. Since such sections can be completed within 12 months as a rule, and since the order in which the sections would be constructed is not known, the undiscounted construction cost was used for the evaluation of BCR's. Thus the BCR's for the Federal and Barton Highways are applicable in general to any sections which are completed in the first year. The Yass bypass of 13.9 km length, could be constructed in a relatively short time period (say 12 to 18 months), and therefore the BCR for this project was also calculated using the undiscounted construction cost.

The Federal and Barton Highway upgradings involve partial realignment with little reduction in length, and road user benefits consist of:

- reduction in vehicle operating costs because of the improved road standard (partly offset by higher running speeds); and
- reduction in travel time consequent on the increase in road capacity following duplication, and on the improved alignment.

In addition to the above benefits the Yass by-pass construction would attract user benefits from the reduction in distance travelled, comprising both the costs of vehicle operation and the time cost for the distance saved.

4.3.1 Federal Highway

As indicated in Appendix 3, the upgrading of the Federal Highway would generate road user benefits with a present value of $848,000 per km. As the average cost of construction is $950,000 [1] per km, the current BCR is

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(1) Allowing for the retention of the existing carriageway in some sections.

about 0.9. This indicates that construction of the whole of the Federal Highway to NHS standards is not economically warranted at this time (although some sections are likely to be). However with the increase of traffic this construction would be economically warranted in a few years time.(1)

4.3.2 Barton Highway

Upgrading the Barton Highway will generate road user benefits over 30 years with a present value of about $771,000 per km. The average cost of reconstructing the Barton Highway, at about $960,000 per km, is similar to that for the Federal Highway, assuming that the existing highway can be utilised as one of the new carriageways south of the Murrumbateman bypass. Under this assumption the project has a current BCR of about 0.8 suggesting a lower priority than that for the Federal Highway.(2)

4.3.3 Yass Bypass

The Yass bypass, unlike the Federal and Barton Highway reconstructions, provides a significant distance savings for through traffic on the Hume Highway. The bypass and associated works were divided into two sections for anlaysis: the Yass bypass (Z_2BC in Figure 3.1); and the connection to the Barton Highway (BY_2).

Appendix 3 shows that, were the bypass and the connection to the Barton Highway to be built now, the present value of benefits to Hume Highway traffic and Barton Highway traffic would be $31 m and $6.3m respectively. The costs of the bypass and the Barton Highway connection are $15.6 m and $4 m respectively. The BCR of the bypass is thus about 2.0 and the BCR of the Barton Highway connection is 1.6, indicating that the Yass bypass might be constructed some time before the connection to the Barton Highway. It should be noted that construction in this manner would tend to buffer the impact of the bypass on the economy of Yass.

4.4 OTHER ISSUES

The principal issues of general concern common to all options are severance, aboriginal and historic sites, and highway services.

(1) Under the assumptions made for the calculation of the BCR's and with the assumed traffic growth of 3.9%, construction would be economically warranted in 1980.

(2) With the assumed traffic growth of 4.1%, this project would be economically warranted in 1983.

4.4.1 Severance

The main implications of the realignments under consideration here are gains or losses for particular properties. A direct Highway frontage can be a disadvantage rather than an advantage in rural areas (because of risks of fire, trespass, vandalism and so on); changes in alignment would mean gains for some and losses for others in this respect. Heavy traffic is seen as degrading the immediate environment, and disturbance during road construction may be significant. Probably most serious is the prospect of severance of rural holdings by a new Highway route - for example north of Yass or west of Murrumbateman. Severance may create any of a wide variety of practical problems of property use and management. While a sensitive approach to compensation and reinstatement can cope with many of these, subjective and/or objective losses may remain.

It is not possible to generalize about likely degrees of inconvenience or hardship - while the potential problems are obvious enough, impacts actually experienced depend entirely on the details of routes chosen and compensatory measures adopted. However this issue reinforces the view that the existing route should be maintained.

4.4.2 Aboriginal and Historic Sites

There are three kinds of aboriginal sites relevant to environmental investigations:

- Aboriginal sites in use. There are no sacred sites used by present day aboriginals in the area of concern;
- Aboriginal art sites, stone arrangements, etc. Some of these are present, but are unlikely to be on road sites; and
- Aboriginal archaeological deposits. There are some known archaeological sites, especially around Lake George, but no major sites. However there have been some significant deposits in the general area. Archaeologists should carry out a survey along the routes when a precise alignment is decided upon. They should also co-operate during road construction, do retrieval work if road making exposes previously unknown aboriginal deposits, and advise on any minor deviation of the road needed to avoid significant sites.

A very large number of sites in the area have some historic importance. The ACT Historic Sites and Building Committee has compiled a map, whilst the local historical society has a much larger collection, not yet collated on a map. It will be feasible to study this aspect in detail when the route selection is at the design stage.

4.4.3 Highway Services

Bypassing urban settlements which have previously provided services to travellers such as food, fuel and accommodation, raises both the question of possible losses to the relevant businesses and of whether replacement facilities need to be provided. Subject to the not unimportant fact that as Highway improvement proceeds, traffic volume and thus total demand for highway services is increasing, the bypassing of individual towns should not mean a loss of business potential at any point on the road. In principle, therefore, it ought to be possible to compensate for any loss of jobs or income within Yass or Collector, say, by setting up on the Highway, somewhere nearby, new businesses to play a similar role.

The Department of Main Roads does not appear to have yet developed any comprehensive policy on the question of highway services which would guide either individuals or local authorities to plan ahead in this connection. The Department does not permit roadside development on limited-access dual-carriageway road such as any new town bypasses. On the other hand, it is in general opposed to isolated roadside centres and prefers service points to be in or close to settlements which can themselves make use of the facilities, provide labour and so on.

If Collector is bypassed and the existing service station closes, will there be need or justification for a replacement on the Highway nearby? If so, can or should any preference in relation to it be given to the existing proprietor or employees? Ought the highway construction authority take an active role in such matters? There would be obvious value from a community point of view for the Department of Main Roads to develop a clear general policy and location strategy on questions of this kind, to help reduce uncertainty for the communities and individuals who face decisions on relevant matters.

APPENDIX 1 - ACKNOWLEDGEMENTS

Both the DMR and the NCDC assisted in the planning of the study and officers of both of these authorities were closely involved in the study. The DMR provided much background data on the study area, advice on traffic, land use, environmental and construction matters. DMR developed most of the route alternatives and provided all of the cost estimates used in the study.

DMR also undertook appropriate liaison with the relevant NSW Government Departments and Authorities including: National Parks and Wildlife Service, Public Works Department, State Pollution Control Commission, Planning and Environment Commission.

Officers of the Commonwealth Department of Environment, Housing and Community Development, and other Commonwealth Authorities provided assistance through discussion.

The South East Region Joint Steering Committee produced a report on future development in the north of the ACT. This report was made available and advice and assistance was received from many members of the Steering Committee.

Much useful advice was also received from members of the South East Region Advisory Council and members and staff of the following Local Government Authorities : Braidwood, Goodradigbee, Gunning, Mulwaree, Tallaganda, Yarrowlumla and Yass.

In addition to the above, helpful information and advice was received by the study team through discussion with and submissions from numerous organisations and individuals with interest in the study area. Two written submissions were made direct to the CBR. These were from the Gundaroo Committee, and from Mr. E. McReynolds of Yass respectively.

Much of the field work for this study was undertaken by three consultants assisting in the social and environmental investigations. They were John Paterson Urban Systems, James Holdsworth and Dr. C.D. Ollier. Mr. Holdsworth received valuable information from a number of sources including written comments from the following persons and organisations : Mr. and Mrs. B. Turton, Mrs. J.C.H. Betts, the Yass Public School Parents' and Citizens' Association, and the Yass and District Pre-School Association.

APPENDIX 2 - TRAFFIC PATTERNS AND FORECASTS

2.1 SOURCES OF DATA

Current traffic patterns were examined primarily for estimating the amount of "through" traffic, i.e. traffic which travels the whole length of the Federal and Barton Highways, and traffic which could bypass Yass. For these purposes it was necessary to use data collected manually in classifications based on vehicle origins and destinations. Such counts also provided estimates of the proportion of commercial vehicles in each traffic stream. The following manual counts were used:

- origin/destination surveys in September 1974 by the CBR in conjunction with DMR at:
  - the Federal Highway, south of Yarra
  - the Hume Highway, west of Yass
  - the Hume Highway between Yass and the junction with the Barton Highway.
- cordon surveys in November 1975 on the ACT border, carried out by NCDC as part of the Canberra Short-Term Transport Study, at Ginn's Gap and north of Hall.

Traffic flows have been measured by DMR with mechanical counters (supplemented by manual counts) located at various parts of the study area. These counts were used in this study primarily to determine past trends in growth as a basis for forecasting growth in traffic. The counts were also used for adjusting origin/destination data to allow for variations in flow (by hour of the day, day of the week, and week of the year) in the estimation of equivalent average daily flows as used in this Appendix.

2.2 FEDERAL HIGHWAY CORRIDOR

The origin-destination survey data obtained at Yarra was classified by southern trip-end as shown in Table A2.1 together with the estimated average daily traffic corresponding with the trip-end.

TABLE A2.1 - FEDERAL HIGHWAY TRAFFIC AT YARRA, 1976[a]

Southern Trip-end	Cars	Trucks[b]	Av. Daily Total
Canberra	1910	690	2600
Local	210	90	300
Cooma/Snowy Mts.	220	40	260
Queanbeyan	200	20	220
Sutton/Gundaroo	10	20	30
Other[c]	100	20	120
TOTAL	2650	880	3530

(a) Source : CBR survey 1974. DMR traffic and classification count 1976.

(b) 2 axle 6 wheel and larger.

(c) Victoria, South coast of NSW.

The northern trip-ends of the traffic passing Ginn's Gap are as given in Table A2.2, together with the estimated average daily traffic flows.

TABLE A2.2 - FEDERAL HIGHWAY TRAFFIC AT GINN'S GAP, 1976[a]

Northern Trip-end	Average Vehicles Per day
Sutton[b]	1130
Gundaroo[b]	290
Gunning/Crookwell[b]	110
Bungendore/Braidwood[b]	180
Geary's Gap/Lake George[c]	130
Collector/Breadalbane[c]	70
Goulburn	670
North of Goulburn	1890
TOTAL	4470

(a) Source : 1975 NCDC Survey. No distinction in destination was made between cars and trucks. The average proportion of heavy commercial vehicles was 17%.

(b) Turns off at TR52.

(c) Terminates before Yarra.

In addition to the traffic leaving the ACT by the Federal Highway, traffic also feeds onto the route from TR52, the Queanbeyan-Gunning road. From DMR records, this additional traffic is estimated as 25% of the east-west traffic passing through the intersection (estimated at 2760 from Table A2.2 above) giving a total traffic flow east of TR52 of 3450, of which 250 terminates at Lake George or Collector. The trip matrix of Table A2.3 was used as a basis for detailed analysis, and represents average daily traffic flows.

TABLE A2.3 - FEDERAL HIGHWAY TRIP MATRIX, 1976

	Canberra[(a)] via SH3	Queanbeyan[(a)] via TR52	Goulburn[(a)]
Sutton	1130	n.a.	30
Gundaroo/Gunning	400	n.a.	-
Bungendore	180	n.a.	n.a.
Geary's Gap	130	30	-
Collector	70	20	300
Goulburn[(a)]	2560[(b)]	640[(b)]	-

(a) And Beyond.

(b) Through Traffic.

After consideration of the past growth in the Federal Highway traffic as indicated in Table 2.1 (Chapter 2), and the likely future population growth of Canberra, an annual traffic growth of 3.9% was adopted for the purpose of calculating road user benefits.

2.3 BARTON HIGHWAY CORRIDOR

The origin/destination survey data obtained on the Hume Highway east of Yass is given in Table A2.4 for the various trip-end points in the form of the equivalent average daily traffic flows.

TABLE A2.4 - TRAFFIC FROM HUME TO BARTON HIGHWAYS, 1976[a]

Southern Trip-end	Cars	Trucks[b]	Av. Daily Total
Canberra	2240	270	2510
Local	190	0	190
Murrumbateman	140	20	160
Hall	50	0	50
Sutton/Gundaroo	40	0	40
Queanbeyan	100	20	120
Cooma/South Coast	80	40	120
TOTAL	2840	350	3190

(a) Source : CBR survey 1974,
DMR traffic and classification count 1976.

(b) 2 axle and 6 tyre and larger.

The northern trip-ends of traffic just north of Hall are shown in Table A2.5.

TABLE A2.5 - BARTON HIGHWAY TRAFFIC NEAR HALL, 1976[a]

Northern Trip-end	Average Vehicles Per Day
Local	680
Murrumbateman	330
Gunning	40
Yass	1080
West of Yass	1720
TOTAL	3850

(a) Source : 1975 NCDC Survey. No distinction by destination was made between cars and trucks. Average proportion of Heavy Commercial Vehicles was 11%.

The trip matrix of Table A2.6 based on the above data, was used as a basis for later analysis, and shows the estimated average daily traffic flows between the locations indicated.

TABLE A2.6 - BARTON HIGHWAY TRIP MATRIX 1976

	Canberra[a]	Yass[a]
Canberra[a]	n.a.	2750[c]
Murrumbateman	330	160
Hall	n.a.	50[c]
Barton Highway[b]	680	190
Gundaroo/Sutton	n.a.	40
Gunning	40[c]	n.a.

(a) And beyond.

(b) Not otherwise defined.

(c) Through traffic.

As indicated in Section 2.8, the future rate of growth on the Barton Highway is estimated to be somewhat lower than past growth rates. Allowing for expected increases in the growth in population of Canberra and Queanbeyan, and other factors, an annual growth rate of 4.1% was assumed for the calculation of road user benefits.

2.4 THE BYPASS OF YASS

The two origin/destination surveys on the Hume Highway, east and west of Yass respectively were used as the basis for the traffic volume details given in Table A2.7 below.

TABLE A2.7 - HUME HIGHWAY TRAFFIC NEAR YASS, 1976[(a)]

	Cars	Trucks[(b)]	Av. Daily Total
Traffic To and From East			
Terminating in Yass	1430	130	1560
Through Yass	3600	1290	4890
TOTAL	5030	1420	6450
Traffic To and From West			
Terminating in Yass	740	170	910
Through Yass	3450	1010	4460
TOTAL	4190	1180	5370

(a) Source : CBR surveys, 1974.

(b) 2 axle 6 tyre and larger.

The two surveys are in reasonable agreement on the traffic bound for destinations beyond Yass, and an average flow of 4680 bypassable vehicles with 25% trucks has been assumed.* This estimate is slightly high, since a proportion of "through" traffic would continue to pass through Yass for refreshment, overnight stops, fuel etc. This proportion was neglected for the purposes of calculating road user benefits. (The 1974 surveys showed that 25% of through traffic stopped for fuel or food but under 1% stopped for an overnight halt).

The 1974 surveys also indicated that, of the 4680 bypassable vehicles, an estimated 1660 vehicles (1500 cars and 160 trucks) would travel to and from the Barton Highway, and 3020 vehicles (2030 cars and 990 trucks) would travel to and from the Hume Highway east.

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* The surveys were carried out in daylight hours. Department of Main Roads point out that heavy vehicle operation at night is significant enough to suggest that the commercial vehicle content may be closer to 35%. This would increase the warrant for the Yass bypass.

These estimates are for a northern bypass. If a southern bypass were constructed, traffic bound for Bowning would continue to use the existing highway. This was neglected in later calculations.

After consideration of the past growth in the Hume Highway traffic (as indicated in Table 2.1) the likely future population growth of Canberra, and general traffic growth on the Hume, an annual traffic growth of 3.0% was adopted for the Yass bypass. An annual growth of 4.0% was adopted for the Barton Highway connection to the Yass bypass.

APPENDIX 3 - ROAD USER AND MAINTENANCE BENEFITS

3.1 GENERAL COMMENTS

In this Appendix benefits are calculated for the purposes of estimating the economic warrant for construction on each recommended route. The economic warrant is expressed in terms of benefit-cost ratio (BCR), as indicated in Section 4.3. The denominator of the BCR is confined to the cost of construction. The numerator is the sum of the benefits resulting from changes in:

- road user costs - vehicle operation, time costs and accident costs; and
- maintenance costs - including reconstruction and rehabilitation costs where needed to cope with the traffic over the period of the evaluation.

All costs are expressed in 1976/77 prices. Future costs were discounted to the base year 1976 using a 10% discount rate. An evaluation period of 30 years was adopted, and the salvage value of the improvements was assumed to be zero.

It was assumed that road user costs grow proportionally to the increase in traffic. The combined vehicle operation and time cost (for both private and business travel) was assumed to increase at 2% p.a. as a result of increases in the value of time.

Costs used to calculate benefits in this Appendix, other than maintenance costs, are those used previously in benefit-cost calculations by the CBR [(1)] adjusted to 1976/77 prices. Maintenance costs were provided by the DMR.

The accident rates used for the existing roads were those provided by the DMR. The predicted accident rates used for the new facilities were average rates used by the CBR for economic evaluation purposes [(1)].

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(1) Commonwealth Bureau of Roads, Evaluation of Roadworks - Principles and Procedures, Melbourne 1973.

3.2 FEDERAL HIGHWAY

3.2.1 Vehicle Operation Benefits

For the estimation of vehicle operating costs on the existing road, the following average conditions were assumed to apply over the evaluation period:

- grades between 2% and 4%
- speeds of 70 km/h for cars and for trucks
- pavement structural condition poor.

The traffic composition used for both the existing and improved roads is given in Table A3.1.

TABLE A3.1 - FEDERAL HIGHWAY TRAFFIC COMPOSITION [a]

Vehicle Type	%
Private Car	22
Business Car	52
2 axle 4 tyre	4
2 axle 6 tyre	10
3 axle	3
4 axle	4
5 axle	5

(a) Source: 1974 CBR survey, and 1976 DMR traffic and classification count.

For the estimation of vehicle operating costs on the new four-lane divided road on the recommended route, the following average conditions were assumed to apply over the evaluation period:

- grades between 2% and 4%
- speeds of 90 km/h for cars and 70 km/h for trucks
- pavement structural condition very good

The resulting weighted operating costs and weighted time costs are given in Table A3.2.

TABLE A3.2 - FEDERAL HIGHWAY UNIT COSTS

	Car	Truck
Operatinc Cost (¢/km)		
- existing route	7.5	32.3
- new route	6.0	25.2
Time Cost ($/hr)	4.51	4.76

The above Tables give an average unit cost [(1)] of 20.4 ¢/km on the existing road and 16.5 ¢/km on the upgraded road, a saving of 3.9 ¢/km per vehicle. With a 1976 traffic volume of 3,200 [(2)] growing at 3.9% p.a., these savings over the evaluation period have a present value of $833,600/km.

3.2.2 Accident Benefits

The accident rates adopted for the existing and for the new roads were 1.43 and 0.93 accidents per million vehicle - kilometres respectively. Using the weighted cost of all accident types per accident of $4,510, and the traffic volume of 3200 vehicles per day, the accident benefits amount to $2620 per kilometre in 1976. With a traffic growth rate of 3.9% p.a. the present value of the accident benefits over the evaluation period amounts to $47,900/km.

3.2.3 Maintenance Benefits

The cost of maintaining the existing road to carry the traffic forecast for the evaluation period was estimated at $2,330/km p.a. for routine maintenance, $7000/km every 7 years for resealing, and a provision of $11,680/km p.a. to allow for any rehabilitation and/or reconstruction works. The cost for the new road was assumed to comprise $5600/km p.a. for routine maintenance and

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(1) Combined vehicle operating and user time cost.

(2) From Table A2.3 in Appendix 2. This figure excludes short distance traffic.

$83,950/km every 10 years for re-sheeting with asphalt. The present value of the maintenance costs over the evaluation period amount to $147,250/km and $180,580/km for the existing and the new road respectively, giving disbenefits of $33,300/km.

3.2.4 Total Benefits

The benefits per km for upgrading the Federal Highway are thus $833,600 for vehicle operation savings, plus $47,900 for accident savings, less $33,300 for increased maintenance costs. The net benefits amount to approximately $848,000/km.

3.3 BARTON HIGHWAY

3.3.1 Vehicle Operation Benefits

The assumptions relating to grades, speeds and pavement condition outlined in Sub-section 3.2.1 of this Appendix for the existing and new road conditions were assumed to apply also to the Barton Highway. The traffic composition given in Table A3.3 was adopted, giving the weighted vehicle operation costs and weighted time costs shown in Table A3.4.

TABLE A3.3 - BARTON HIGHWAY TRAFFIC COMPOSITION [(a)]

Vehicle Type	%
Private Car	60
Business Car	25
2 axle 4 tyre	4
2 axle 6 tyre	5
3 axle	1
4 axle	2
5 axle	3

(a) Source: 1974 CBR survey, and 1976 DMR traffic and classification count.

TABLE A3.4 - BARTON HIGHWAY UNIT COSTS

	Car	Truck
Operating Cost (¢/km)		
- existing route	7.5	39.9
- new route	6.0	30.7
Time Cost ($/hr)	4.51	4.69

The above Tables give an average total unit cost of 18.8 ¢/km on the existing road and 15.0 ¢/km on the new road, a saving of 3.8 ¢/km per vehicle. With a 1976 traffic volume of 2840 (1) and a growth rate of 4.1% p.a. these savings over the evaluation period have a present value of $740,600/km.

3.3.2 Accident Benefits

The accident rates adopted for the existing and for the new roads were 1.06 and 0.93 accidents per million vehicle - kilometres respectively. Using the weighted cost of all accident types per accident of $4,510, and the traffic volume of 2840 vehicles per day, the accident benefits amount to $580/km in 1976. With a traffic growth rate of 4.1% p.a. the present value of the accident benefits over the evaluation period amounts to $10,900/km.

3.3.3 Maintenance Benefits

The cost of maintaining the existing road to carry the traffic forecast for the evaluation period was estimated at $1870/km p.a. for routine maintenance, $7000/km every 7 years for resealing, and a provision of $17,650/km p.a. to allow for any rehabilitation and/or reconstruction works. The cost for the new road was assumed to comprise $5600/km p.a. for routine maintenance and $83,950/km every 10 years for re-sheeting with asphalt. The present value of the maintenance costs over the evaluation period amount to $199,930/km and $180,580/km for the existing and the new road respectively, giving benefits of approximately $19,300/km.

(1) See Appendix 2, Table A2.6. This figure excludes short distance traffic.

3.3.4 Total Benefits

The benefits per km for upgrading the Barton Highway are thus \$740,600 for vehicle operation savings, plus \$10,900 for accident savings and \$19,300 for maintenance savings. The total benefits amount to approximately \$771,000/km.

3.4 YASS BYPASS

3.4.1 Vehicle Operation Benefits

The assumptions relating to grades, speeds and pavement conditions for existing road conditions as outlined in Sub-section 3.2.1 of this Appendix were assumed to apply also to the Hume Highway in the general vicinity of Yass with the exception that the average speed of both cars and trucks was assumed to average 50 km/h within the town of Yass. The assumptions in Sub-section 3.2.1 relating to conditions on the new road were assumed to apply also to the Yass bypass.

The traffic composition given in Table A3.5 was adopted, giving the weighted vehicle operation costs and weighted time costs shown in Table A3.6. The composition of cars and trucks is assumed to be independent of destination.

TABLE A3.5 - YASS BYPASS TRAFFIC COMPOSITION [(a)]

Vehicle Type	%
Private Car	50
Business Car	21
2 axle 4 tyre	4
2 axle 6 tyre	5
3 axle	2
4 axle	7
5 axle	11

(a) Source: 1974 CBR survey, and 1976 DMR traffic and classification count.

TABLE A3.6 - YASS BYPASS UNIT COSTS

	Car	Truck
Operating Cost (¢/km)		
- existing 50 kmh average (within Yass)	7.0	33.9
- existing 70 kmh average	7.5	38.3
- new (90 kmh cars 70 kmh trucks)	6.0	29.5
Time Cost ($/hr)	4.51	4.75

Table A3.7 shows the resulting average trip costs on the existing route and the proposed bypass.

TABLE A3.7 - YASS BYPASS TRIP COSTS

Sections (a)	Distance km	Cost in Cents/Vehicle		
		Operating	Time	Total
Existing				
Through Hume Traffic				
Z_2D_3 and C_3C	14.6	239	95	334
D_3C_3	3.3	49	30	79
Total	17.9	288	125	413
Barton Traffic				
Z_2D_3 and C_3Y_2	8.2	134	53	187
D_3C_3	3.3	49	30	79
Total	11.5	183	83	266
Bypass				
Through Hume Traffic, Z_2BC	13.9	178	76	254
Barton Traffic, Z_2BY_2	11.4	146	63	209

(a) See Figure 3.1.

The savings per vehicle resulting from the bypass are thus 159¢ per trip for through traffic on the Hume Highway. These savings, over the evaluation period have a present value of $29,094,000 based on the traffic flow of 3020 vehicles per day and the adopted growth rate of 3% p.a.

The savings per vehicle resulting from the bypass for traffic from the Barton Highway amount to 57c per trip. The corresponding present value of savings over the evaluation period is $6,389,000, based on the traffic flow of 1660 vehicles per day and a growth rate of 4% p.a.

3.4.2 Accident Benefits

The accident rate adopted for the existing Hume Highway was 1.43 accidents per million vehicle-kilometres. For both the Yass bypass and its connection to the Barton Highway it was assumed that access would be fully controlled and that the accident rate would be 0.62 accidents per million vehicle-kilometres.

For the bypass, using the traffic volume estimate of 3020 vehicles per day, the benefits amount to $84,200 in 1976. Allowing for traffic growth at 3% p.a. the present value of accident benefits amounts to approximately $1,398,000.

For the Barton Highway connection to the bypass, using the traffic volume estimate of 1660 vehicles per day and a 4% p.a. growth rate, the present value of accident benefits over the evaluation period is $490,000.

3.4.3 Maintenance Benefits

The cost of maintaining the full length of the relevant section of the existing Hume Highway without the bypass, considering the traffic expected over the evaluation period, was estimated at $58,440 p.a. for routine maintenance, $125,220 every 5 years for resealing, and a provision of $280,500 p.a. to allow for rehabilitation and/or reconstruction works. For the evaluation period the estimated present value of maintaining the existing road without the bypass amounts to $3,544,000.

The cost for the bypass was assumed to comprise $5600/km p.a. for routine maintenance and $83,950/km every 10 years for re-sheeting with asphalt. Assuming construction of the Barton Highway connection, the cost of maintaining the bypassed section of the Hume Highway for the remaining traffic to and from Yass was assessed as \$33,390 p.a. for routine maintenance and \$83,480 every 7 years for reseal with no provision for reconstruction. The present values of the maintenance costs for the bypass and for the bypassed section of the Hume Highway respectively, amount to \$2,510,000 and \$476,000 - giving a total of \$2,986,000.

Thus the maintenance savings are \$3,544,000 less \$2,986,000, i.e. \$558,000. These maintenance savings were apportioned between the Yass bypass and the Barton Highway connection to simplify the analysis, since the results would have changed only marginally by costing the intermediate stage between construction of the bypass and the later construction of the Barton Highway connection. After considering the relative amount of travel which would transfer to the bypass after the addition of the connection to the Barton Highway, it was assessed that about 20% of the bypass maintenance savings should be attributed to construction of the Barton Highway connection. Thus the maintenance savings are approximately \$446,000 and \$112,000 for the bypass and the Barton Highway connection respectively.

The cost of maintaining the Barton Highway connection to the bypass was estimated as \$21,260 p.a. for routine maintenance and \$319,000 per 10 years for resheeting, using the same costs per km as for the bypass. The estimated total present value of these costs over the evaluation period amounts to \$686,000. Allowing for the maintenance savings due to the use of the bypass of \$112,000, the net maintenance cost increase amounts to \$574,000.

3.4.4 Total Benefits

The benefits of constructing the Yass bypass comprise \$29,094,000 for vehicle operation savings, \$1,398,000 for accident savings, and \$446,000 for maintenance savings. The total amounts to \$30,938,000.

The benefits of constructing the Barton Highway connection to the Yass bypass amount to \$6,389,000 for vehicle operation savings plus \$490,000 for accident savings, less \$574,000 for additional maintenance costs, giving net benefits of \$6,305,000.

APPENDIX 4 - VARIATIONS IN THE LEVEL OF LAKE GEORGE

4.1 SCOPE

This Appendix discusses variations in the level of Lake George, and gives an explanation of this variation in terms of the rainfall in the catchment area. It then uses this derived relationship to generate a frequency distribution of the heights which the lake might reach.

4.2 BASIC DATA

Records of the height of Lake George have been maintained (or can be inferred with varying levels of precision) since the early 1800's. However, for the purposes of this study, records commencing in 1858 were selected, (this is just prior to the big increase in lake level in the 1870's). Some uncertainty on datum for lake levels has existed in the past but this has been resolved following work by DMR.

Rainfall records have been maintained at a number of stations surrounding Lake George. For the purposes of this study three stations were selected as being representative of the catchment. These stations are at Collector P.O., Bungendore (Gidleigh) and on the shores of Lake George. Records have not been maintained at any of these stations over the entire period. There are often significant variations between stations in any one year, as well as a steady divergence in measurements. As shown in Table A4.1 between 1892 and 1925 the annual difference between Bungendore and Collector averaged 7.4 cm (σ[1] = 8.1 cm) but between 1942 and 1972 this increased to 12.0 cm (σ = 9.7 cm). It is not known what caused this (significant) divergence but the data is clearly deficient. Evidence from an adjacent station (Gunning) where rainfall during 1892-1925 and 1942-70 averaged 61.7 cm and 71.4 cm respectively suggests that Bungendore is the inconsistent station.

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(1) σ denotes standard deviation.

TABLE A4.1 - RAINFALL AT SELECTED STATIONS

Parameter	Annual Rainfall in cm		
	Lake George	Bungendore	Collector
1892-1925			
Mean	66.5	60.0	67.4
σ	14.1	15.0	16.4
1942-1972			
Mean	-	63.1	75.1
σ	-	19.1	23.1

An average rainfall for the catchment was estimated by averaging all available records. The trends outlined above suggest that from 1940 onwards, this procedure may underestimate by about 5% compared to pre-1940 (i.e. 3 or 4 cm p.a.).

Table A4.2 shows the data base used for this analysis.

4.3 MODEL STRUCTURE

There are five basic features which a model should reflect:

. when rain falls on the lake surface there is 100% yield to the lake;
. forming the bed and also surrounding the lake, there are 290 sq. km. of sediments (including the lake bed) which give a comparatively high yield (say around 50%);
. the remainder of the catchment (650 sq. km) has a lower yield (say about 10%);
. as the lake rises its surface area increases giving rise to three distinct effects:
  - the yield in the area now covered by the lake but previously dry increases (from 50% to 100%. say)
  - the height gain for a given increase in volume decreases; and
  - the total evaporation increases as the surface area is larger;

- lastly, there is the possibility that the lake is affected by the rainfall of previous years that entered the sediments and reached the lake by underground seepage rather than by surface runoff.

If we denote the area of the lake at any given time by A, and its height by H, then the yield Y from the catchment into the lake following rainfall R is given by

$$Y = A \times R + (290-A) \times k_1 \times (R-a_1) + 650 \times k_2 \times (R-a_2) \tag{1}$$

where k_1, k_2 are the proportions of rain on the two parts of the catchment, (above the thresholds a_1, a_2) that runoff as yield to the lake.

In addition there may be seepages through the sediments, giving a total yield of

$$Y^* = Y + S$$

The associated rise in height ΔH is given by

$$\Delta H = Y^*/A$$

However, evaporation E also occurs from the surface of the lake and the net rise in height of the lake is given by

$$\Delta H^* = Y^*/A - E.$$

TABLE A4.2 - WATER LEVELS IN LAKE GEORGE

Year	Height of L. George (a) m	Rainfall in mm.				
		Shore of L. George	Bungendore (Gidleigh)	Collector P.O.	Average of 1, 2, and 3	Average of 2 and 3
1858	0.3	625				
59	0.3	600				
1860	1.7	1015				
61	1.6	590				
62	1.6	415				
63	1.5	765				
64	5.2	800				
65	4.5	300				
66	3.8	625				
67	3.1	795				
68	2.5	400				
69	2.5	740				
1870	5.2	1275				
71	5.9	780				
72	6.4	750				
73	7.0	790				
74	7.2 (b)	670				
75	6.9	635				
76	6.5	590				
77	6.2	625				
78	6.1	695				
79	6.5	850				
1880	5.9	695				
81	5.2	490				
82	4.7	470				
83	4.2	415				
84	3.7	400				
85	3.2	685				
86	2.8	765	614			
87	3.4	1055	894			
88	2.9	610	442			
89	2.5	650	573			
1890	2.5	735	697			
91	3.8	920	1025			

(a) Level recorded in the month of December.
(b) Maximum level recorded in 1874 was about 7.3m above datum.

Year	Height of L. George m	Rainfall in mm.				
		Shore of L. George	Bungendore (Gidleigh)	Collector P.O.	Average of 1, 2 and 3	Average of 2 and 3
1892	3.7	740	786	817	781	802
93	3.7	770	710	951	810	831
94	4.4	940	908	1051	966	980
95	3.6	410	363	435	403	399
96	2.8	615	537	733	628	635
97	2.1	515	523	524	521	524
98	1.3	485	645	548	559	597
99	1.2	645	577	678	633	628
1900	1.9	965	899	973	946	936
01	1.2	645	483	603	577	543
02	0.5	505	319	427	417	373
03	0.3	735	656	739	710	698
04	0.5	525	487	467	493	477
05	0.6	705	494	647	615	571
06	0.5	725	607	707	680	657
07	0.5	480	441	–	–	–
08	0.4	580	531	525	545	528
09	0.3	610	471	566	549	519
1910	0.3	705	544	624	624	584
11	0.2	660	635	588	628	612
12	0.2	595	538	547	560	543
13	0.1	560	562	531	551	547
14	0.2	570	517	574	554	546
15	1.4	685	669	696	683	683
16	2.1	1000	811	932	914	872
17	1.4	845	688	851	795	770
18	0.9	515	426	501	481	464
19	0.9	445	378	436	420	407
1920	1.4	710	658	757	708	708
21	1.7	660	781	807	749	794
22	1.5	675	655	740	690	698
23	0.9	705	511	745	654	628
24	1.8	695	554	700	650	627
25	2.7	790	875	822	829	849
26	1.9	510	456	663	543	560
27	1.4	610	527	591	576	559
28	1.1	610	390	866	622	628
29	0.8	540	541	572	551	557
1930	0.8	560	467	595	541	531
31	0.8	690	739	803	744	771
32	0.7	515	429	545	496	487
33	0.9	465	482	628	525	555

Year	Height of L. George m	Rainfall in mm.				
		Shore of L. George	Bungendore (Gidleigh)	Collector P.O.	Average of 1, 2 and 3	Average of 2 and 3
1934	1.2	845	999	926	923	963
35	1.1	610	621	697	643	659
36	1.0	665	677	598	647	638
37	0.9	595	544	523	554	534
38	0.7	615	456	483	518	470
39	0.4	565	626	–	–	–
1940	0.1	420	636	412	489	524
41	0.0	415	599	647	554	623
42	–		531	769		650
43	–		640	733		687
44	–		265	291		278
45	–		521	593		557
46	–		493	575		534
47	–		564	740		652
48	–		709	774		742
49	0.0		696	862		773
1950	3.0		1049	1137		1093
51	2.9		608	696		652
52	3.8		939	1149		1044
53	3.2		501	620		561
54	2.6		366	506		436
55	2.6		776	919		848
56	4.1		957	1134		1046
57	3.5		406	481		444
58	2.9		550	768		659
59	3.8		937	1111		1024
1960	4.0		834	1014		924
61	4.4		803	–		–
62	4.2		752	794		973
63	4.2		718	721		720
64	4.0		701	839		770
65	3.3		408	462		435
66	2.9		713	660		687
67	2.1		360	381		371
68	1.5		585	798		692
69	1.9		742	1009		876
1970	1.8		732	–		–
71	1.4		564	708		636
72	0.9		408	524		466
73	0.8		737	869		803
74	2.5		1016	1166		1091
75	3.0		857	923		890
76	2.5		698	717		707

4.4 VALIDATION AND CALIBRATION

As an initial step, estimates were made of the relative orders of magnitude of the four components of the yield. The lake normally varies in area from about 50-125 sq. km. and the area of sediments is thus normally between 165 and 240 sq. km; an average 9 sq. km. for the lake and 200 sq. km. for the sediments is assumed for this study.

The runoff thresholds and yields are not known precisely. For the bulk of the catchment, 10% (the average for the Upper Lachlan) is a reasonable estimate of runoff. (i.e. $k_2(60-a_2) = 6$, as the average rainfall is about 60 cm). For a normal river system $k_2 = 1$ and $a_2 = 54$. However, few streams in the Lake George catchment actually reach Lake George itself. Instead they peter out in surrounding marshes and sediments where they suffer large evaporative losses. A more realistic estimate of k_2 in this system could be about .1. Runoff from the surrounding sediments can be expected to be very high, with k_1 close to unity (say .8) but with a_1 depending on the prior wetness or otherwise of the sediments. An average estimate for a_1 is about 20.

A rough calibration of equation (1), from prior data is thus

$$\begin{aligned} Y &= 90 \times R + 200 \times 0.8 \times (R-20) \\ &\quad + 650 \times .1 \times (R-54) \\ &= 90 \times (3.5R-75) \qquad (R>54) \end{aligned}$$

$$\therefore \text{yield/sq. km. lake area} = 3.5\,R-75 \quad (R>54) \qquad (2)$$

Evaporation averages 110 cm annually in the Lake George area. Table A4.3 gives the main elements of net yield to the lake, for annual rainfalls of 40 cm, 60 cm and 80 cm (neglecting underground seepage).

TABLE A4.3 - NET YIELD ESTIMATES

Source	Annual Net Yield in cm per sq. km. of Lake Area		
	Rainfall 40 cm	Rainfall 60 cm	Rainfall 80 cm
Lake	40	60	80
Sediments	36	71	107
Catchment	-	4	19
Evaporation	-110	-110	-110
Net yield	- 34	25	96

No annual records of lake area have been maintained. However, measurement of known lake boundaries showed that height and area are linearly related over the range of interest

A = 23.4 x H (A sq. kms
H metres above bed)

The first relationship examined was that between changes in the lake height level and rainfall in the preceding ten years. This showed

- a very strong influence of the current year's rainfall
- a weak influence of the rainfall of between five and eight years previously
- no other year's rainfall had any influence.

However, the influence of the rainfall of five years previous was not significant statistically, and was also, on a priori grounds, in the wrong direction. The only rainfall included in the remainder of the analysis was that of the current year. (It should also be noted that each year's rainfall is independent of that of previous years).

Annual evaporation data was not available. There is some evidence that evaporation and rainfall are inversely related (E x R = 8200 where E and R are in cm), but in any event it does not vary much outside the range 100-130 cm p.a.

It was therefore assumed to be constant. Various formulations were tried using different combinations of rainfall and height. Many of these were unsatisfactory because of correlations between the independent variables (e.g. those which included both R/H and R). The model finally selected was

$$\underset{(17)}{\Delta H = -172} + \underset{(.24)}{2.84R} - \underset{(.02)}{.08H} \qquad R^2 = .61,\ \sigma = 42 \qquad (3)$$

where all measurements are in cm (Standard errors in brackets).

This may be compared with that deduced on a priori grounds above

$$\Delta H = 3.5R - 185$$

The average height of the lake is 257 cm and so (3) then reduces to

$$\Delta H = -192 + 2.84\,R$$

Comparison with equation (2) suggests a lower runoff from the sediments (say 0.5) together with a rather higher threshold (say 40 cm). However, these interpretations can only be tentative because of the poor quality of the base data and the coarseness of the analysis.

The height term in (3) encompasses the various effects of height - declining height gain/volume gain, greater evaporative loss, increasing efficiency of catchment as the lake size increases.

The expression given in (3) has a standard error of 42 cm. (i.e. 95% of estimated changes are within 80 cm of the actual change).

4.5 FORECASTING THE HEIGHT OF THE LAKE

The relationship (3) forms the basis of a procedure for simulating the height of the lake. Rainfall in the catchment is generated to the same pattern as that observed historically. The effect on the height of the lake is estimated using (3) and the distribution of lake heights over a period recorded.

Table A4.4 gives the results of the simulation of 100 100-year periods, starting from an assumed lake height of 4.5 metres. Table A4.5 gives the distribution of peak heights for the 100 simulations.

TABLE A4.4 - RESULTS OF SIMULATIONS

Height (m)	No. of Years Lake is Above Height
6	520
7	202
8	60
9	25
10	9
11	1

TABLE A4.5 - FREQUENCY OF PEAK HEIGHT

Peak Height (m)	Frequency of Occurrence
4	.06
5	.27
6	.30
7	.23
8	.10
9	.02
10	.01
11	.01