HUMPHREY RIVULET, GLENORCHY

Proposal for an open space system

Malcolm Clark, M.I.E. Aust., M.R.A.P.I.
Jim Russell, B.A. (Psych. Hons.), Dip.Ed.

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U S E   O F   T H E S E S

The traffic routes sweep along impersonally but the tenacious and light-hearted pedestrian network creates the human town. Sometimes brash and extrovert, it may synchronize with the great traffic routes or with shops and offices, at other times it may be withdrawn and leafy; but it must be a connected whole.

Gordon Cullen, 1961

As far as possible, the environment planned for working, trading, circulating, and dwelling should be recreational as well as utilitarian. To be effective, recreation has to be found casually in the factory at the hour of rest, on the way home, and at home.

Artur Glikson, 1971

The role of landscape within the town is ... to contribute to the happiness of urban life.

Sylvia Crowe, 1956.

CONTENTS

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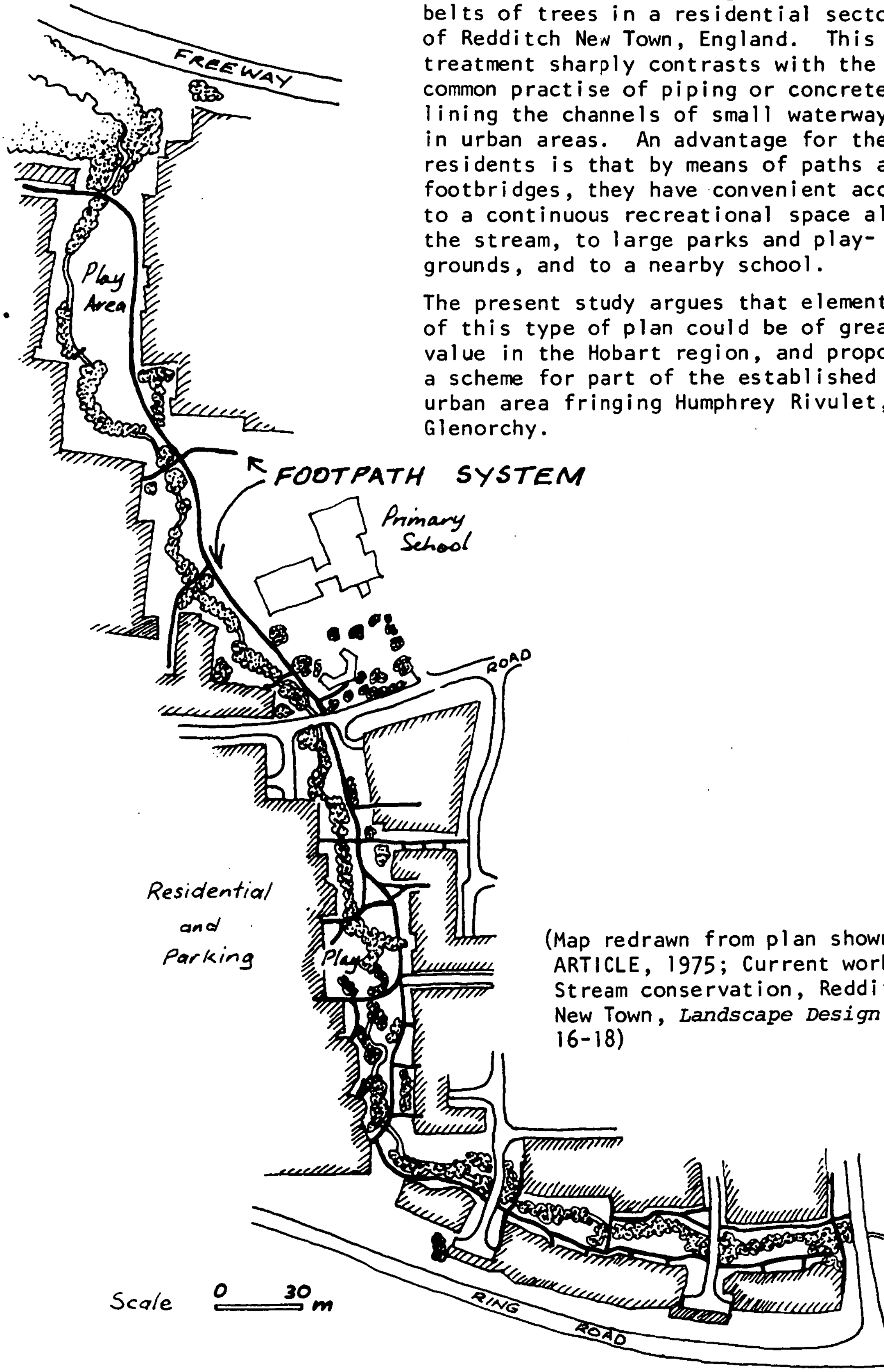
INTRODUCTION

Map 1 A local open space system which illustrates some of the concepts discussed in the following pages. It is based on an existing stream and belts of trees in a residential sector of Redditch New Town, England. This treatment sharply contrasts with the common practise of piping or concrete lining the channels of small waterways in urban areas. An advantage for the residents is that by means of paths and footbridges, they have convenient access to a continuous recreational space along the stream, to large parks and playgrounds, and to a nearby school.

The present study argues that elements of this type of plan could be of great value in the Hobart region, and proposes a scheme for part of the established urban area fringing Humphrey Rivulet, Glenorchy.



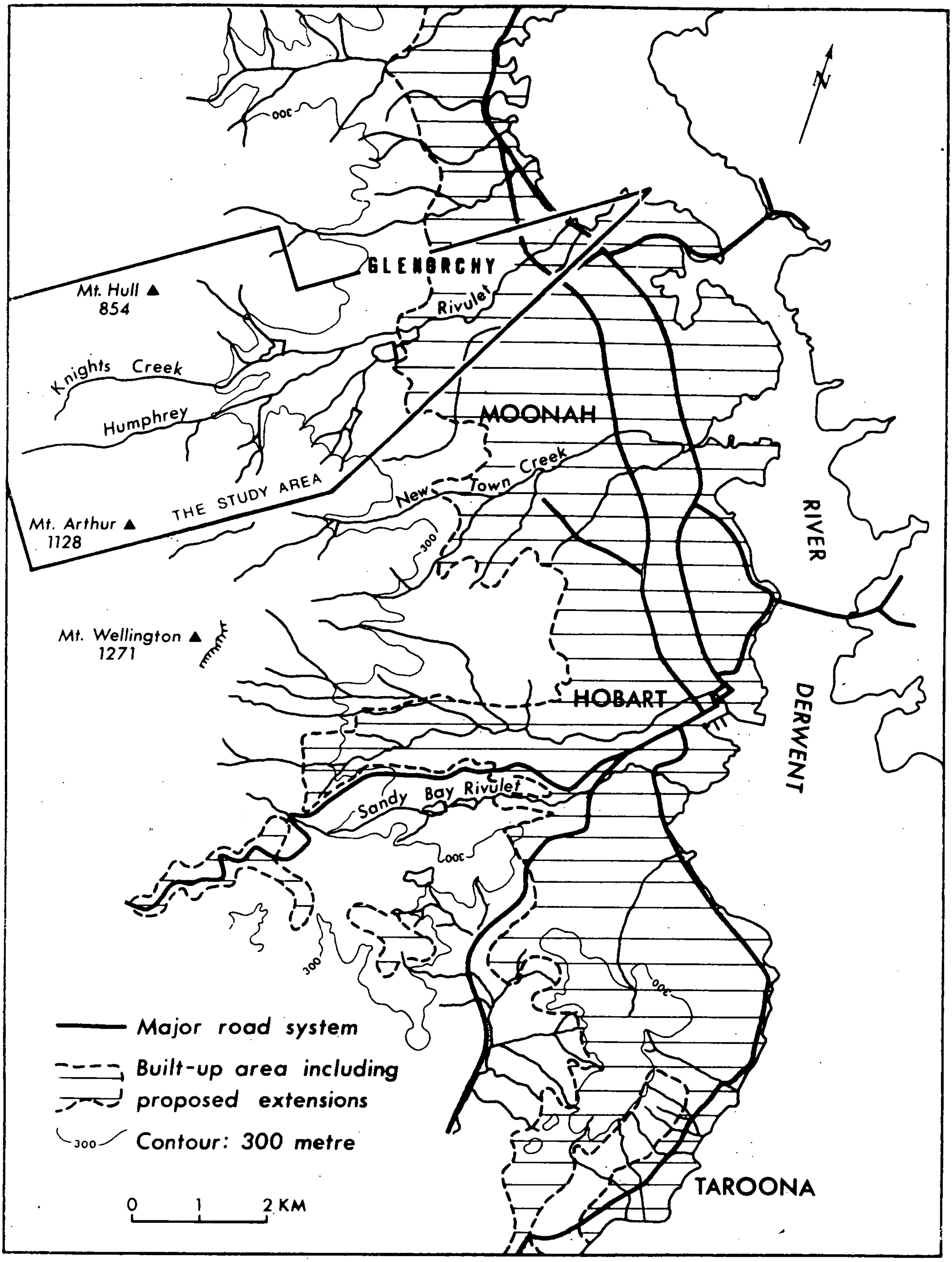
(Map redrawn from plan shown in: ARTICLE, 1975; Current work: 1, Stream conservation, Redditch New Town, *Landscape Design* 111, 16-18)

PRINCIPLES

The intention underlying this report is to explore ways of gaining improved benefits for the community from the physical environment of the Hobart region, especially through use of elements of the natural landscape which form the setting of the urban area. In particular, we are interested in the application of plans for public open space systems, which are of proven value in many other cities. It does not necessarily follow that such plans are suited to Tasmanian conditions, but we believe there is much to learn from observation of practice elsewhere, together with a critical evaluation of local urban environments.

Stockholm offers a good example of the implementation of open space system concepts[1]. Footpaths, cycle ways and motor drives have been linked with playgrounds and parks of all kinds to establish a city wide network of interconnected public spaces. The particular application of the concept in Stockholm also demonstrates that urbanization may co-exist with a natural environment, rather than displace it to the extent that has been usual with many of Hobart's development projects. Much careful use has been made of Stockholm's existing waterways, islands, rugged land and vegetation as part of the system. An additional lesson which may be of value to other cities is that the success and comprehensiveness of the scheme has been largely attributed to a policy of "always building within a landscape rather than creating a landscape around the buildings when they are erected."[2]

The potential gains from open space systems are many. It is now widely recognized, for instance, that trees and larger varieties of shrubs can contribute significantly to control of atmospheric pollution and noise in cities, and can moderate climatic conditions. These results occur to a greater extent if vegetated strips of land wind more or less continuously throughout an urban region than if confined

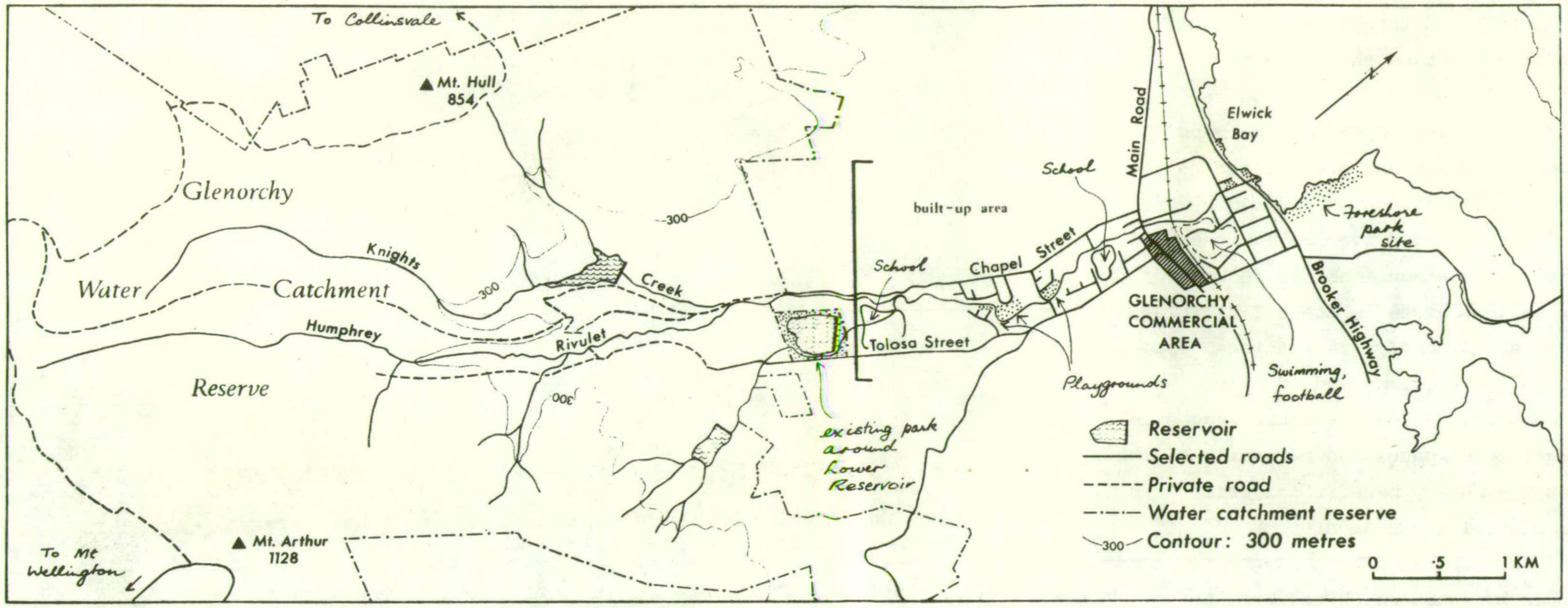


Map 2 The regional setting of Humphrey Rivulet, Glenorchy, selected as the study area for this report in order to investigate the feasibility of instituting a local public open space system in an established urban area.

to discrete plots. As a source of variety and interest in the built environment, such a system can also help to widen the range of experience of city dwellers, especially if based on topographical elements such as streams or land with rocky outcrops. But perhaps the most important advantages of open space systems are related to access for residents to urban amenities. If footpaths and cycle ways are threaded through residential areas and lead conveniently to schools, shops and larger recreational spaces, two consequences may follow. Within a small locality, people can walk or cycle to these facilities, free from worries about traffic dangers. Secondly, recreational opportunities as a normal function of daily life are improved, not only because the path system itself can be a recreational resource accessible to many homes, but also because larger open spaces can be easily reached if placed at useful intervals. A supplementary benefit for parents is that there may be less need to make special arrangements for younger children to reach playing facilities than where parks, playgrounds, and sports fields are separated from homes by roads which are busy and dangerous. As well as serving such functions in each locality, a city wide system of walkways allows more extended journeys. In Stockholm, for example, the open space system interconnects the city centre, the suburbs, and nearby country walks.

APPLYING OPEN SPACE SYSTEM CONCEPTS : HUMPHREY RIVULET

To establish this type of facility throughout the Hobart region may appear impractical, as the structure of its established urban areas, including parks, is already laid down. It could also be argued that lack of demand may not warrant the effort and expense. On the other hand, since awareness of possibilities for urban improvement often seems to be conditioned by existing opportunity, an apparent lack of demand does not necessarily imply that changes should not be considered. In any case, we believe that the existing city structure fails to respond to many genuine needs. In support of this contention, and to show the potential for introducing to a small locality an open space system which could be part of a larger network, we have undertaken a study of Humphrey Rivulet and its immediate environs, within the City of Glenorchy. By selecting a stream valley we have also investigated the feasibility of basing a pedestrian and recreational facility on a topographical element of interest and beauty, although degraded in many ways by pressures accompanying development since European settlement in 1809.



Map 3 Humphrey Rivulet and its immediate environs. Footpaths and cycling tracks along the Rivulet in the urban area could provide access from many homes to existing public open spaces, schools, a regional shopping centre, and industrial premises. Private unsealed roads (for City Council access and for fire fighting purposes) within the Water Catchment Reserve could extend the system for the more energetic into mountainous country adjoining Hobart's Mount Wellington Park.

Plate 1 Part of Tolosa St. Reservoir Park, with the Water Catchment Reserve in the background. The far edge of the grassed area marks the limits of public access to the upper valley. Humphrey Rivulet's source is at the head of the valley at the top left.

Plate 2 The Rivulet mouth (foreground) in Elwick Bay, River Derwent. The long low peninsula is the site of a new foreshore park, but Glenorchy people living nearby cannot get to the park without crossing the 4-lane Brooker Highway, a priority route for through traffic. A well sited overpass or underpass seems the only way of ameliorating this problem.

The Rivulet is one of the numerous streams which originate in mountainous country fringing the western suburbs of the Hobart region. Many of the Rivulet's characteristics favour the proposition that it could be a segment of a larger open space system, as well as a system of great local value. Glenorchy could be linked to its rugged mountain hinterland by means of walking tracks through Humphrey Rivulet's upper valley, which is reserved for water catchment purposes by the Glenorchy City Council. The land is mainly covered with largely unaltered forest, save for three reservoirs which store water from the Rivulet and its tributaries for urban use. The Water Catchment Reserve adjoins Hobart's large Mt. Wellington Park, and is already linked to it by means of fire trails. Bushwalkers use these, entering the Water Catchment Reserve via the road from Hobart to the summit of Mt. Wellington, although it is doubtful whether many would continue through to Glenorchy. Public access to the reserve at the Glenorchy end is not permitted, however, except to parkland around the Lower, or Tolosa Street, Reservoir. Heavy use of this area, which offers good play and picnic facilities largely in keeping with the bushland of the valley upstream, amply demonstrates a demand for large open spaces near the city. The Tolosa Street Reservoir Park is very good; we think it could be even better if it was linked to nearby residential areas not only by road, but by a pathway along the Rivulet and possibly a footbridge or two.

After leaving the reserve, Humphrey Rivulet flows through the expanding suburb of Merton, passes close by Glenorchy's commercial centre and quickly joins the River Derwent at Elwick Bay. Land adjacent to the estuary of the Rivulet and to the Derwent is currently being developed as a foreshore park. A path to central Glenorchy along the Rivulet could add to the value of this area. Such a link is problematical, as the four lane Brooker Highway separates the foreshore from nearby housing. The highway is dangerous for pedestrians, and already limits the park's usefulness to local residents.

The main concern of this report, however, is the urban section of the Rivulet between the Reservoir Park and the Brooker Highway, where it might be possible to construct pathways passing by many homes to connect with shops, industrial premises, several playgrounds, two schools, and a large swimming and sports complex. Another opportunity

Plate 3 View to the east over the mixed residential, commercial, and industrial area of central Glenorchy. Elwick Bay on the Derwent is to the left of the centre of the picture, and Humphrey Rivulet's mouth is marked approximately by the clumps of large trees on the near shore of the bay.

Plate 4 Within the urban area the Rivulet channel remains unpaved (save for one length of concrete retaining wall, built after flooding in 1960 to prevent further undermining of a street and two homes off Main Road). At many points the stream appears visually continuous with the landscape of its mountain hinterland, offering variety in the built environment. Access and views are closed off, however, by back fences, while rubbish is a common sight in the channel and along banks.

for pedestrian planning arises because the Council envisages placing a ring road around the congested business centre and expanding shopping and parking facilities. The Derwent Regional Library is also to be constructed within the area in the near future. It would be a great asset to shoppers if the centre was designed as a pedestrian precinct, with direct footpath and cycle routes which avoided busy roads through to suburban streets, at least via the Rivulet if they could not be built in other directions as well. The Rivulet itself could be a superb edge along the northern side of the centre. If land near the banks was treated sensitively shoppers and local workers could enjoy a place to rest or simply sit and watch nearby activities, for instance.

In the past, the urban reaches of the Rivulet contributed much to the livelihood of the residents as a source of water and motive power. Today, in common with other streams throughout the Hobart region, and indeed, with those in many urban areas throughout the world, its economic significance is very limited. The Rivulet is an open drain, discharging city wastes which consist of runoff after rain from roofs, streets and gardens, and some effluent from industrial premises.

PROBLEMS

Except for its usefulness as a drain, the Rivulet is a thorough nuisance and a problem to the community. Many factors which commonly arise from urbanization perpetuate an unfortunate situation. The contribution the Rivulet makes to waste disposal, for instance, has a less attractive side. Parts of the channel are often littered with rubbish and effluent washed from streets and gutters. Four playgrounds adjoin the stream, but some parents are uneasy about allowing their children near the water. They say it is dirty and "stagnant", fearing it may lead to infection. Negative attitudes towards the Rivulet are bolstered further because land suitable for development close to the Glenorchy business district is scarce and in great demand. Houses and factories press close to the stream banks, closing off views and denying access. The community also incurs extra costs because roads servicing the area or carrying through traffic cannot cross the Rivulet unless expensive bridges are built.

Additional continuing problems are those of periodic flooding and associated economic and social costs, although these have been substantially lessened by the capacity of the reservoirs to retain water in the upper catchment. Difficulties arising from flooding could be expected to worsen rather than improve in the future, however, if development in the urban area adds more runoff at high velocity from paved areas such as roofs, gutters and stormwater drains. When high flows occur, the fast disposal of water through to the Derwent is dependent on interactions between many factors. A critical combination of variables hinges on the maintenance of a sufficiently large channel free from obstructions. Staff of the Glenorchy City Council are well aware of this. Their vigilance, however, is impeded because the Rivulet is hidden away behind buildings, and their efforts to clear fallen trees or accumulated rubbish and boulders are hindered by access difficulties. Limited access also increases the danger from summer fires which have started in clumps of dense grass and weeds lining the banks. The Rivulet thus remains a source of annoyance and expense.

POSSIBLE SOLUTIONS : FOUR OPTIONS

Several options which represent different approaches to solutions and imply various consequences appear to be available. These options are :

1. To be content with existing circumstances, undertaking periodic removal of obstructions to flow;
2. To attempt control of flooding by sectional channel improvement works, such as the use of concrete and/or stone paving in the vicinity of flood-prone land so that water rapidly escapes downstream, or construction of a concrete invert;
3. To attempt control of the entire channel within the urban area by more extensive works, such as piping below ground level and/or paving of bed and banks;
4. To begin a long term programme designed to achieve : (a) flood control, by means of minimal works to the Rivulet Channel and measures to limit expected increases in runoff from the urban catchment, and (b) an open space system which connects homes with parks and the other urban facilities.

Each option has its own merits and costs. The studies which form the bulk of this report examine the practicability of the fourth. Although its acceptance by the Council would imply physical changes in the vicinity of the Rivulet and some public expense, we feel it is the best alternative of those listed *and the least costly in the long run*.

With regard to work on the Rivulet channel, option 4 compares more than favourably with the alternative of continuing as at present because it gives a greater guarantee of flood protection. The paths could open the Rivulet to regular, efficient inspection and at the same time decrease maintenance costs overall because of improved access for Council staff and equipment.

It should also be emphasized that to let the current situation persist will almost certainly mean that channel improvements on a larger scale, as in option 2, and eventually to much of the channel within the urban area, as in option 3, will be necessary. This result is expected on the assumption that urban expansion and redevelopment in the catchment will increase runoff and overtax the Rivulet's capacity to deal with flood flows. Similar problems resulted in an outlay of £300,000 for channel modifications to Hobart Rivulet after severe inner city flood damage in 1960. Apart from this outcome, an additional factor to take into account in relation to the second option is that speeding the flow through one section of the Rivulet by channel alterations may result in increased damage downstream.

Our studies indicate that wise investment on a small scale in the near future will save ratepayers very large sums, probably millions of dollars, at a later date by circumventing the need for extensive channel works. Works necessary for the favoured option might include stabilization of some banks where high flows threaten property, and the repair of small sections of old flood retaining walls, built in 1858. The control of increases to future runoff necessary for the long term viability of these measures will require some planning and construction techniques for urban development which are practised elsewhere. Some of these are outlined in a section of the first chapter of this report (p. 25 ff.).

A further great advantage of the fourth option is the opportunity to retain the landscape qualities of Humphrey Rivulet in a way which gains better access to facilities and a valuable recreational facility for the residents. The benefits from this sort of asset cannot be measured in dollars.

Opening routes along or across the Rivulet and landscaping should be subject to a least cost, minimal interference policy. Limited land acquisitions for paths may require extra finance, but the possibility of some routes exists already where the Council has right of access to a narrow maintenance easement along the banks. Other opportunities for strips of land should arise with subdivision. Residents might also consider surrendering a small portion of their land to public ownership in return for flood protection and regular waterway maintenance, provided they know the Council's intentions and can see the advantages of change.

A low capital cost policy could avoid conflict arising from a programme of works and landscaping which the residents might not want; it could also avoid the risk of disrupting established patterns of usage along the Rivulet. Many children enjoy the stream as it is, and extensively use some areas which adults would normally describe as derelict and polluted. It would be a great loss if any plan was introduced in a way which denied children of the area the secret, wild places they seem to appreciate so much.

The best course of action from many points of view would seem to be based on a policy of preserving existing amenity values, the addition of low cost amenities where there is a need, and the removal of threats to public health and dangers from flooding. It is difficult to see that such a programme will be satisfactory unless residents to be affected by change review and modify suggested plans. Even better results could be expected if attempts were made to arouse local interest at an early stage. Residents, schools, and social groups might want to become involved in the formulation and implementation of plans.

CONTENTS OF THE STUDY

The chapters which follow give a more detailed analysis of the social, economic, and environmental issues already raised, and include the results from field work and a household survey in the vicinity of the Rivulet.

The first chapter is a review of literature indicating how cities and towns elsewhere are attempting to improve access for city dwellers to facilities of different kinds, recreational opportunities, and the quality of the urban landscape. A final section within the chapter discusses principles of effective urban creek management. Next, in Chapter 2, we describe the population and physical characteristics of the study area, interpreting the locality as a land unit which man has settled and changed since 1809. The various pressures which accompanied change help in understanding how the Rivulet has come to be in a degraded condition. The district has a rich and interesting history. A considerable number of old buildings remain, already adding to the visual appeal and interest to the area. If some could be incorporated usefully in an open space system, their value to the community might be enhanced.

In Chapter 3, there is a closer look at physical factors affecting the Rivulet, especially those affecting its susceptibility to flooding, and the constraints they place on future management. Some of the needs and opinions of the residents, insofar as we have been able to gauge them from short interview in their homes, are presented in Chapter 4. Finally, after relating the findings of all our studies to the options previously listed, we give a broad outline plan for an open space system, together with recommendations for its gradual implementation.

The plan is intended for consideration by the residents and the Glenorchy City Council. The choice as to what should be done, if anything, belongs to them. Our own viewpoint has already been stated and will become clearer in the following pages.

We also hope that this report will help stimulate interest in other rivulets and creeks throughout the Hobart region, as well as in the resources of its wider landscape.

1. CHADWICK, G.F., 1966; *The Park and the Town*, pp. 308-11,373; The Architectural Press, London.
2. *Ibid.*, p. 284.

CITY ENVIRONMENTS

CHAPTER ONE

CITY ENVIRONMENTS

The primary purpose of this chapter, which draws on selected literature related to theory and practice in urban planning, is to show how open space systems can improve conditions for people in cities. In taking the point of view that the physical structure or layout of cities is a significant determinant of the satisfaction of their residents, it must be acknowledged that there is a danger of ignoring many social and economic factors which may be more fundamental to judgements by individuals and groups of the priorities most important to them[1]. For this reason, this chapter, and indeed the report as a whole, is intended to bring forward ideas for discussion and consideration, particularly by the people who stand to be most affected by any changes to the physical environment of Humphrey Rivulet, rather than prescribe what should or should not be done.

Since the report is a particular application of open space system concepts, i.e., to an urban stream, the chapter's third section is devoted to principles of catchment management in an urban context, as proposed in recent literature. This discussion may provide starting points for further investigation of techniques which could be adopted in Glenorchy, if it is accepted that limitations to the volume of runoff to the Rivulet from the urban area is a desirable and feasible aim.

CITY LAYOUT AND ACCESS TO FACILITIES

> *Present day urban milieux ... are unfit for human life. The Housing Foundation will exert every effort to make Tapiola Garden City into a housing district protecting man, his home, life, rest and recreation. A good and safe environment must be provided for children to grow up in.... Traffic may not dominate here.*[2]

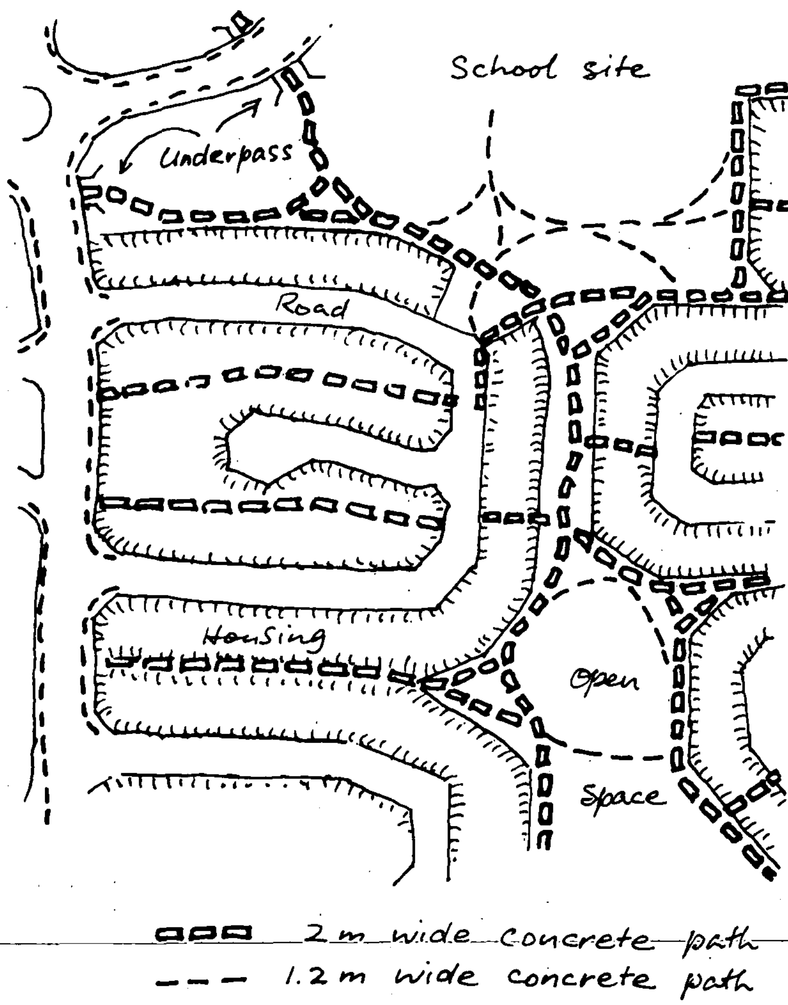
This quotation, from a leaflet distributed to prospective home buyers in the new town of Tapiola, Finland, reflects the concern of many people involved in urban design about how well existing town environments cater for their residents and how improvements might be made. The car, in particular, is the focus of much attention. Its use has become so widespread that road systems are powerful determinants of many city layouts, connecting every home to all parts of the city, and beyond to other towns and the countryside. The advantages, notably in terms of personal mobility, have proved very great, but significant problems have emerged as well.

Conflicts arise, for instance, because the road system is multifunctional. An example common in Australian cities, including Glenorchy, is the predominantly residential street which not only provides access for its residents, but is also a through route for cars on longer journeys and for heavy vehicles. Residents have to suffer noise and exhaust fumes; parents must be constantly watchful to ensure that young children do not cross the road or run on to it in front of relatively fast traffic while playing. This sort of situation can also result in restrictions on freedom of movement, independence, and activities for both adults and children, since parents may have to allocate time to accompany children to and from school, playgrounds, and friends' homes. All people moving about in urban areas commonly experience difficulties where the path system is built alongside roads and is discontinuous, so that the pedestrian must give way to vehicles at intersections, except where special provision is made in the form of zebra crossings or traffic control lights. An Australian author, Hugh Stretton, is amongst those in recent years who have been critical of conventional suburban layouts for these reasons. He pointed out that, whereas design of residential areas is largely determined by the road system for the benefit of commuters, the people most affected are the larger number of women, children, and the aged who spend most of the working day within the suburb[3].

Many plans designed to make urban areas safer and more convenient for pedestrians, cyclists, and children have been implemented in various cities throughout the world. These range all the way from partial solutions such as cul-de-sac street arrangements, which exclude through traffic[4], to suburban and town-wide path and bicycle-track systems independent of most of the road network. Pedestrian precincts in shopping centres (malls) are now common[5]. In some cases, as at Cumbernauld, Scotland, they operate in conjunction with paths connected to the town centre. Similar principles are being followed in the construction of the new centre of Tuggeranong, Australian Capital Territory, where "major movement" throughout the urban area is planned by use of networks of trails for pedestrians, cyclists, and horse riders[6]. Within the Hobart region, the Tasmanian Government Housing Department's developments are provided with a system of paths which is largely off-street, while at least one private developer is building a sub-division with elements of this concept included (Maps 4, 5 over page). It is probably too early to evaluate the Housing Department's work[7], although apparently there has been resistance in some estates from householders who feared that their privacy was threatened. This eventuated because the main living areas in their homes, orientated inwards towards parts of the path system, faced similar houses across a narrow expanse of public land reserved for paths. In any case, resident satisfaction with internal access in centres such as Rokeby might be difficult to assess, as the urgent problems there seem to be a lack of elements of community infrastructure and poor transport arrangements beyond the area for residents without continual access to a car.

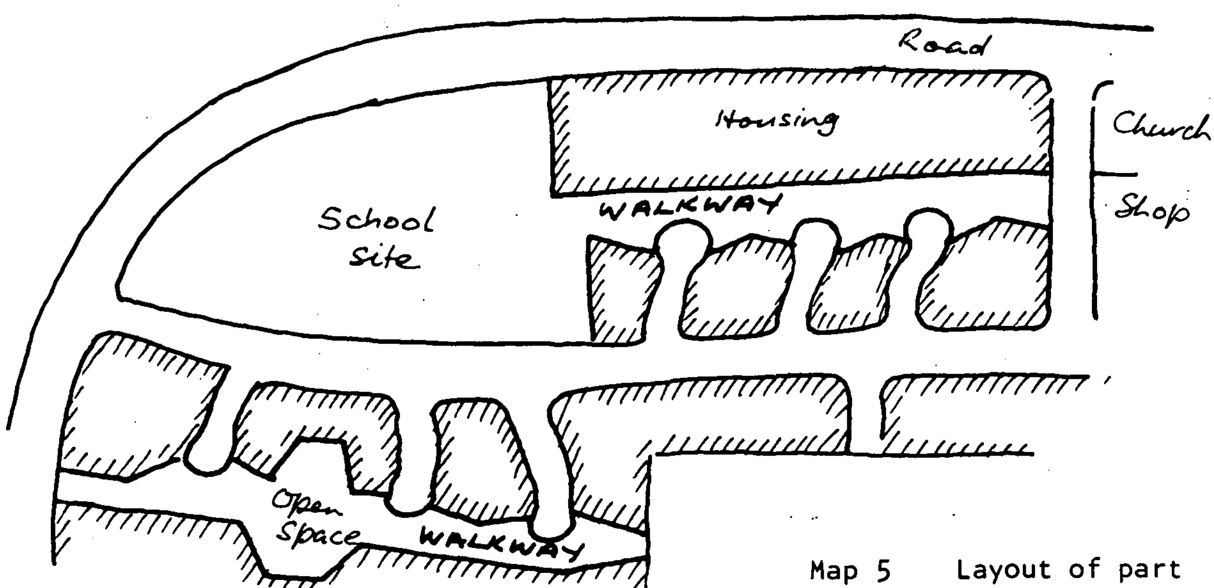
Path, Cumbernauld

Bikeways are currently receiving attention in many countries, including Australia, where systems are either being constructed or reinstated in Melbourne, Canberra, and Adelaide and the sale of bicycles is increasing dramatically[8]. Parts of the Hobart region are hilly and unsuitable for bicycles; much of Glenorchy, on the other hand, is particularly suitable. A retailer in Moonah, within the City of Glenorchy, reports a 300 per cent increase in bicycle sales in the last year compared with sales about five years ago, and these are mainly for adult use[9]. Yet there are no facilities for these riders in the Hobart region; they must compete unfavourably with faster traffic. Ample literature is available on principles of design for bikeways both in new and existing urban areas[10]. It can be expected that bicycles and other small, slow vehicles will be an increasingly important means of access in cities as the costs of motoring rise.



Map 4 Plan for a sub-division built by the Housing Dept. of Tasmania. Children from many homes can reach school and a substantial play area without crossing busy roads. Underpasses carry the path system beneath roads where the traffic is expected to be heaviest.

(Redrawn from plan supplied by Housing Department, Derwent Park)



Map 5 Layout of part of a private residential development in the Hobart region. In this case paths connect the closed ends of cul-de-sacs, and can be lit at night by street lamps at the end of each cul-de-sac. (Redrawn from plan supplied by Jennings Industries Ltd)

Some of the benefits which can arise from positive planning for alternative modes of movement to motor vehicles in urban areas have been outlined previously (Introduction, pp. 1, 2). Others, attaching particularly to more or less separate open space systems, include a closer integration between many utilitarian and leisure activities, allowing some purposeful events of the daily routine like shopping and school journeys to have connotations of pleasure, interest, breathing space and rest (for adults and children), and playfulness (for children particularly) when moving through the built environment. Further advantages more specific to recreational opportunities and landscape values are treated in following pages. Increased safety from the danger of road accidents should be emphasized. During the 1960's, deaths and serious injuries amongst pedestrians and cyclists increased greatly in both Britain and the United States, and "the likelihood of a child between the ages of ten and fourteen being killed or maimed doubled"[11]. By contrast, Clarence Stein, co-planner of Radburn, New Jersey (1928-29), which included a footpath system within an open space layout, wrote that in the suburb's first twenty years, two road deaths were recorded : an incidence well below that in most other conventionally designed housing estates in North America[12]. With regard to social values, Paul Ritter carried out research in Britain comparing Radburn-type developments with others. One conclusion was that roads discouraged social contact within residential areas, but "where walking becomes more frequent ... friendships start more frequently and loneliness is likely to be a rarer event"[13]. The same author also gave a summary, backed by evidence from independent research, of the positive relationships between walking and good health[14].

In conclusion to this section, two points are made. Firstly, to plan comprehensively for improved pedestrian access between homes and urban facilities is subject to fewer constraints and should be less costly if incorporated into the initial stages of development, but there are many opportunities in established areas as well. We maintain that Humphrey Rivulet is a case in point, and could be developed as an open space "corridor" which has as one of its main functions convenient access routes within central Glenorchy and Merton. To implement the system, however, is merely a start since it would assist a limited number of households. Other opportunities to widen the range of the system or to begin fresh systems undoubtedly exist as well, but better access for many more people would be best served if opportunities were sought whenever alterations are made to the existing city structure, e.g., plans for re-routing traffic to relieve congestion, re-zoning, building of shopping facilities. In short, we are arguing that the principles under discussion related to urban access ought to be a normal input to all planning throughout the Hobart region.

Secondly, the application of such concepts should be carefully researched in the local context before plans are finalized. Planners themselves disagree over the best ways of coping with the conflicts between man and motor[15]. Schemes must meet needs realistically : any form of open space system for instance, runs the risk of being a desert bereft of people if it does not relate to established or emerging patterns of behaviour.

RECREATIONAL OPPORTUNITY AND LANDSCAPE QUALITY

> *It is precisely the specialization of functions which upsets the equilibrium of man in the modern city... Planning for recreation should be enlarged from compensatory or defensive zoning to planning for comprehensive purposes of higher environmental quality everywhere...a landscape should be useful and beautiful at the same time...*[16]

The amount of literature related to recreational needs in urban areas, assessment of demand, and supply of facilities is vast. In this section only a few key issues relevant to public open space needs in the context of the aims of this report are discussed.

Recreation is not an experience which can be classified as exclusive of other activities. It is distributed across complex patterns of behaviour which include "the interdependent realms of active recreation, creative and educational interests, informal socializing, and diversionary activities"[17]. These pastimes involve not only formal public facilities like parks, sportsfields, and libraries, but the commercial leisure environment, the informal setting of the streets, the open spaces of the townscape and its region, and the home. It follows that city layouts should not adhere to a rigid dualism between places for recreational and utilitarian functions. The whole townscape would best suit its resident 's needs if it was both recreational and utilitarian at once.

A system of linked open spaces, some primarly for outdoor leisure activities and others combining essentially utilitarian functions such as shopping with casual relaxation and play would seem to fit this concept very well. Some cities in Germany such as Stuttgart evolved a tradition of linked open spaces during the nineteenth century and have continued the policy into the present century[18]. Many other examples of such systems in various parts of the world could be cited, while the towns named in the previous section, in connection with access to urban facilities in general, also demonstrate some of the concepts involved.*

Access to recreational resources is also improved by linkages between open spaces, whereas in many cities people have experienced the situation where they are forced to drive to a nearby park because a freeway cuts residential areas off from the parkland. The need for recreational areas within convenient, safe walking distance of homes always exists at least for children, the aged, and those without cars. Moreover, larger numbers of people may place heavier demands on local facilities as motoring becomes more expensive. It seems that this trend has been evident in the United States for some years[19]. A British Study acknowledged that "at the city scale of development it is essential to achieve a continuity of readily accessible open spaces and recreational areas"[20]. That report's schematic representation of such an arrangement is shown below (Figure 1). This approach effectively creates an open space system with linear connections between larger nodes of parkland, thus providing access for many more people than when parks are encircled by roads. Advocates for a reserve along streams of Melbourne's Koonung-Mullum valleys, which was planned to incorporate areas catering for a diversity of interests at different points, claimed that 1000,000 people could live within walking distance of the park system; three times more than with a square, centralized facility[21].

* For additional examples and further discussion, see: RUSSELL, J.A, 1976; *The Function of Parks and Open Spaces in the City: a Literature Survey and an Application to a Project in the Hobart Region;* unpublished Working Paper, Environmental Studies, University of Tasmania.

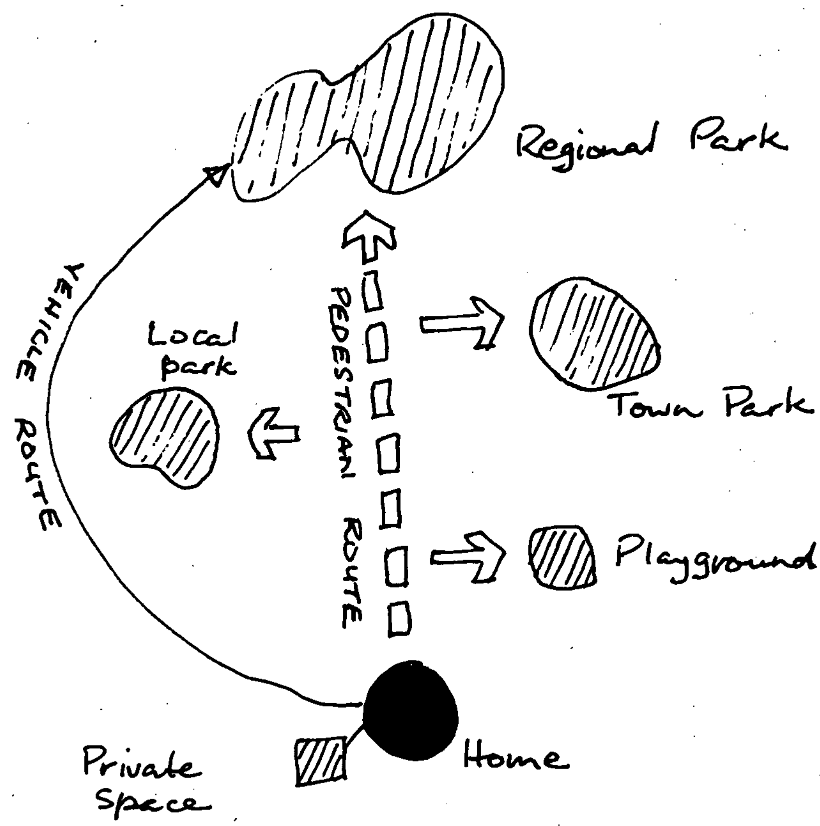


Figure I   A sequence of linked recreational spaces for a city. The aim is to improve accessibility.
(Redrawn from: MINISTRY OF HOUSING AND LOCAL GOVERNMENT, 1967; *Central Lancashire: study for a City,* p. 65; H.M.S.O., London)

The quality of open spaces is also important, as people are generally not attracted by featureless open areas. On land which has already been cleared, and perhaps cut and filled, the only solution is good design to create interesting spaces of varying types according to function, but this requires finance as well as expertise. It would seem better to retain natural topographical features in the first place. In a study of non-use of playgrounds in the United States, Whyte[22] found that where natural areas were retained in housing developments, children used them intensively.

Such strips of land have effects on people's perception of the city. Responding to a survey, residents who never used the pedestrian system in Hughes, Canberra, either by choice or because they lived too far away from it, nevertheless said that suburbs with green spaces running through them "looked or felt good"[23]. If natural features like creeks, ridge tops, belts of indigenous vegetation, and rocky outcrops can be kept, the built environment may take on a unique identity or imageability, contributing to a strong "sense of place"[24] in the minds of its people. The likelihood of this occurring is enhanced if treatment is carried through consistently, to the point where man-made elements fit into the landscape rather than subdue it.

The topographical elements of the Hobart region are ideal for application of these principles, especially the many small creeks and rivulets which flow through built-up areas to the Derwent (Map 2, p.4). Yet little use has been made of them, and the qualities of all too many are being lost as a result of piping or concrete channelization as sub-division occurs. There are exceptions,including some within the City of Glenorchy,where sections of a few streams are being treated as a focus of interest in reserve areas. Most current development plans for land which includes a small watercourse, however, appear to assume the need for piping at the outset. Techniques in operation in other cities, as explained in the following pages, show that this result can be avoided.

URBAN CATCHMENT MANAGEMENT

The circumstances which lead to neglect of streams and often to major engineering modifications are common to many urbanized catchments throughout the world. A large number of interacting factors contribute.

Plate 5 A relatively rare instance of use of a stream for landscape effect in the Hobart region. In this case a grassed verge and trees around New Town Creek provide a scenic edge along section of Lenah Valley Road.

Plate 6 Part of Barossa Creek, Glenorchy, within a tract of public open space. The landscape value of the water-course has been lost as a result of piping, undertaken to overcome flooding of the urban area.

Those operative up to the present in the case of Humphrey Rivulet are discussed in the historical segment of the next chapter (p. 53ff.), while this section deals with some of the main factors involved as well as preventative measures available.

All streams are susceptible to flooding, but urbanization of catchments usually results in floods of increasing frequency and severity. A study of 33 catchments in the Houston Metropolitan area of the United States, for instance, showed that in a catchment with 35 per cent impervious surface (arising from building and paving, such as roadworks), the magnitude of a two-year flood rose by a factor of nine, and that of a fifty-year flood by five, as compared with pre-urban conditions[25]. Another U.S. report identifies three important factors contributing to this type of effect:

> 1. *Impervious areas increase the natural rate of surface runoff;*
> 2. *Gutters and stormwater drains carry flows at much higher velocities than natural watercourses;*
> 3. *Natural stream channel capacities can be reduced by flood plain development, enclosure of flow in stormwater drains, and aggradation of the channels by increased sediment from the construction phase of urban development.*[26]

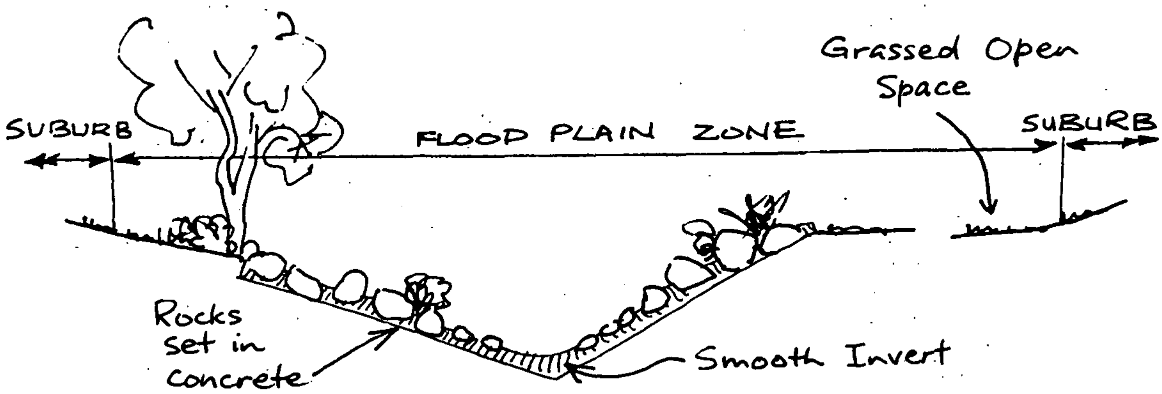
Plate 7 Clearing of land at the edge of a stream and location of a stormwater outlet on the bank, resulting in increased sedimentation in the stream and consequent reduction of channel capacity for flood containment. The picture was taken at a site on Humphrey Rivulet.

Once flooding has worsened, city authorities are compelled to respond. The standard response is channel improvement, such as straightening the course of the stream to dispose of floodwaters more quickly, followed by more extensive artificial channelization when the situation deteriorates later, as is often the case. These solutions amount to treatment of the effects of urban development. Design of works is usually purely functional and not particularly compatible with recreational and aesthetic values. Nevertheless, methods which are more visually attractive can be used (see Figure 2). Other techniques, such as construction of levee systems, floodways (diversion of some flow to storage areas), and the use of small dams on creeks are summarized in the *Northern Melbourne Waterways Study*[27]. The environmental pros and cons are presented in each case.

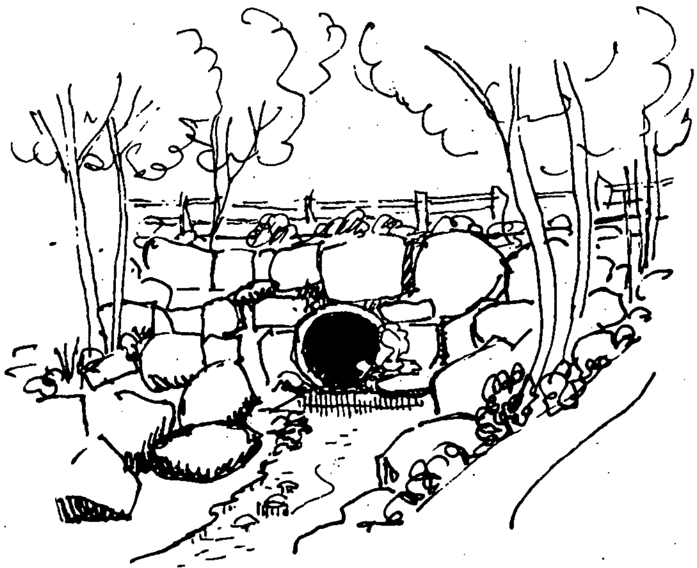
Another range of possibilities lies in the treatment of the causes of flooding, an approach implying catchment management aimed at preventing additions to peak flood flows in streams from urban runoff. The most radical application of this principle, suitable for new urban development, presupposes the ideal of maintenance of the natural hydrologic cycle of the watershed in question. A method was implemented in the Wissahickon Valley outside Philadelphia.[28] Prior to planning, six factors judged important to the objective were used to map the catchment (such as forest cover, per cent slope, and 170 year flood plain). A composite map of ranked values then provided a basis for decisions about a location and intensity of building which would not disturb the functioning of the hydrologic cycle. The consultants working on this project later refined their technique to include a "Cover Model"[29]. The model allowed computation of the permissible proportion, in each four acre grid of a development site, of the impervious surface area compatible with the land's natural capacity to cope with runoff.

Comprehensive planning of this type is applicable to as yet undeveloped catchments, but many methods designed to decrease the amount and rate of discharge to flood flows in streams can be used in the further development of catchments which are already partly urbanised. Impervious surfaces like roads need not be as wide as is common in Australian residential streets, as traffic in most is not heavy; in any case, it is desirable for safety that vehicles should travel slowly. Paths and driveways can have joints through which rainwater can penetrate. In the United States a permeable

Figure 2 Three ways of handling modifications to stream channels when additions to peak flood flows from urban runoff aggravate flooding. Each has been suggested as a means of retaining the visual and recreational potential of urban streams.



1. Paving with rocks, preservation of a flood plain. (Redrawn from:- BONHAM, A., 1974; Urban stormwater drainage planning and environmental design, *Royal Australian Planning Institute Journal* 12, 86-89)



2. Stone lining and planting, a concept suggested by the late Ellis Stones for streams in Melbourne. (From: PRESTON INSTITUTE OF TECHNOLOGY, SPECIAL PROJECT COMMITTEE, 1975; *Northern Melbourne Waterways Study*, p. 24; Preston Institute of Technology Press)

3. Piping combined with landscape treatment. The buried pipes take some of the flow during floods, while low flow is accommodated by the turfed channel above. This method is currently under investigation by the Housing Department of Tasmania.

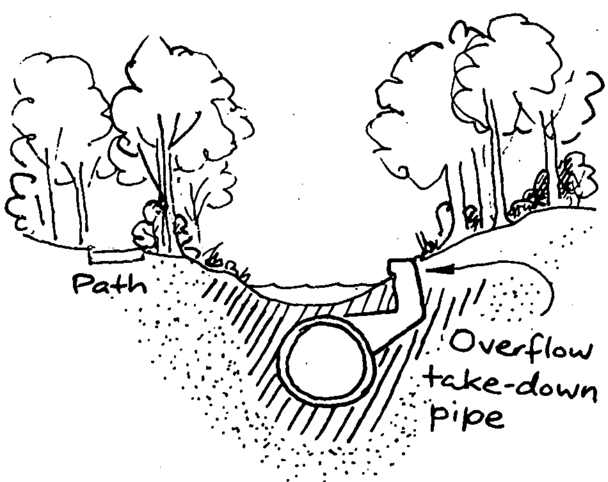


Plate 8 Concrete lining of banks, New Town Creek. It would be unfortunate if all urban streams were treated in this manner, since the process tends to create visual uniformity in the built environment.

Plate 9 Concrete paving, rock lined banks: a more interesting solution for the bank areas, but as Ellis Stones pointed out it is "easy to make rocks look as bad as concrete. You have to know how to handle rocks. It's like a work of art." (Quote from *The Melbourne Times*, 19/6/1974).

bitumenous concrete suitable for hard surfaces, including roads, has been tested successfully for rates of rainfall up to 8 inches per hour[30]. Parking areas can be grassed over a firm but porous base. Extensive concrete kerbing and guttering is not necessary, and turfed or otherwise vegetated swales as substitutes will both reduce and slow runoff. Rainwater can be stored in tanks and ponds, for use on the property later or for release at a controlled rate. Layout of the road system and homes can be designed to fit the topographical characteristics of a site and retain some of its natural features, thus taking advantage of the land's capacity to absorb runoff. Cluster and medium density housing projects are well suited to this treatment, using landforms like natural drainage lines for open space purposes.

Reviewing hydrologic design in urban areas in the United States, Aitken[31] reported that acceptance of the premise that urbanisation must unavoidably increase volume and rate of peak runoff was being challenged. In support of this conclusion, he cited the instance of a consultant engineer in Texas who was contracted to design a drainage system for a satellite city covering 20,000 acres, without utilizing underground stormwater pipes at all. A Maryland planning ordinance does not allow developers to increase the magnitude of recorded floods, while land under development is controlled to reduce sediment transport and consequent siltation in streams.

CONCLUSION

Planning and development control in urban catchments in the Hobart region aimed to reduce runoff would save future expenditure needed to correct the consequences, i.e., flooding and erosion, of mismanagement. In addition, the streams could form a basis for linear reserves and be segments of open space systems. Precedents for valuing urban waterways as recreational and landscape resources already exist in many countries; in Melbourne for several years many community groups have been advocating treatment of the Yarra River and creeks throughout the suburbs in this fashion. At present, parkland throughout the cities and Municipalities of the Hobart region is scattered and not easily accessible to many residents, particularly children. Nor is it integrated into the urban structure in ways which could improve access to other facilities.

The advantages of linear reserves in general, as summarized below by Whyte[32], are equally valid for stream reserves of the type proposed in this report for Humphrey Rivulet:

> *Per acre...linear strips are probably the most efficient form of open space...when they are laid along the routes people travel or walk, or poke into the places where they live, the spaces provide the maximum visual impact and the maximum physical access. The linear concept...provides us a way of securing the most highly usable spaces in urban areas where land is hard to come by, and, in time, a way of linking these spaces together.*

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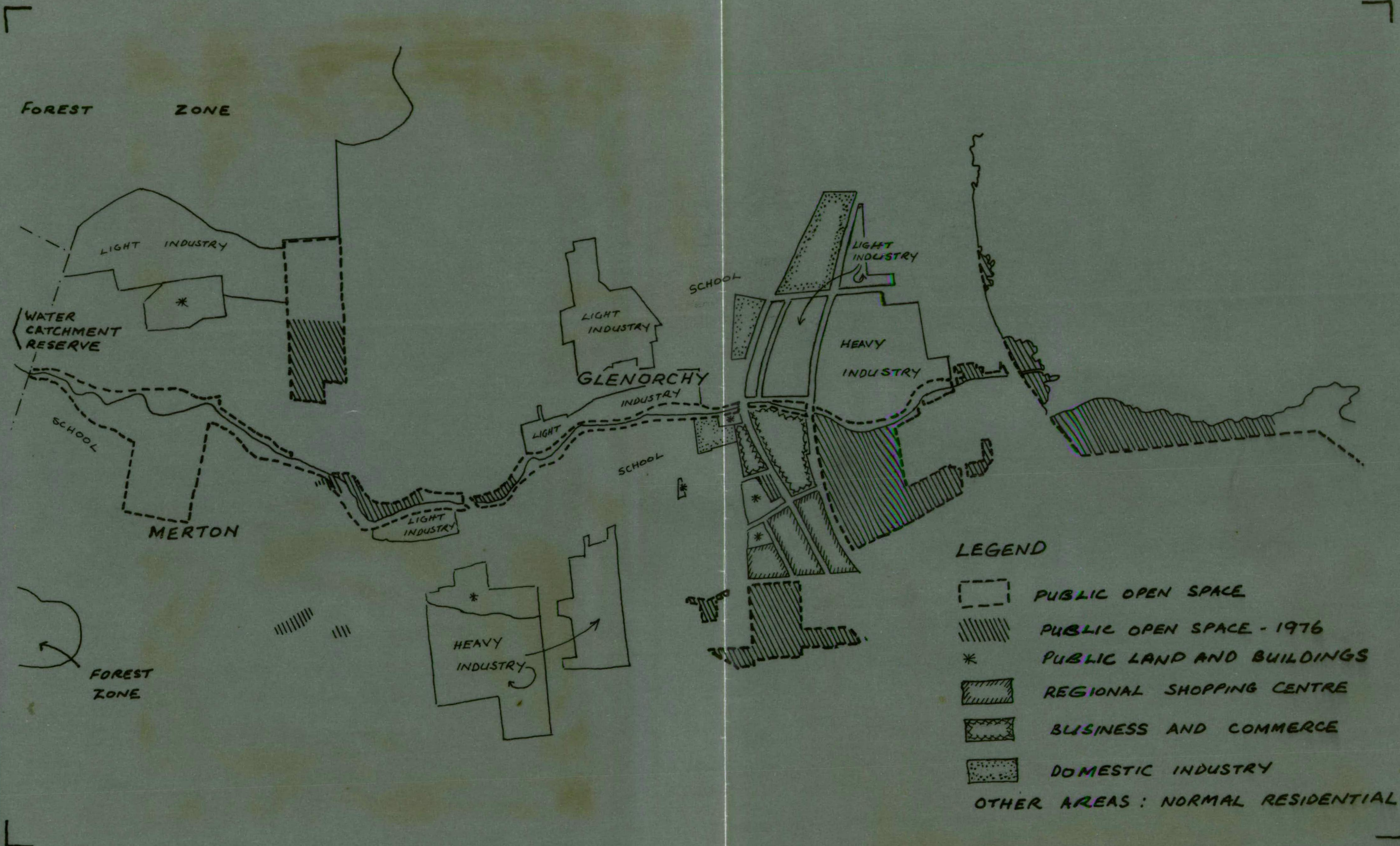
1. See GANS, H.J. 1972; *People and Plans*, Ch. 3. Urban vitality and the fallacy of physical determinism, pp. 30-40; Penguin Books, Ringwood, Victoria.
2. Quoted in: RITTER, P., 1964; *Planning for Man and Motor*, p. 144; Pergamon Press, Oxford.
3. STRETTON, H., 1970; *Ideas for Australian Cities*, p. 73; Griffin Press, Adelaide.
4. It has been suggested that many Australian suburban streets which carry a low traffic flow could be closed at one end to capitalize on this potential.
   See: KORNWEIBEL, R.C., 1972; *Open Space in Urban Australia*, p. 9; publisher not stated.
5. BISHOP, D., 1975; User response to a foot street, *Town Planning Review* 46, 31-46.
6. McCOY, K., 1975; Paradise found at Tuggeranong, *Landscape Architecture* 65, 51-58.
7. Personal communication: Mr. J. Olding, Housing Department of Tasmania.
8. FEROS, V.G., 1976; Bicycling for Brisbane - a Plan, *Planner* 1, 8-21.
9. Personal communication.
10. For example, see:
    (a) FEROS, V.G., 1976; *op.cit.*; p. 15.
    (b) DUEK-COHEN, E., 1976; Slow Ways for Transport, p.149-53, in: Australian Government Habitat Task Force, *Habitat Australia 1976*, Australian Government Publishing Service, Canberra.
11. BENDIXON, T., 1974; *Instead of Cars*, p. 56; Temple Smith, London.
12. STEIN, C.L., 1966; *Toward New Towns for America*, p. 41; Massachusetts Institute of Technology Press, Massachusetts.
13. RITTER, P., 1964; *op.cit.*, pp. 27-31, 225.
14. *Ibid.*, p. 38.
15. See, for example, comments on pedestrian-vehicular separation in : ALEXANDER, C., HIRSHEN, S., ISHIKAWA, S., COFFIN, C., and ANGEL, S., 1971; Houses generated by patterns, p.102; in: Lewis, D. (ed.), *The Growth of Cities*, Wiley-Tutor Science (Garden City Press Ltd., Letchworth).
16. GLIKSON, A., 1971; *The Ecological Basis of Planning*, pp. 28, 29; Martinus Nijhoff, The Hague.
17. PLANNING WORKSHOP PTY. LTD. and P.A. MANAGEMENT CONSULTANTS PTY. LTD., Implications of community centre development, 48-126, in: Department of Tourism and Recreation, *Leisure - a New Perspective*, Papers presented at a National Seminar in Canberra, 22-24 April 1974, Australian Government Printing Service, Canberra.

18. CHADWICK, G.F., 1966; *The Park and the Town,* p. 335; The Architectural Press, London.
19. HOMBURGER, W.S. and A.L., 1971; Problems of recreation areas in the United States, p. 56, *Urban Renewal,* Papers presented at a symposium in the Department of Civil Engineering, University of Salford.
20. MINISTRY OF HOUSING AND LOCAL GOVERNMENT, 1967; *Central Lancashire: Study for a City,* p. 65; H.M.S.O., London.
21. ARTICLE, 1975; Forestway: a kid's paradise, *Community* 2, 8-9.
22. WHYTE, W.H., 1968; *The Last Landscape,* p.264; Doubleday and Company, New York.
23. STRETTON, H., *op.cit.,* p. 79.
24. SEDDON, G., 1972; *A Sense of Place,* p. 262, University of Western Australia Press, Nedlands.
25. JOHNSON, S.L. and SAYRE, D.M., 1973; Effects of urbanization on floods in the Houston, Texas, Metropolitan Area, *U.S. Geol. Sur. Water Resources Invest.,* April 1973. Cited in: Aitken, A.P., 1975; *Hydrologic Investigation and Design of Urban Stormwater Drainage Systems, p.103;* Australian Water Resources Council Technical Paper No. 7, Australian Government Publishing Service, Canberra.
26. AMERICAN SOCIETY OF CIVIL ENGINEERS, 1969; Effect of urban development on flood discharges, *Jour. Hydrol. Div.* 95, 287-309. Cited in: Boughton, W.C., 1970; Effects of Land Management on Quantity and Quality of Available Water - A Review, Australian Water Resources Council Report No. 120, Australian Government Publishing Service, Canberra.
27. PRESTON INSTITUTE OF TECHNOLOGY, SPECIAL PROJECT COMMITTEE, 1975; *Northern Melbourne Waterways Study,* p. 24, Preston Institute of Technology Press.
28. RAHENKAMP, J., SACHS, W., and WELLS, R., 1971; A strategy for watershed development ... that beats the bulldozer by using land sale profits to preserve greenspace, *Landscape Architecture,* April 1971, 227-234.
29. WELLS, R., 1974; The power of water in planning, *Landscape Architecture,* January 1974, 21-26.
30. AITKEN, A.P., 1973; *Hydrologic Investigation and Design in Urban Areas - a Review,* p. 15; Australian Water Resources Council Technical Paper No. 5, Australian Government Publishing Service, Canberra.
31. *Ibid.*.
32. WHYTE, W.H., *op.cit.,* p. 173.

HUMPHREY RIVULET
AND ENVIRONS

CHAPTER TWO

Map 6 Aerial photograph of Humphrey Rivulet and environs. The symbols S1 to S4 indicate the sites at which samples of water were taken for microbiological analysis. Results are discussed on p. 91.



Map 7 Drawing from the *City of Glenorchy Zoning Plan (1964)* showing public open space planned along Humphrey Rivulet. Land for this purpose, however, was not acquired as sub-division proceeded (see text, p.67).

HUMPHREY RIVULET AND ENVIRONS

The purpose of this chapter is to summarize some social and physical characteristics of Humphrey Rivulet's setting. In addition, we try to show the interactions over time between man and the place he has settled. This is done with a principle in mind: that careful management of the land in man's interests, and of the Rivulet in particular, presupposes knowledge of both community needs, which can change, and the functioning of the natural systems which formed and continue to maintain the present physical environment.

THE URBAN SETTING

Population, transport, and housing

The mixed residential, industrial, and commercial area of Glenorchy in the vicinity of Humphrey Rivulet continues to be a regional centre for the larger area administered by the City of Glenorchy. There were 41,666 people throughout the city in 1971, but preliminary results from the 1976 Australian Population Census indicate a population decline of 0.10 per cent annually.[1]

In 1971, of the people living within the census collector's districts adjacent to Humphrey Rivulet,* 56 per cent had been resident for at least five years. Only one tenth were born overseas. Sixty-nine per cent owned or were purchasing their homes. Most houses were of timber construction, and many had been built and owned originally by the Tasmanian Government Housing Department. Residential premises rented privately and by the Housing Department were approximately equal in number.

Ninety-two per cent of the labour force were wage or salary earners; of these 40 per cent were tradesmen, production process workers, and

* Full results from the 1976 census are not yet available.

labourers. Women made up one third of the labour force.

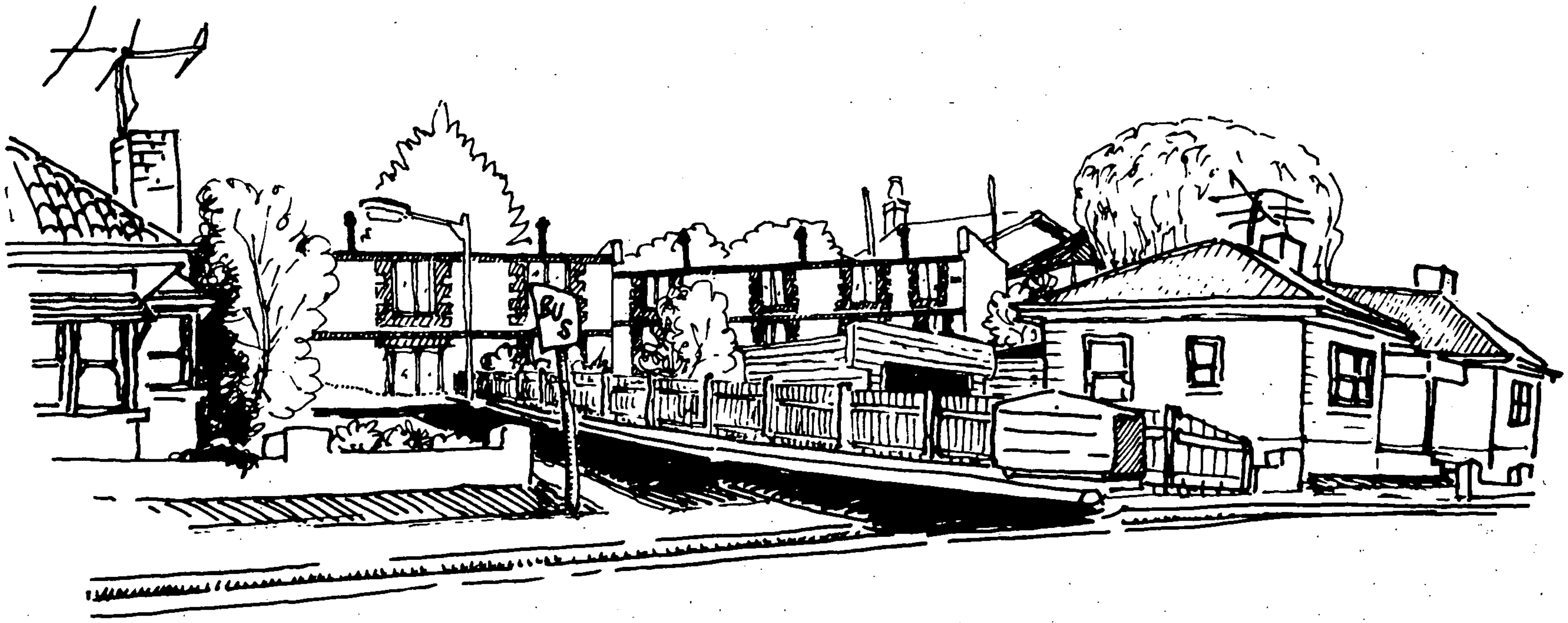
Approximately 16 per cent of households did not own a vehicle; a further 52 per cent owned one. It can be inferred that nearly one sixth of families were entirely dependent on public transport, apart from assistance from friends with cars. It is likely that many women without employment were in a similar position throughout the business week, since family cars are often driven to the work place of one member of the family daily. Dependence on public transport currently means travel by bus or taxi, since there is no longer a passenger rail service within the Hobart region.

Despite the fall in population, the number of occupied private dwellings throughout the City of Glenorchy increased by 10.7 per cent since 1971. Presumably the increase reflects the Hobart regional and Australia-wide trend towards a lower number of occupants per dwelling, so that there is still a demand for new housing. Relatively few homes are being built within the study area, except in small sub-divisions adjacent to the Rivulet at Merton, but there is little further land available for new housing within the catchment. On the other hand, some young families have been left a home near central Glenorchy by parents, while others are purchasing old homes there because they tend to be cheaper than in other areas closer to Hobart.

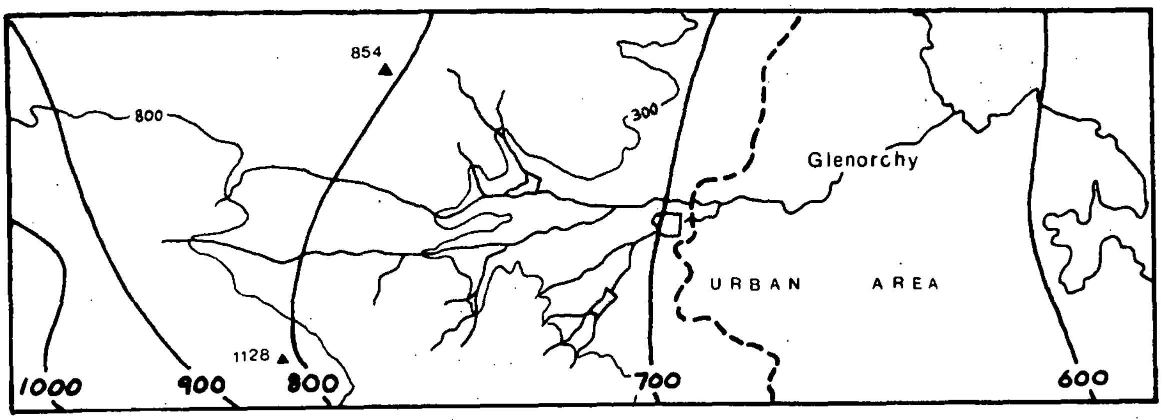
Redevelopment in the form of flats and home units has also occurred, but rising costs have recently contributed to high rents and sale prices, with a consequent fall in demand. In the event of improvements in the Tasmanian economy it could be expected that pressures for this type of residential development in the vicinity of the Rivulet would grow. Such a future is likely because the area is convenient to the Glenorchy business centre and is only 8 kilometres from Hobart, where many entertainment, commercial, and administrative functions are centralized.

Effects of future development on the Rivulet

If this change in the pattern of building does eventuate on a fairly wide scale, together with a probable tendency towards higher density construction and an increase in paved surfaces to lessen regular maintenance, there is little doubt that Humphrey Rivulet will



Residential, Glenorchy



Map 8 Distribution of average annual rainfall over the catchment of Humphrey Rivulet; isohyets in mm.
(Source: Staff of Bureau of Meteorology, Hobart)

Table I Monthly rainfall (mm) as recorded at Tolosa St. Reservoir between 1898 and 1972.
(Source: Bureau of Meteorology, Department of Science, 1975; *Climate of Hobart*; Australian Government Publishing Service, Canberra)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	47	45	48	64	55	64	63	60	62	74	59	61
Wettest month on record	145	172	163	326	278	236	151	199	160	215	148	145
Driest month	5	5	9	0	4	8	8	16	15	12	7	3

fail to cope with the extra stormwater drainage during some periods of prolonged and intense rainfall. Nearby creeks carrying stormwater (Barossa Creek, to the south, and Littlejohn, to the north) have no excess capacity and in fact have caused more damage from flooding than Humphrey Rivulet in recent years. Part of the flood flow in Littlejohn Creek is already diverted to Humphrey Rivulet downstream from Brent Street by pipeline. The engineer who advised this measure in 1967 also commented on a need to plan for the future, and assumed that the urban sections of all three streams would be "properly channelised and paved more or less like the Hobart Rivulet".[2] In the case of Humphrey Rivulet there seems only the one alternative to such an expensive solution, v.i.z., the prior application of planning and construction measures which are designed to restrict the amount and velocity of runoff leaving individual properties or sub-divisions, as explained in the previous chapter. In assessing the impact of development on the drainage system, an added factor is probable expansion of the business district and industry, involving further runoff problems as large buildings and car parks replace residential allotments.

THE PHYSICAL SETTING

Climatic conditions

The weather conditions which affect Glenorchy and contribute to changes in the Rivulet's flow characteristics are described in broad terms as maritime temperate, in accord with prevailing mild summers and cool to cold winters.[3] Rainfall in the catchment is usually fairly evenly distributed throughout the year. Nevertheless, considerable variation in monthly averages together with significant differences in the distribution of rainfall over the catchment can lead to flooding (see Map 8 and Table 1 opposite).

Through the urban area, the Rivulet must carry runoff from its mountain catchment, where average precipitation is higher than on the plain. Flow is also augmented by melted snow from the heights, particularly during winter and spring. The most critical period with regard to flooding, however, usually occurs in the warmer months when moist easterly air streams sometimes bring heavy rain, expecially to the upper catchment.

Hot dry days towards the end of summer often contribute to the

Plate 10 The landscape of Humphrey Rivulet, Glenorchy, and Merton from the slopes of Mt Direction, on the eastern side of the Derwent, after winter snowfalls on the Wellington Range. The urban study area is situated on the alluvial fan (shown below: f) built up from rocks, soil, and other debris carried downstream and deposited by the Rivulet.

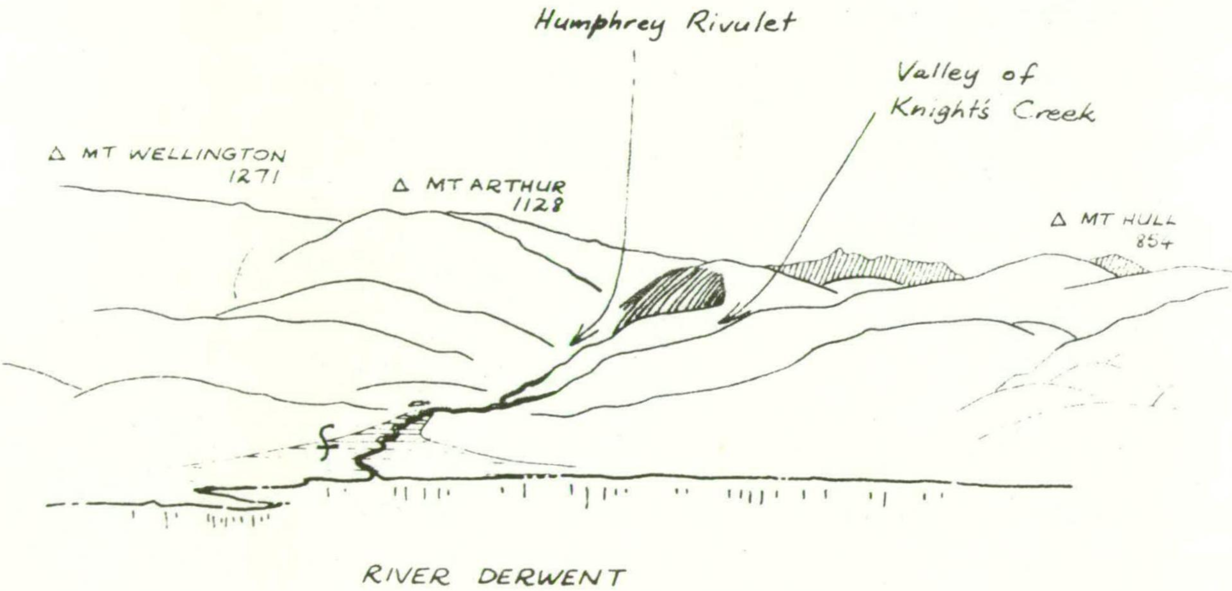


Figure 3 Schematic drawing of the major landforms shown in Plate 10.

likelihood of wildfire on the forest slopes and on hills fringing the suburbs. The risk increases when exposed slopes are subjected to northerly winds. Some homes at the top of Tolosa Street suffered in the widespread fires of 1967. The continuous urban area around the Rivulet is probably now free from fires originating in the forests because of the buffering effect of large cleared areas, such as the Reservoir Park. Brigades within the Hobart Special Fire Area also carry out controlled hazard reduction burning in some sections of the upper catchment.[4] A potential hazard for some more isolated homes near bushland undoubtedly remains, while areas within the suburbs are at risk where property owners fail to clear thick grass and weed near buildings, as is the case at several locations along the Rivulet.

Topography, vegetation, fauna

The land around Humphrey Rivulet is part of a compact, beautiful landscape which would be highly prized as the setting for a city anywhere in the world.

The bulk of the urban area is situated on an alluvial fan, a plain which owes its origin to soils and rocks carried down by the Rivulet from the foothills and mountains of the Wellington Range. The fan is bordered on the east by the River Derwent, and from the river edge slopes to a point about four kilometres inland, at 130 m above sea level. The apex of the fan is just below the Tolosa Street Reservoir. Upstream, the country within the Water Catchment Reserve is rockier, rising steeply to the mountains heading the twin valleys of the Rivulet and Knight's Creek. The sources of the streams are five kilometres from the Reservoir, at an altitude of 900 m.

Man's activities in the upper catchment have always been restricted by its ruggedness. Most of the land is unsuitable for agriculture; building would be expensive even in the few areas where the terrain is suitable because of current limits to the height of the reticulated water supply and the difficulty of extending the sewerage system. In 1945 the Water Catchment Reserve was proclaimed a sanctuary under The Animals and Birds Protection Act 1928.

Glenorchy is fortunate in having such a large reserve for water catchment purposes, not only because of the protection the valley gives

Plate 11 New homes under construction in Merton, across the Rivulet from the grassed land of the Brent Street Playground. The retention of a stand of eucalypts (within another small reserve on the Rivulet) promotes the impression that the residential area fits into the wider landscape with some harmony, rather than destroying the relationship between the site and its surroundings.

The tall trees in the reserve are a mixed stand of manna gum (*E. viminalis)*, blue gum (*E. globulus*) and stringybark (*E. obliqua*). The smaller trees on the near side of the Rivulet are mainly willows (*Salix spp.)*

Plate 12 By contrast, a view across the Rivulet from another part of Brent Street playground shows how the clearing of vegetation and building on a denuded skyline (top left of picture) results in a much harsher environment visually. People in these homes probably also experience greater climatic extremes than if shelter belts of trees had been left. There is no shade in summer and the hillside is exposed to cold westerly winds in winter.

to the quality of urban water supplies and the control that its forest exercises over runoff to the Rivulet, but also because of its landscape and potential recreational value so close to the city centre. Public access from Glenorchy is not permitted, but pressures for access may grow, as they have in the case of water catchment land near cities in other parts of the world. If the Council does eventually develop more parks modelled on the Tolosa Street Reservoir Park, for instance, it would seem essential that access to the wider reserve be controlled so that its steep slopes remain protected against excessive erosion.

The range of botanical species growing in the Water Catchment Reserve is wide. Gullies and lower slopes are generally covered with eucalypts adapted to damper conditions, such as stringybark (*E. obliqua*), blue gum (*E. globulus*), and swamp gum (*E. ovata*), together with smaller trees, shrubs, and grasses. Rainforest species, dominated by myrtle (*Nothofagus cunninghamii*), grow in small sheltered pockets. Stony ground, particularly on ridges where the soil is not deep, supports vegetation usually associated with well-drained sites in Tasmania, like the white peppermint (*E. pulchella*, formerly *E. linearis*). Above 800 m there are eucalypts able to withstand colder conditions, including snow and ice. Tasmanian snow gum (*E. coccifera*) is one such tree, and low sub-alpine shrubbery grows on the rocky ground.

In the continuous built up area, development has left only small isolated stands of indigenous vegetation, mostly along the Rivulet. In Merton, eucalypts of different species (*E. obliqua, E. viminalis, E. ovata,* and *E. globulus*) grow together in the deep alluvial soil. The variety of smaller trees and shrubs which grow beneath the gums and commonly line the Rivulet banks and channel is quite extensive, including some which are usually associated with wet sheltered positions and others with dryer exposed conditions. Many seem to be serving the useful function of slowing down processes of bank erosion, especially where they grow in looser soil and gravel. Blackberries have infiltrated most of the more open sites. Clearing for building has recently resulted in the loss of many trees; where they remain, the contrast between the urban environment and the timbered hills is softened. A walk to the edge of small stands of trees can give a sense of enclosure that is very different from experience in the suburban streets. Usually

Plate 13   Manna gums (*E. viminalis*) on undeveloped land adjacent to the Rivulet between Brent and Bowden Streets. This area, surrounded by homes and industry, is less than a quarter of a kilometre from the Glenorchy business centre, yet is quiet and secluded. It is also used by children as a play area and as an access route, and fulfils an important function in protection from floods as it is a flood plain (see text p. 83).

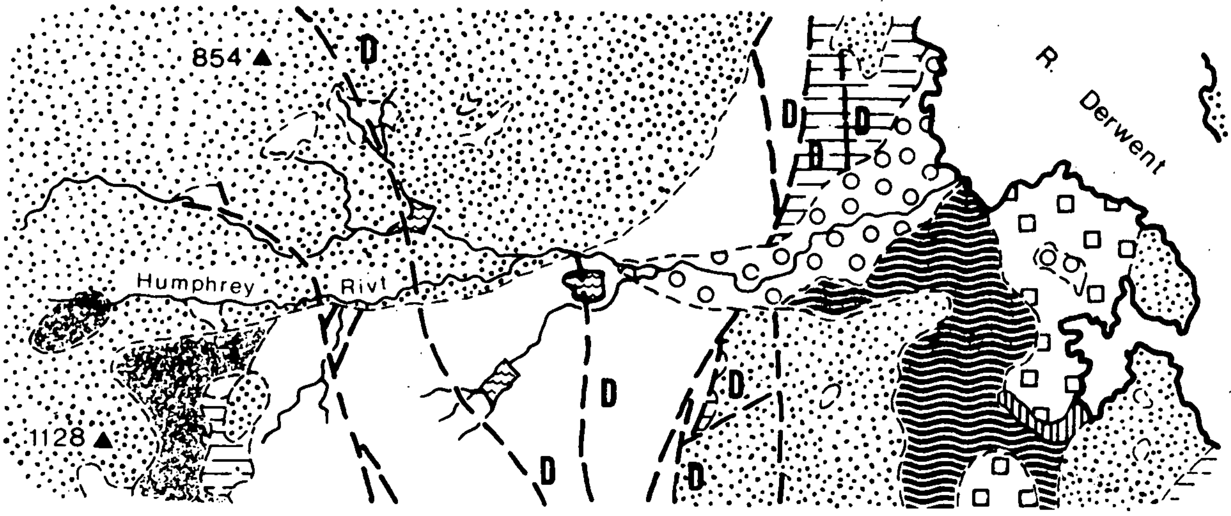
many bird calls are heard. Towards central Glenorchy below Brent Street the only stand of eucalypts (*E. viminalis*) gives a similar atmosphere on vacant land. Apart from whether indigenous trees are the best means of vegetative control of erosion, pollution, and climatic conditions, the desirability of replanting some areas with them is largely a matter of taste. Our feeling is that some sensitive siting of large eucalypts, for instance, could help promote in people's experience a sense of affinity between the suburbs and the wider landscape without detracting from Glenorchy's urban character. The same measure could also create a "corridor" for birds, which can be a source of pleasure for many people.

No formal recording of wildlife communities has ever been undertaken in the Rivulet catchment, as far as we are aware. We can only assume that a full range of species suited to habitat conditions in the upper catchment are present in that area. Within the urban area, we saw children catching small native fish (*Galaxias maculatus*) close to where the diversion pipe from Littlejohn Creek enters the Rivulet. The presence of these fish probably implies that other aquatic animals lower in the food chain are also present, including invertebrates and micro-organisms. It is regrettable that time did not permit us to sample aquatic organisms in the Rivulet as we might have learned much about the quality of its water in the urban area by inference from species diversity and population numbers.

Evolution of the landscape

The forces which lead to the development of Glenorchy's physical environment represent complex interrelationships between climatic conditions, geological processes, vegetation, and animal life. The account below is vastly simplified, dealing almost entirely with climatic and geological variables, and with inferences from geomorphological principles derived from studies of similar streams to the Rivulet elsewhere.

Approximately 150 million years ago the terrain was low. Its surface layers consisted of sediments, previously deposited by the action of wind and water. Into lines of weakness in the sediments, molten material from deep within the earth rose under pressure.



Map 9 Geology of Humphrey Rivulet and environs (adapted from Department of Mines, *Geological Atlas*, 8312S Zone 7, Sheet No. 82)

LEGEND

Post-dolerite fault (down thrown side indicated) D

Representative rocks

Duration and time before present (millions of years)

Period	Representative rocks
Present - 3 (Quarternary period)	*Alluvial deposits: including younger gravel, marsh, swamp deposits* *Alluvial deposits: older gravel* *Dolerite talus*
3 - 70 (Tertiary)	*Basalt* *Predominantly sub-basalt silt and fine sand (thought to be old channel of River Derwent)*
70 - 135 (Cretaceous)	
135 - 180 (Jurassic)	*Dolerite*
180 - 225 (Triassic)	*Sediments, including sandstone and mudstone*
225 - 270 (Permian)	*Sediments, including sandstone, siltstone, mudstone, and limestone.*
3980 (Godthaab) 5000	

(Inferred time of origin of earth)

Sometimes the volume of fluid was sufficient "to float off whole blocks of overlying rock, and spread into the vacated space."[5] It cooled to form extensive sheets of dolerite rock (bluemetal). Despite long periods of erosion, much of the resistant dolerite remained,[6] as it does today, capping the range and peaks around the upper valley of Humphrey Rivulet and many of the slopes.

The next major geological phase, the occurrence of widespread fault movements between twenty-five and seventy-five million years ago,[7] determined the structural units of the present landscape. Along fractures in the earth's crust, there was relative movement of land masses.

Mount Wellington is the dominant feature resulting from uplift movements in the Hobart area.

In comparison, later disturbances such as the volcanic activity which sent lava flows down some streams to solidify as basalt rock (like that beneath Elwick Racecourse), had only a minor influence on the topography. Otherwise, processes of erosion and deposition of sediments common today have been the main agents of modification of the uplifted blocks and the coastal plain. The intensity of these processes, however, varied with changes in climate and sea level. Erosion, for example, produced scarps with free faces on the dolerite blocks.[8] Subsequently, severe frosts and periglacial activity resulted in accumulations of worn rock debris (talus, often called "ploughed fields" or "potato fields") towards the foot of slopes.[9]

The courses of the streams draining excess water (runoff) from the mountains after rain often followed fault lines, as did Knights Creek. Humphrey Rivulet, on the other hand, followed a contact zone between dolerite and the older Permian sediments (such as limestone, quarried near Lime Kiln Gully Reservoir).

The alluvial fan is probably underlain by a dolerite spur which was eroded by the Rivulet.[10] The later climatic changes which helped produce talus resulted in periods when up to one fifth of Tasmania was covered by ice.[11] Although glaciation did not occur in the catchment of Humphrey Rivulet, vegetation was sparse and the stream vigorous. Soil and rocks were loosened, carried by the Rivulet, and deposited to form

Plate 14 Meandering channel of Humphrey Rivulet below Brent Street. The Rivulet is undercutting the right bank, advancing towards fences in the process, and depositing debris on the left.

the fan on the valley floor below. Landslides probably also contributed material to be washed downstream.

Aboriginal man, present in Tasmania at least 23,000$\pm$500 years ago,[12] is believed to have indirectly assisted processes of erosion and deposition in stream valleys. He periodically fired vegetation to promote the development of open grassland where game could be hunted more easily. The extent to which these nomadic people were active in the Hobart region, however, is uncertain.[13] In any case, most of the alluvium of Humphrey Rivulet is of older origin. It more likely resulted from natural events than from man's activities.

Today, the Rivulet continues both to add to the accumulated soil and coarse gravels of the fan, and to cut its channel through them. Its flow consists of two inter-mingled streams: water, and water borne debris.[14] The latter consists of soil and rock particles, derived from the catchment and from the stream's own bed, and of organic material from plants and animals. When floods occur, this debris or silt, is left on the banks as the waters subside. Erosion of banks is related to turbulence in the flow, and to the fact that the current oscillates from side to side. The swinging current exerts more pressure on the outside of curves,[15] undercutting the bank, and deposits debris from upstream opposite. The result is a meandering, S-shaped channel. Once the Rivulet enters the fan, the evidence of this action is marked. The soils and gravels are relatively free to move, unconstrained by harder rocks as in the upper catchment. Examples can be seen at many places along the Rivulet, such as between Brent Street Bridge and Bowden Street.

The Rivulet's tendency to erode banks and migrate laterally across the fan remains strong, although reduced by man-made structures, particularly the reservoirs. Because of these modifications, the effects on adjacent land due to the shifting channel should be less pronounced. On the other hand, other activities of man, as discussed in the historical section below and in Chapter 3, have aggravated the processes contributing to erosion and flooding.

EFFECTS OF SETTLEMENT, 1809 - 1976

A comprehensive history of Glenorchy has never been written. There is sufficient information available, nevertheless, to allow a broad

Plate 15 "Murrayfield" today (Tolosa Street). The original house consisted of the ground floor only, and was built of coarse gravels from the Rivulet in the early 1800's. The first story was added about 1910.

interpretation of the progressive impact of man on the land around the Rivulet during development from a relatively few rural holdings and cottage industries to the current pattern of urbanisation. Some of this information was provided by descendants of early settlers.

1809 - 1864

In 1794 the area was part of King George's Plains,[16] a hint that the landscape before settlement included grassland against the backdrop of eucalypt forest on the slopes of the Wellington Range. Settlement along the banks of the Rivulet began in 1809, when people moved from Hobart to take up land grants and farm the soil of the alluvial fan. Apparently they came in search of clean water as well, as Hobart Rivulet is reputed to have been polluted at the time.

Agriculture and small industries grew quickly. Soap, candles, starch, vinegar, wine, cider and hats, were produced at "Murrayfield",[17] while Thomas Cooke tanned hides adjacent to O'Brien's Bridge.[18] Limestone was burned in pits at Lime Kiln Gully,[19] to provide a main ingredient of the mortar used to construct stone houses and walls.

The Rivulet was important as a source of water for domestic and agricultural purposes. Water Lane (now Brent Street) gave access to the stream for people drawing water in buckets for their houses. Mills supplying stone ground flour used its current for power. Two mills operated on the northern bank, attached to "Murrayfield"[20] and "Ravensdale",[21] and a third within the property of "Houghton"[22] on the opposite side.

Even at these early stages of man's intervention, changes in the characteristics of the Rivulet almost certainly occurred. The settlers cleared forest country to gain more land for pasture and crops and to obtain building materials. They also peeled acacia trees to obtain wattle bark for tanning. Conversion of forest areas to farmland increases the volume of runoff after rain and shortens the time interval in which it reaches streams. A consequence is that streams tend to break their banks more frequently and severely.[23] Removal of vegetative cover also lowers the moisture content of the soil, as loss of water to the air by evaporation is higher. This effect, combined with the rapid loss of runoff to streams, diminishes the volume of water available for

Plate 16 Mortar and stone wall, built in 1858 by landowners along the Rivulet for protection from floods. It still serves that purpose but some sections are in need of repair.

Plate 17 "The Grove" is now deteriorating. The homestead is surrounded by industrial premises and is all but hidden from nearby streets. It does not appear to have been recorded by the National Trust. (Humphrey Rivulet just out of the picture to the left).

percolation down to ground water supplies. Thus a reduced volume of flow could be expected in dry periods, when flow is normally augmented by underground water. Changes to the level of the water table can also adversely affect the vegetation adapted to the particular conditions of a site and destabilize slopes.

In fact, property owners whose land abutted the Rivulet were only too painfully aware of its inclination to flood. They met at Glenorchy's first inn, "The Dusty Miller", in 1858.[24] The flood protection walls erected, of mortar and of stone collected from the Rivulet, still stand, although some sections have deteriorated.

Evidently the desire of the community to reproduce elements of the British landscape in the new land was strong. Older residents still talk of the grounds of "The Grove" as reminiscent of an English land-scaped park, extending to the edge of the Derwent. The trees and scrub lining the Rivulet were replaced by willows and poplars. These deciduous trees, which lose their foliage in autumn each year and allow sunlight to penetrate unhindered throughout the winter months, undoubtedly helped to bring about changes in the physical and chemical properties of the water. Consequently, the structure of aquatic plant and animal communit-ies was also affected, as the set of environmental conditions to which they were adapted altered. The tenacious blackberry, introduced to Tasmania because of its excellent fruit, rapidly colonized the banks of the Rivulet after disturbance of the indigenous vegetation and, as in many parts of the state, continually threatened to encroach upon pasture land.

By today's standards, with rapid transformation of the landscape by urbanization, the ecological changes resulting from the basically rural activities of the early nineteenth century were small. In terms of earth history, and in terms of the complex chain of environmental effects initiated, they were sudden and dramatic.

1864 - 1901

In 1864, with a steadily growing population and considerable prosperity, Glenorchy was declared a rural municipality,[25] separate from Hobart. Despite economic recession in the 1890's and the failure of the Van Diemen's Land Bank,[26] which resulted in the collapse of many pioneer enterprises in Glenorchy, the years to 1901 saw expansion.

Irrigation from the Rivulet was introduced to the orchards and hopfields of "Clydesdale" and "The Grove".[27] This occurred at a time when agricultural development in the Hobart region, New Norfolk, and the Huon Valley had reached a stage at which export to the mainland and to Britain could be made profitable. "Murrayfield" continued and expanded its diverse range of activities, producing 4,000 gallons of cider under the original "Mercury" label in 1898.[28]

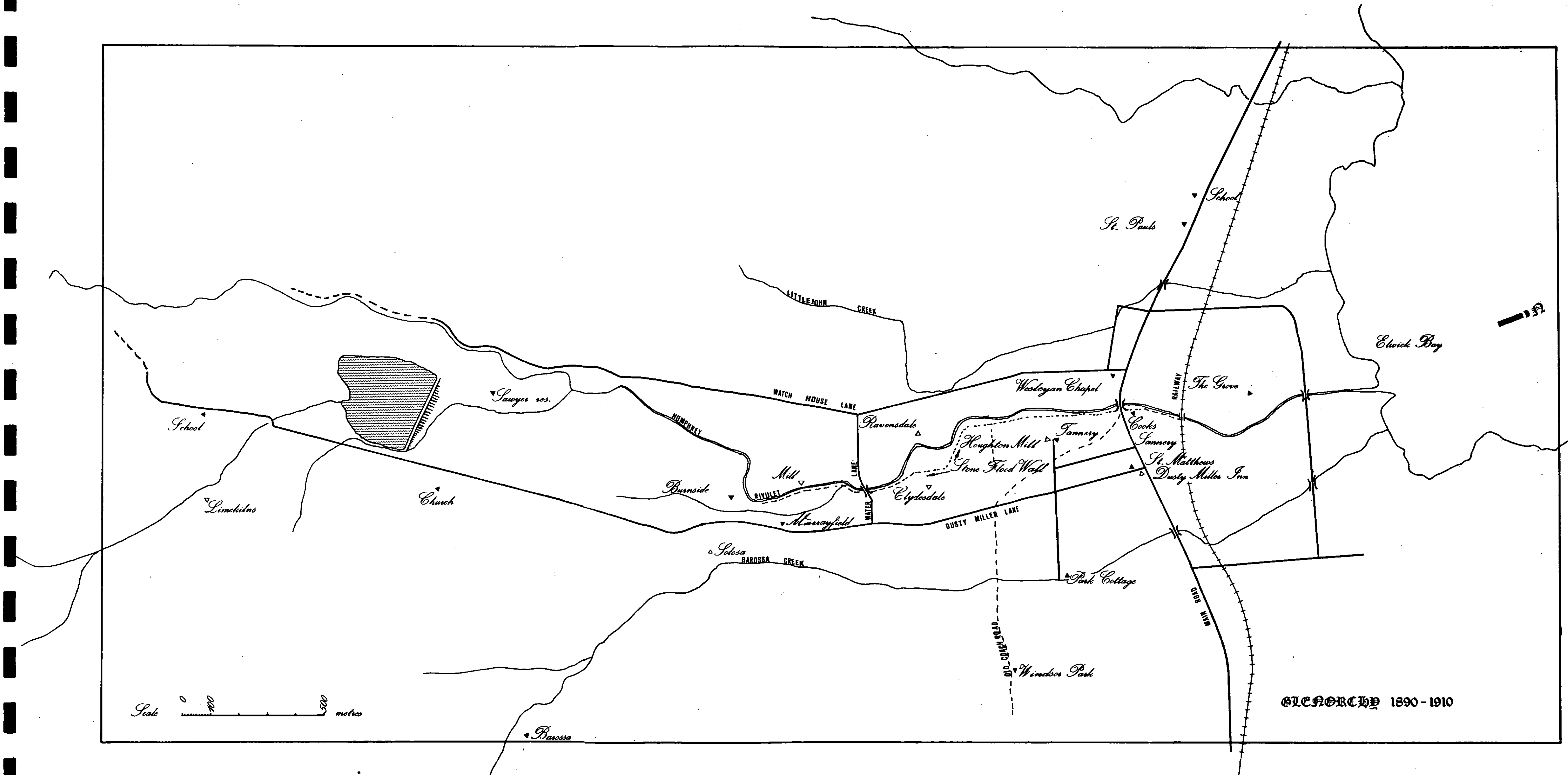
Under normal conditions, the stone walls of 1858 gave the people of central Glenorchy relief from flooding. The landslip and flood of 1872, as recorded by Stancombe, were quite unusual.

> *One would have thought that, after the liquidation of the bushrangers and the moonlighters, the little town would have settled down... but one night in 1872 disaster befell the valley. Winter rains had filled the streams and saturated the mountain so that a great landslide carried huge trees, boulders and thousands of tons of earth into the bed of Humphrey Rivulet some distance above the town, forming a dam some sixty feet high. The flood waters rose, until, at one o'clock in the morning, the dam broke with a roar that was heard far across the Derwent. The deluge raced down carrying all before it - homes, orchards, and gardens were hopelessly destroyed, but only one life was lost, because the people had been moved to safety. Nowadays, even the yellow gash of the landslide has been softened by time and few have even heard the story.*[29]

Some enterprising beachcombers are said to have enjoyed a high old time on the sand of Elwick Bay with a cask of wine, presumably washed down from "Murrayfield".[30]

A turning point in the history of the Rivulet came when the demand for domestic, agricultural and industrial water exceeded supplies. The first stage of the present Tolosa Street Reservoir was constructed about 1890.[31] A small weir and pipeline, built further up the valley to serve people above the reservoir, are still in operation. In the same decade, fear of the spread of a typhoid epidemic[32] probably lead to uneasiness about the use of the lower Rivulet as a source of water. In any case, the presence of the reservoir largely removed the need to maintain water in the town reaches in a drinkable condition.

By this time, it is evident that rural land use patterns were



Map 10 Historical map of Glenorchy. The buildings marked ▲ still stand. In addition, a number of other cottages in Tolosa Street (not shown) have been recorded by the National Trust.

Plate 18 View across the Rivulet to "Murrayfield" factory buildings, about 1900.

Plate 19 Apple packing at "Murrayfield".

Plate 20 Glenorchy's last mill, near "Murrayfield". Some remnants of the foundations remain in Norman Circle Playground.

Plate 21
Hopfields at "The Grove", early 1900's. Main Road is in the foreground.

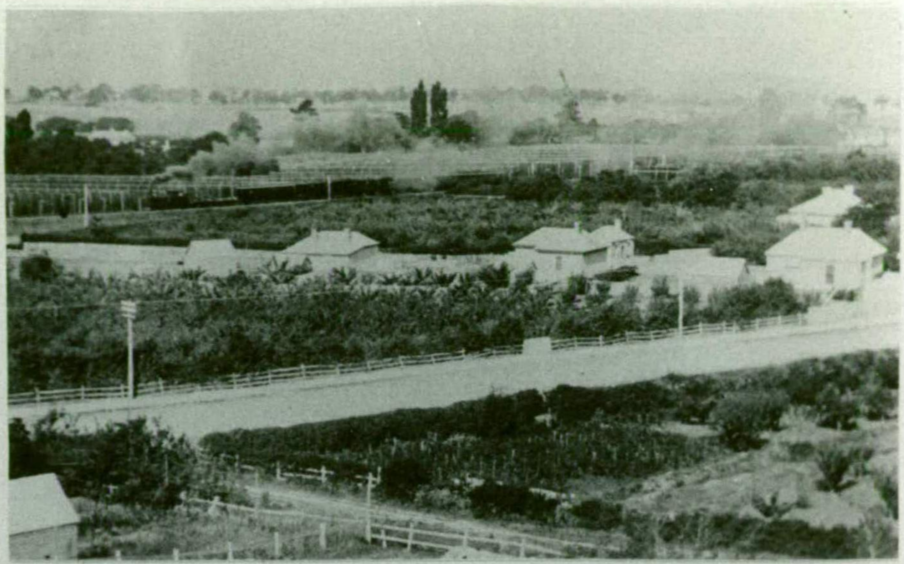


Plate 22
Picnic group, upper Humphrey Rivulet.

Plate 23 The Rivulet near upper Watch-house Lane (now Chapel Street), about the turn of the century.

(Photographs on this and facing page by courtesy of Miss Mary Murdoch) changing in response to demands imposed by a larger community. In 1893, a Hobart real estate firm offered for sale the 58 lots of Kensington Estate, the site of the present shopping centre between Main Road and the railway line.[33]

1901 - 1976

Many of the businesses along Humphrey Rivulet ceased operations or moved elsewhere after replacement of a partly protective system by free trade, a change which accompanied federation of the Australian States in 1901. Mainland factories closer to large markets disadvantaged some of Tasmania's export industries. Another factor contributing to relocation was hydro-electricity, introduced to the south of the State in 1916 for domestic and tramway needs and extended to industry in 1919.[34] Power derived from small streams was rendered obsolete.

Water consumption, however, increased to such an extent that it was necessary to raise the storage capacity at Tolosa Street twice, in 1915 and 1922.[35] Several implications of these works for the Rivulet can be discerned. Provided the reservoir was not full prior to heavy rain, its ability to take part of the flow generally gave the community a measure of flood protection. On the other hand, it is likely that the reduced flow in the Rivulet below the reservoir intake resulted in the gradual formation of a channel of smaller dimensions, with less capacity to move floodwaters downstream quickly. This effect eventuates as plants colonize a strip of land below the original banks (see Figure 4, p. 66). In addition, efforts to gain full advantage from the water supply system during dry months probably lead to diversion of the entire flow from the Rivulet's upper catchment to storage. Once again aquatic organisms suffered changes in their habitat. Knight's Creek, however, which contributed a greater volume of flow overall, continued to run unimpeded at this time.

Events towards the end of the 1914-18 war and in the 1920's sealed Glenorchy's transition from a community largely dependent on the resources of its own land to one which was essentially urban in character. Subdivision of the old properties for housing intensified, and many residents of Glenorchy travelled to work in factories processing raw materials brought from elsewhere. The two largest industries were Cadbury-Fry-Pascall Pty. Ltd., established at Claremont between 1921 and 1924,[36]

Plate 24 This market garden and nursery remain on the bank of the Rivulet as one of the few cultivated areas not yet displaced by residential or industrial development. (It would seem of value to consider retention of such land uses in urban areas, not only for landscape but also for educational reasons).

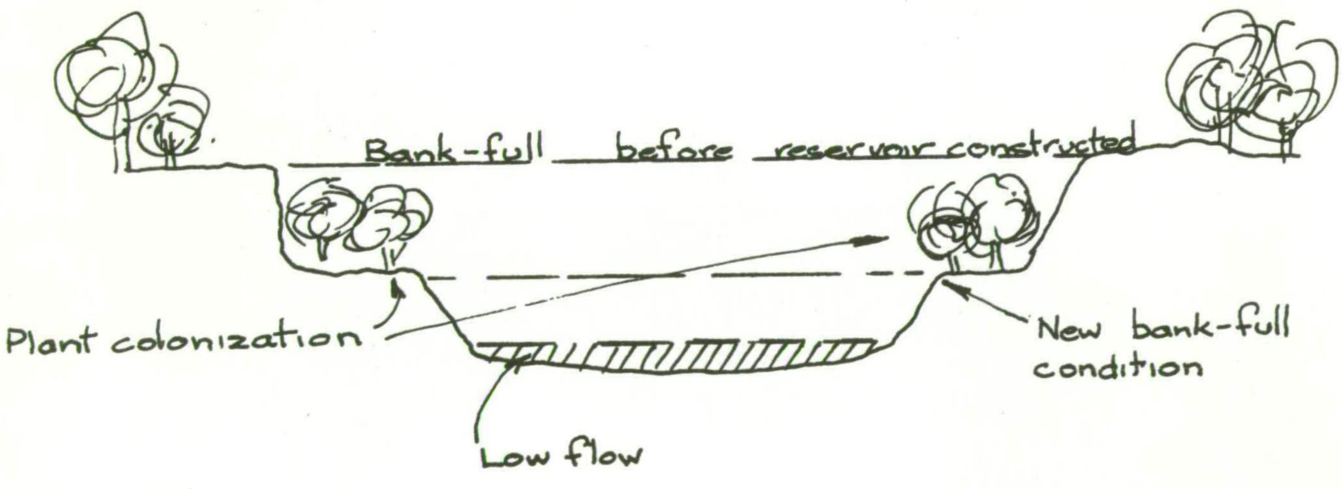


Figure 4 Cross-section of a stream channel downstream from a reservoir. It seems likely that this type of shrinkage of channel capacity has eventuated along sections of Humphrey Rivulet (cf. Figure 7, p. 84). (Figure redrawn from: GREGORY, K.J. and PARK, C; Adjustment of river channel capacity downstream from a reservoir, *Water Resources Research* 10, 870-873).

and the Risdon plant of the Electrolytic Zinc Co., 1916-1922.[37]

Lime Kiln Gully Reservoir was constructed in 1925,[38] but it was not until 1958 that the largest dam, on Knight's Creek,[39] was completed. The City Council now also obtains water from the Metropolitan Water Board by pipeline from the upper Derwent, mainly in summer.

After 1920, much of the area formerly under orchards and hops was used for market gardens supplying vegetables locally and to metropolitan Hobart. These were replaced by residential and industrial development. Only a few gardens remain, contrasting strongly with the surrounding urban landscape, but will probably become building sites in the not too distant future.

Construction of a reticulated sewerage system began in 1940, but it was not until between 1954 and 1968 that it was extended to properties adjacent to the Rivulet. Previously, many sewerage effluent pipes had discharged into the stream, making the Rivulet an unpleasant place to visit. Sewerage probably also detrimentally affected aquatic organisms, as it can seriously decrease dissolved oxygen concentrations in the water.

A planning scheme for the southern half of Glenorchy was formally accepted in 1964. A strip of land along either side of the Rivulet within the urban area was zoned as public open space (Map 7, p. 38). As properties were sub-divided, however, the Council did not take the opportunity to reserve the areas necessary to institute this part of the plan, presumably because the Rivulet was regarded as valueless. Hence property along the Rivulet remains almost invariably in private ownership, with title extending to the top of the bank. Exceptions are Council-owned playgrounds, plus the sports facilities (football ovals and a public swimming pool) between Main and Grove Roads. Amongst a small number of titles we have not searched, there may be a few where ownership extends to mid-channel. Three (adjacent) properties extend either side of the Rivulet between Brent Street Playground and Bowden Street, but this situation has eventuated only because of the 1872 flood, when the channel changed course and sliced each of these properties in two.

There are no restrictions on construction works arising from the proximity of allotments to the Rivulet, save for the Council's right of access to narrow maintenance easements in some areas, varying in width from 4.5 to about 8 m. These were registered on titles to sub-divided land where building occurred during and after the 1960's. In Melbourne, on the other hand, the policy of the Metropolitan Board of Works (M.M.B.W.) is that no structure should be erected within 100 ft. of specified creeks and rivers, nor within 50 ft. of others, listed separately.[40] Admittedly flooding in some suburbs of Melbourne is more severe than in Glenorchy and 100 or even 50 ft. wide reserves in the latter's compact landscape may be unnecessarily extravagant. Nevertheless, the value of such a strip of land in terms of flood protection and erosion control is potentially high. These problems are discussed in more detail in the next chapter, with a section specifically devoted to interactions between flooding and building practices adjacent to the Rivulet (pp. 85-87).

From the point of view of community awareness and attitudes, one result of the lack of a building code with regard to the Rivulet is that, concealed from most streets by development, it is inaccessible except to agile children. A combination of other factors reinforces disinterested and unfavourable attitudes. Presumably because of the Rivulet's past history as an open sewer and its present neglected state, some people apparently feel no qualms about dumping rubbish in the area. The portions of most industrial premises backing on to the Rivulet are ugly. Solid waste also enters the Channel through stormwater pipes: pipe entrances off gutters apparently lack grates or traps. In some dry summers when the reservoirs retain most flow, the Rivulet comes close to being a chain of stagnant pools.

CONCLUSION

A consequence of settlement around Humphrey Rivulet is clearly that the functioning of many natural systems which affect the Rivulet's flow and the quality of its water in the urban area have been disturbed. The characteristics of a stream are determined to a greater or lesser extent by occurrences anywhere within its catchment. Disturbances to natural systems can become manifest as problems for the community, however, when they result in damage to health or property to the extent that correction of disturbance is necessary. In our view, Humphrey Rivulet is at a stage when, if modern techniques working within the constraints set by its natural systems are applied, further disturbance can be prevented. A judgement that it should be prevented depends on whether it is recognized, as suggested by Brotchie, a C.S.I.R.O. research worker, that the costs of correction are strongly correlated with the degree of disturbance to natural systems. Our study of the present condition of Humphrey Rivulet supports the concept he proposed: "that minimal disturbance requires minimal correction and results in minimal overall cost."[41] We would add that there are potentially many community benefits to be gained from making the most of the Rivulet as an element of the urban landscape.

1. Personal communication from staff of the Australian Bureau of Statistics, Hobart. Additional census figures quoted were also provided by the Bureau.
2. RITCHIE, R.F., 1967; *Report on Flooding - Glenorchy Creeks,* p.6; unpublished report to Glenorchy City Council.
3. Rainfall information from: BUREAU OF METEOROLOGY, DEPARTMENT OF SCIENCE, 1975; *Climate of Hobart;* Australian Government Publishing Service, Canberra.
4. PAGE, B., and SMITH, H., 1976; *Wild Fire Hazard in the Environs of Hobart;* unpublished thesis, Department of Environmental Studies, University of Tasmania.
5. LEWIS, A.N., 1946; *The Geology of the Hobart District,* p.42; The Mercury Press, Hobart.
6. DAVIES, J.L., 1965; Landforms, p.19, in: Davies, J.L. (ed.) *Atlas of Tasmania;* Lands and Survey Department, Tasmania.
7. *Ibid.*
8. *Ibid.*
9. DAVIES, J.L., 1958; The cryoplanation of Mt. Wellington, *Papers of the Proceedings of the Royal Society of Tasmania* 92, 151-154.
10. Argued in: LEWIS, A.N., *op.cit.,* p.113.
11. DAVIES, J.L., 1971; Tasmanian landforms and Quaternary climates, 1-35 in: Jennings, J.N. and Mabbutt, J.A. (eds) *Landform Studies from Australia and New Guinea,* Australian National University Press, Canberra.
12. BOWDLER, S., 1975; Further radiocarbon dates from Cave Bay Cave, Hunter Island, N.W. Tasmania, *Australian Archeological Association Newsletter,* 3, 24-26.
13. See, for example, an early report on the aboriginal people of Southern Tasmania, in: WALKER, J.B., 1888-99; *Early Tasmania;* Papers read before the Royal Society of Tasmania (4th impression, 1973), Government Printer, Tasmania.
14. Principles of stream geomorphology applied to Humphrey Rivulet are our interpretations from field observation and from theory as stated in: CRICKMAY, C.H., 1974; *The Work of the River,* pp.14-27; The Macmillan Press, London and Basingstoke.
15. *Ibid.,* p.24.
16. Named by Captain John Hayes when exploring the Derwent in 1794.
17. Personal communication from Miss M. Murdoch, a descendant of early owners of "Murrayfield" and resident of Lenah Valley, Hobart.
18. ANONYMOUS: Unpublished paper from State Archives file *Glenorchy* without title commencing "Mr. Proctor...".
19. Personal communication, Mrs. M.E. Scott of "Burnside", Tolosa Street, Glenorchy.
20. Personal communication and photograph, Miss M. Murdoch.
21. ALLEN, J.H., 1969; *Serving God at Glenorchy,* p.8., Cox Kay, Hobart.
22. The mill race is still included in the survey diagram of the title to the property of Dominic College Primary School.

23. INSTITUTION OF ENGINEERS AUSTRALIA, 1958; Stormwater Standards Committee, Report on Australian rainfall and runoff, Figure 2-3.
24. Minutes of meetings in the possession of Miss M. Murdoch.
25. Programme of Glenorchy Municipal Celebrations, 1954, for the Tasmanian Sesquicentenary.
26. Information from Mr. B. Thomas of the Commercial Bank of Australia, which took over the assets of the Van Diemen's Land Bank in 1918.
27. *The Cyclopedia of Tasmania, 1900*. p.431 (Vol.1); Maitland and Krone, Hobart.
28. *Ibid.*, p.329.
29. STANCOMBE, G.H., 1968; *Highway in Van Diemen's Land*, p.84; Halstead Press, Sydney.
30. HULL, T.J.M., 1940; *Round the Fireside: Reminiscences of an old Glenorchy Resident*; unpublished manuscript in possession of Mrs. M.E. Scott.
31. Plans of the original structure, dated 1892, are in the files of the Glenorchy City Council.
32. CENTRAL BOARD OF HEALTH, 1889-1899; Report for the years 1888 and 1898, *Journals and Printed Papers of the Parliament of Tasmania*, Government Printer, Tasmania.
33. Plan of Kensington Estate, 1893, held in Crowther Collection, Tasmanian State Library, Hobart.
34. NORMAN, L., 1946; *Sea Wolves and Bandits*, p.205; W. Walch and Sons, Hobart.
35. Information from Glenorchy City Council records.
36. THE MUNICIPALITY OF GLENORCHY, 1964; *A Century in Glenorchy*, p.39; Specialty Press, Hobart.
37. ELECTROLYTIC ZINC COMPANY OF AUSTRALIA LTD., 1966; *E.Z. Review*, Mercury Press, Hobart.
38. MERCURY, 18 June, 1925.
39. Information from Glenorchy City Council records.
40. See M.M.B.W. Planning Scheme Ordinance, Clause 24(8), quoted in: PRESTON INSTITUTE OF TECHNOLOGY, SPECIAL PROJECT COMMITTEE, 1975; *Northern Melbourne Waterways Study*, p.29; Preston Institute of Technology Press.
41. BROTCHIE, J.F., 1974; Some system concepts for urban planning, *Royal Australian Planning Institute Journal* 12, 43-50.

PLANNING FOR FLOOD CONTROL AND WATER QUALITY

CHAPTER THREE

PLANNING FOR FLOOD CONTROL AND WATER QUALITY

Flooding and water quality are key factors in the study of waterways in urban areas as both can result in detrimental effects to the community.

Humphrey Rivulet has proven destructive ability. The peak of floods in both 1960 and 1961 came to within a few inches of the top of the flood protection walls built in 1858[1]. Results from analysis of expected maximum flows and the channel capacity required to pass them downstream without damage to property are included in this report. Since the Rivulet's hydrological regime is a constraint upon future management, the calculations allow for runoff from the catchment when the remaining land planned for sub-division is developed at a building density similar to that of present residential areas in Glenorchy. The calculations do not allow for further increases in the percentage of impervious surfaces per unit area throughout the catchment which would normally accompany higher density sub-division and commercial or industrial development. As our results indicate that the Rivulet will barely sustain the drainage load from sub-division at current densities, it is worth repeating our opinion that, without methods of catchment management designed to control additional runoff, artificial channelization of the Rivulet at great expense will be inevitable if damage in the urban area is to be prevented.

Water quality is the second factor given detailed attention in view of public comment concerning health risks associated with recreational contact with the stream in the urban area. A bacteriological analysis programme was carried out over a ten week period to provide a data base for recommendations. Discussion of the results and their implications for management form the second section of this chapter.

FLOODING AND EROSION

Calculation of flow

The calculation of flood flows in streams has been the subject of a number of treatise, summarised by Aitken.[2] Several statistical methods have been devised recently for the determination of maximum flows; however, such methods can only be used when detailed data on rainfall and stream flow is available. Records of rainfall at the Tolosa Street Reservoir close to where the Rivulet leaves the water catchment reserve are available,[3] but the stream gauging required to provide the data necessary for statistical models has never been undertaken. In the absence of such data the Rational Formula Deterministic Method (R.F.D.M.)[4] has been widely used by engineers and has proved satisfactory for the calculation of runoff from catchments of less than twenty six square kilometres[5] and so should be reasonably valid for Humphrey Rivulet, with a catchment of twenty three square kilometres. The standard R.F.D.M. was used in this investigation, together with a stream flow formula (see Appendix A) to allow for differences in flow expected to arise from the steepness of the upper catchment.

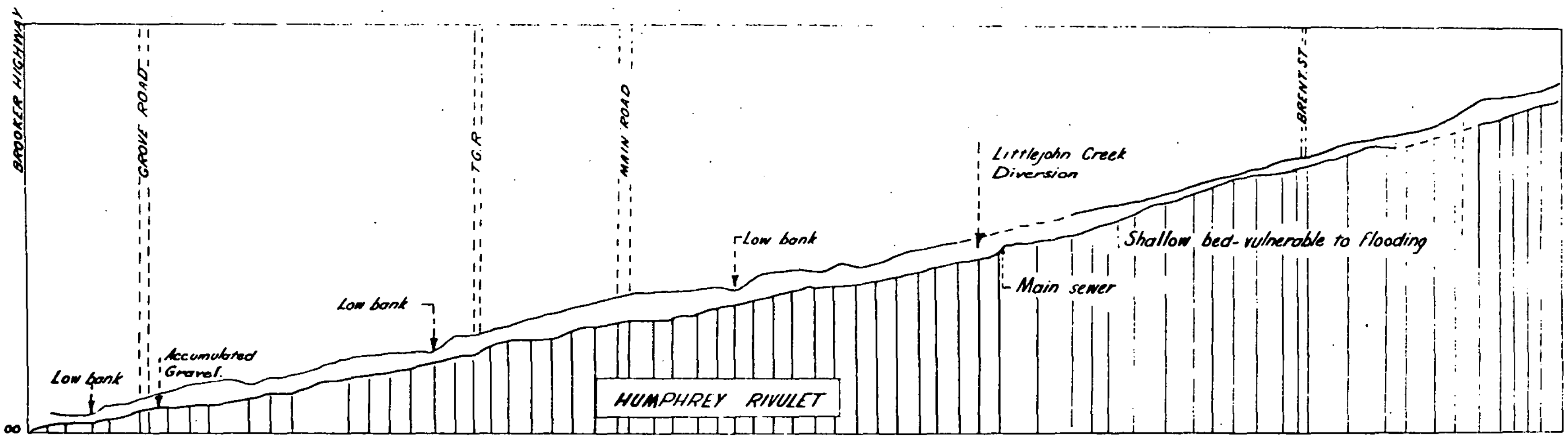
The R.F.D.M. is stated as:

$$Q = \frac{1}{360} CIA,$$

where Q = peak rate of runoff in cubic metres per second;
C = coefficient of runoff;
I = mean storm rainfall intensity for the catchment time of concentration, in millimetres per hour;
A = catchment area in hectares.

This formula utilises information about the area of catchments, the intensity of rainfall, and the percentage of the precipitation (expressed as co-efficient of runoff, C) which is expected to find its way into the stream. These parameters are used to calculate flow in streams at various points and for given storm frequencies.

For the purpose of our calculations the catchment of Humphrey Rivulet and its tributaries was segmented into sub-catchments in order to predict flow at a number of different points (Map 11). Some of these sub-catchments were further subdivided into urban and reserve components,

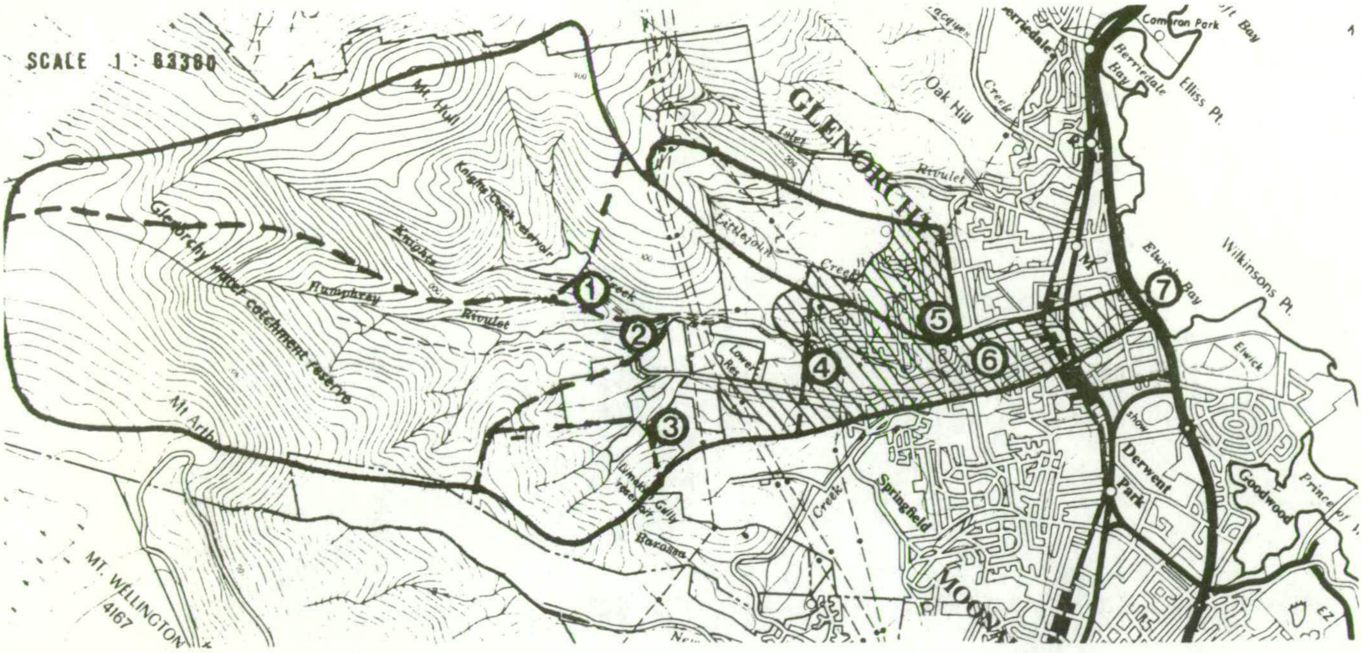


Horizontal distance along Rivulet (feet)	Height of lower bank above sea level (feet)	Height of stream bed above sea level (feet)
00		1.36
100	9.1	2.46
200	9.1	4.08
322	9.4	5.54
400	12.9	5.42
500	14.0	8.45
555		9.24
588		12.47
800	21.3	12.51
900		13.37
975	25.55	14.61
1100	23.0	18.22
1200	27.0	19.46
1300		19.36
1415	29.7	22.30
1500	32.4	25.21
1600	35.4	26.35
1700		27.30
1800	38.1	29.47
1900		31.45
2020	39.4	33.32
2123	43.6	35.66
2205	46.2	36.53
2300	48.1	41.24
2387	50.7	43.43
2500	54.8	44.49
2600		45.62
2700	59.0	48.54
2820	62.3	49.92
2925		51.88
2982		52.28
3100		53.29
3200	68.1	54.84
3312	69.5	58.58
3418	71.8	60.02
3500	69.4	61.82
3600	76.7	64.70
3700		66.23
3800	80.3	69.33
3900	79.6	70.16
4000	82.2	70.54
4100	81.8	72.40
4200		74.62
4300	87.4	76.61
4400		79.47
4500		81.75
4600	93.9	83.72
4700	97.80	84.64
4800		86.94
4810		91.54
4991	98.7	94.55
5166	106.6	97.00
5257	104.9	100.36
5343	110.04	
5467	112.28	106.85
5627	115.02	112.55
5764		116.62
5863	123.0	120.65
5973	122.0	124.20
6085	128.0	125.10
6196	132.84	127.33
6278	135.0	129.13
6329	134.2	130.05
6520	142.9	135.86
6700	144.0	138.41
6800	146.6	
6945	150.3	
7035	155.4	
7167	163.1	151.44
7268	164.5	154.60
7336		156.13
7404	165.2	159.11
7470		160.52
7575	172.0	163.29

Scale - Horizontal 1 inch = 400 feet
Vertical 1 inch = 40 feet

Adapted from Glenorchy City Council Plan No B227 dated April 1967.

Figure 5 Longitudinal section of Humphrey Rivulet from Brooker Highway to a few hundred yards above Brent Street. Slope is an important factor in calculations of channel capacity (see text page 79ff) as it affects velocity of flow and rate of discharge (Q).



Map 11 Division of catchment of Humphrey Rivulet into sub-catchments. Each number represents a point at which flow was calculated by the R.F.D.M. Results are given below. The hatched area around the lower Rivulet is either currently urban or planned urban.

Table 2 Flow at various points along the Rivulet, allowing for planned urban development to current density standards for residential areas in Glenorchy. Catchment portions designated rural are either Water Catchment Reserve or Forest Zone.

FLOW CALCULATION SITE	CATCHMENT AREA (ha)	CATCHMENT ALTITUDE RANGE (m)	LENGTH OF FLOW (km)	TIME OF CONCEN-TRATION (minutes)	RAINFALL INTENSITY (mm/hr)	MEAN COEFFICIENT OF RUNOFF	DESIGN STORM FREQUENCY (years)	FLOW (cubic m/sec)
1 Knight's Creek Reservoir	743	880	6.40	36	32.51	0.45	15	29.93
2 Humphrey Rivt-Knight's Ck Jcn	834	956	5.79	31	35.56	0.45	15	36.76
3 Limekiln Gully Reservoir	74	303	1.31	9	71.12	0.45	15	6.51
4 Upper Chapel Street	Rural 1948 Urban 50 Total 1998	1002	8.53	32	34.80	0.45	15	86.20
5 Littlejohn Ck diversion	Rural 122 Urban 63 Total 185	500	3.27	20	44.45	0.50	15	11.30
6 Balmain Street	Rural 2070 Urban 219 Total 2289	1042	10.20	57	23.50	0.46	15	68.14
7 Outfall to River Derwent	Rural 2070 Urban 278 Total 2348	1072	11.92	68	20.57	0.47	15	62.53

since the co-efficient of runoff usually varies significantly with land use. Flood frequency information, based on the statistical probability of a storm of a particular intensity which may occur at expected intervals, is available for the Hobart metropolitan area as a graph produced by the Institution of Engineers.[6] The calculation of required drainage and waterway capacity for both private and Council development in Glenorchy has for many years utilised this information to provide for a fifteen year flood frequency flow. This has been considered to be a reasonable compromise between flood damage costs and the cost of construction works.

The flows calculated for various points in the catchment and along the Rivulet are set out in Table 2. A flow of 86 cubic metres per second resulted from calculations for site 4. Although a reduction in flow is evident at sites 6 and 7, even with the addition of flow from the Littlejohn Creek diversion (site 5), the adoption of the larger figure will allow more flexibility in selection of waterway design options and future development densities. The apparent anomaly in flows from site 4 to site 7 arises through the method of calculation used and the shape of the catchment; the increasing area of the catchment downstream is more than compensated for by the lower rainfall intensity applicable to the longer time of concentration. The large fifteen year flood flow derived from the application of these formulae prompted the development of a theoretical channel cross-section judged necessary to accomodate these flows through the urban area and an investigation of the Rivulet's existing channel characteristics.

Channel capacity

Channel capacity is calculated with a standard empirical formula for flow and the Manning formula for velocity (see over and appendix B). The complementary use of the two formulae allows assessment of waterway or channel cross-sections for differing rates of flow (discharge Q) and for variations in physical characteristics of the channel. The method of calculation is described together with an explanation of the inter-relationship of the critical variables affecting the capacity of the waterway to contain flows of various magnitudes.

Manning's formula reflects the fact that any increase in the depth

The standard empirical formula for flow is stated as:
Q = AV,

where Q = rate of discharge in cubic metres per second;
A = area of section in square metres;
V = mean velocity of flow in metres per second.

The Manning formula for velocity of flow V is stated as:

$$V = \frac{R^{2/3} S^{1/2}}{N}$$

where V = mean velocity of flow in metres per second;
R = hydraulic mean depth, i.e., cross-sectional area of flow/wetted perimeter;
S = surface slope, i.e., fall/length;
N = rugosity co-efficient or Kutter's N.

(Source: Blake, L.S., 1975; *Civil Engineers Reference Book*, p.5-28; Newnes - Butterworths, London).

Plate 25 Erosion of alluvial gravels and soil, upper Chapel Street. As the far bank is on the outside of a curve, it tends to be undercut by the Rivulet. The eucalypts (*E. viminalis*) slow the erosion process by means of their root systems. (The late Alfred Sawyer's homestead in the background)

Plate 26 Accumulation of gravel, Grove Road bridge. Urgent removal of some of this material is necessary, as channel capacity to carry floodwaters is severely impaired. The channel upstream is also diminished by siltation and subsequent colonization by plants; an effect probably related to diminished flows on account of the holding capacity of the reservoirs upstream.

of flow in most channels results in an increase in the hydraulic mean radius R, with consequent increases in velocity. Increases in gradient or slope S also raise velocity. On the other hand, the velocity of the current varies inversely with the degree of ruggedness of the channel, expressed in the formula as the co-efficient of rugosity N. These parameters are important in understanding flow characteristics in Humphrey Rivulet.

For example, the downstream movement of thousands of tonnes of coarse gravel along the Rivulet bed provides evidence that flows of greater depth and velocity than normal contribute to both erosion and restriction of channel capacity. Severe erosion can result when the gravel is heaped into bars which add to turbulence and cause a redirection of the current. The flow then scours and undercuts banks. The channel dimensions beneath traffic bridges, such as where Grove Road crosses the Rivulet (see Plate 26) are reduced by accumulations of gravel, as well as by other materials carried downstream, including dumped rubbish. In 1959 approximately 5,500 cubic metres of riverwash gravel was removed mechanically from the stream bed between the River Derwent and the railway line to increase the capacity of the waterway. Since that time, an estimated 2,000 to 3,000 cubic metres have again accumulated in the same area. It is thought that most of this movement occurred in the 1960 fifty year flood.[7] Information cannot be located to establish the critical velocity which results in the movement of the larger gravels, but observation of the stream established that no observable movement occurs up to flows of 2.5 metres per second. The velocity and depth of flow which result in both excessive erosion and riverwash gravel movement could be accurately obtained by the monitoring of flows and deposition areas before, during, and after future floods. This data could then be used as a guide for the design of structures within the waterway, such as those of a type designed to dissipate energy, discussed below.

Given that increases in velocity exaggerate erosion and deposition, low velocity flow within the capacity of the waterway should be adopted as a desirable design criterion. The Rivulet, however, has a relatively steep gradient and velocities after rain tend to be high. A longitudinal plot of the Rivulet through the urban area reveals an average gradient of 1 in 50, as shown in Figure 5 . Field observations show

Plate 27 Bed of Humphrey Rivulet, off upper Chapel Street. Steps in the bed dissipate energy, thus reducing velocity.

Plate 28 Ponding at Latrobe University, Melbourne. In this case the small dam walls function as artificial falls during high flows. At the same time they also form a chain of small lakes: part of a scheme which makes the most of the stream as a setting for the University buildings.

many areas with gradient of approximately 1 in 500, with intermittent steps in the stream bed of 0.3 to 1 metre in height. This characteristic is common to many natural streams and has the effect of dissipating energy at each step or fall. As water rises during high flows, the irregularities which dissipate energy at low flows become merely a factor in the rugosity co-efficient and the average slope over longer distances becomes more important in determining velocity. To dissipate energy artificially and reduce velocity during floods, large, well designed falls and a wide shallow channel are necessary. Construction of this nature may prove expensive but the proposal could involve the creation of a series of small lakes, which leads to interesting recreational possibilities warranting further investigation (Plate 28).

Ruggedness in the channel to reduce velocity can also be effected by other means. Willows and other trees on the flood plain and through the bed of the stream act in this way. However, the willows are a mixed blessing. While their strong extensive root systems stabilize banks, broken limbs which fall into the Rivulet tend to take root after lodgement in silt and colonize the bed itself, thus restricting channel dimensions. In addition, large fallen branches are particularly troublesome because, during floods, debris may accumulate behind them and form a dam, causing the Rivulet to overtop banks upstream. One way of overcoming this problem is by pollarding, to prevent growth of extended, aged wood vulnerable to breakage by wind. The pollarded trees are sturdy, shaped "like a shaving brush",[8] and branches at the extremities are young and flexible.

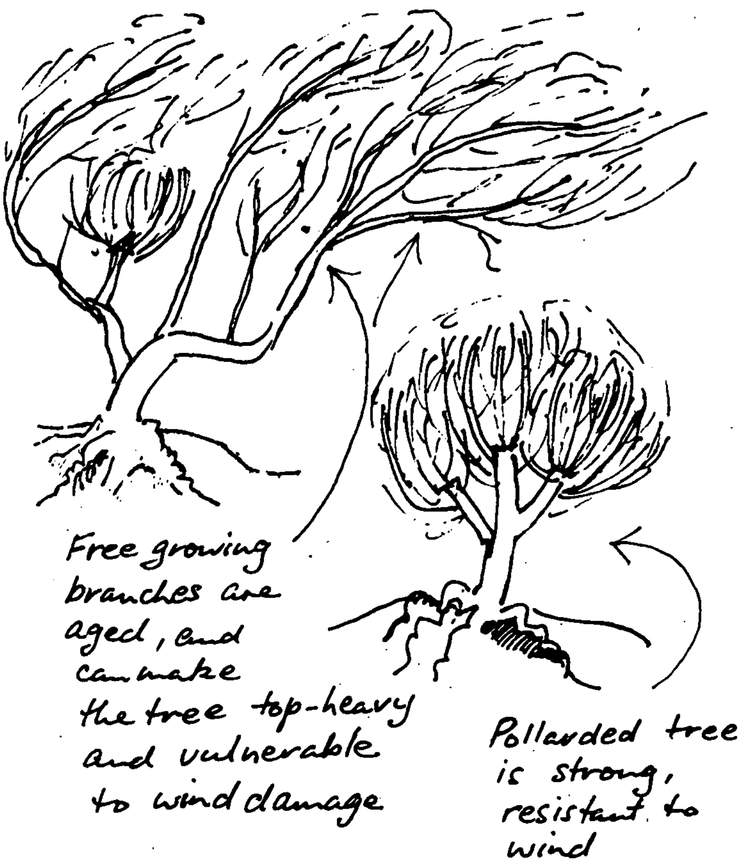


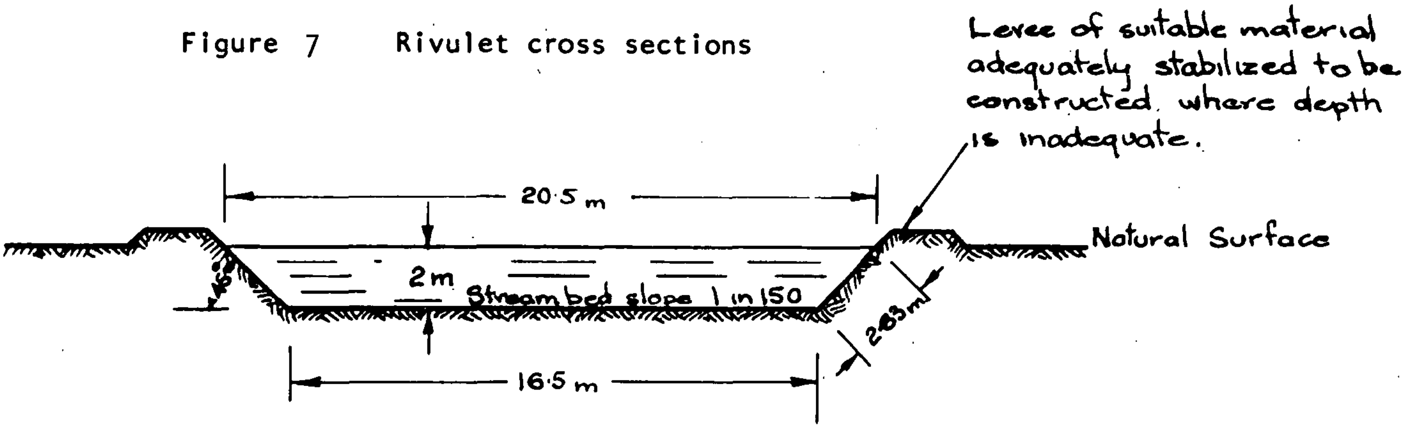
Figure 6 Introduced willows (*Salix* spp.), common along Humphrey Rivulet, are a valuable asset for stabilising banks, and also for reducing velocity of flow when at the edge of a stream channel. However, their growth must be controlled to prevent aged limbs from falling into the channel, as these can obstruct flow and prevent floodwater from escaping downstream.

Plate 29 Willows above Brent Street alongside section of the flood wall (1858).

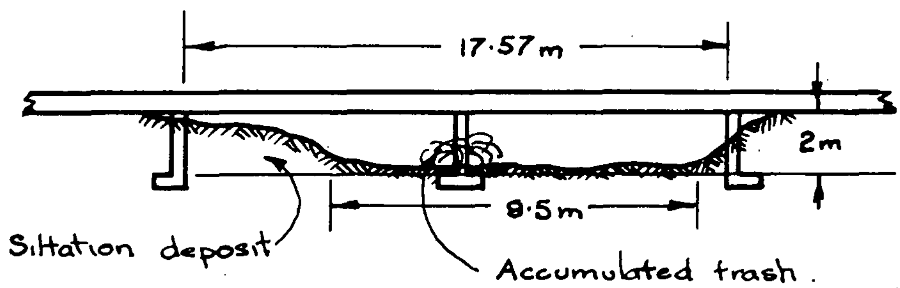
Flood plains contribute to low velocities by ponding, i.e., storing water and retarding flow. To fill a flood plain, on the contrary, results in higher velocities in the adjacent channel and may thereby cause inundation of downstream land which was not affected previously. The most critical area along the Rivulet from this point of view is low lying land below the Brent Street Playground where the channel changed course in 1872. If this land was filled, whatever the purpose, downstream flooding may occur, even without further urbanisation of other parts of the catchment. A major reason for the less damaging flows in Humphrey Rivulet in recent years is the retardation of flow due to the three reservoirs. Discharge over the outlet spillways only occurs once the storage is full and then only at a rate consistent with the height of water over the spillway crest. Maximum discharge would only occur when water reaches the level of the top of the dam, and this is rare. Knight's Creek Reservoir, with the largest catchment and storage capacity has the greatest ponding effect, but storage in Lime Kiln Gully and the Tolosa Street Reservoirs is also beneficial by delaying flow into the Rivulet till the peak of the flood has passed.[9] A deliberate lowering of reservoir levels prior to known flood danger periods (e.g., April) would reduce flood damage to a minimum. Such management could be introduced without detrimental effect to the use of the reservoirs for water supply purposes by a study of rainfall records and water consumption patterns. By chance, Knight's Creek Reservoir was empty[10] at the beginning of the storm which resulted in the 1960 flood and this factor saved Glenorchy from considerable damage. In any case, it seems desirable that discharge from the dam should be increased somewhat above present levels, particularly in summer, in order to provide a "flushing" flow to counteract shrinkage of channel dimensions resulting from siltation and subsequent colonization by plants (refer p. 66). It was also largely by chance that the lower reaches of the Rivulet had been cleared and deepened by the removal of riverwash gravel only months before this flood.

An additional cause for concern is the height of the dam wall on Knight's Creek. In 1967 a consulting engineer, R.F. Ritchie, warned of the need to investigate the spillway capacity and height, as the water had nearly broken over the crest of the wall itself in 1960. Although the dam is strongly built from heavy rock fill, he pronounced the situation as "highly undesirable and risky".[11] Nothing has been done in the meantime.

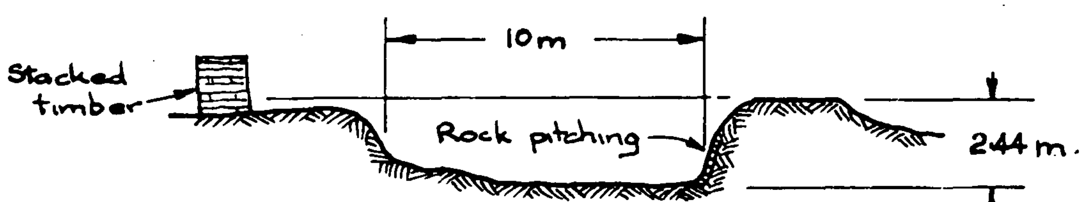
Figure 7 Rivulet cross sections



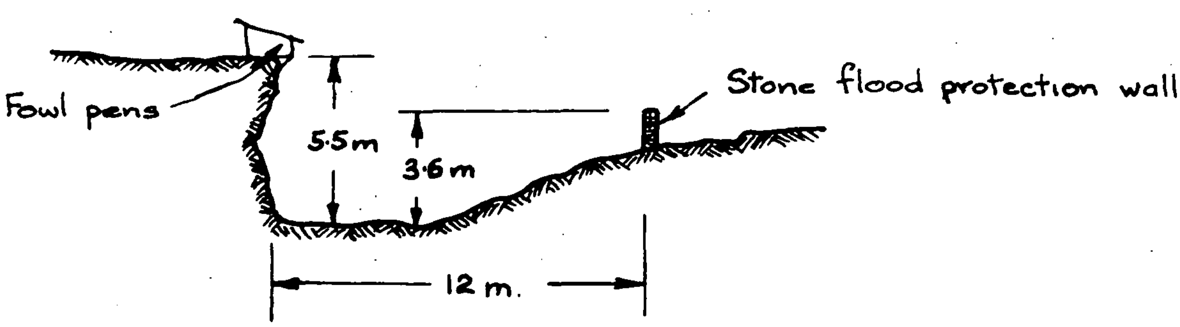
Desirable cross-section with capacity for 86 cu.m/sec flow at gradient 1:150



Observed cross-section, Brooker Highway bridge



Observed cross-section near Glenorchy Olympic Pool



Observed cross-section near Bowden Street

All sections shown viewed downstream.

A channel cross-section designed to accommodate a 15 year flood under conditions of full residential development has been calculated (see Figure 7 and, for more details, Appendix B). Measured cross-sections of the Rivulet at several locations are also included. The theoretical cross-section is drawn on the basis that stream gradient in the urban area can be reduced to 1 in 150 by artificial means, in order to keep velocity low (at 2.29 m/sec). These results imply that either catchment management or channel improvements may be required even if the proportion of impervious surface per unit area in the valley is not increased.

Building, land use, and flooding

In several ways unrestricted building and works adjacent to the Rivulet directly affect flow characteristics as well as limit the range of measures available to prevent damage from flooding.

The effects on flow of filling flood plains have been mentioned in the previous section. With the exception of the larger area between Brent and Bowden Streets and smaller areas upstream (marked on concept plan Maps, p. 125 ff), it is now difficult to determine the full extent of Humphrey Rivulet's flood plain because of existing development. It is likely that some of the low lying land downstream from the railway line suffered inundation in the past,[12] particularly in view of the fact that the outfalls of Humphrey Rivulet and Littlejohn and Barossa Creeks all lie within 0.6 of a km along the Derwent. Rough levees line some of the banks near Grove Road but are severely eroded. Regrading, increases in height, and stabilization are clearly needed. Filling, in at least one location where the banks are high, is causing channel shrinkage (Plate 31, p. 86). This practice, as well as that of building at the top of the bank must be prevented. A major factor contributing to the severe flooding around Hobart Rivulet in 1960 was that structures had encroached upon the channel.[13] These had to be removed at considerable cost afterwards.

Comprehensive action in this regard will be difficult at many locations both in this area and further upstream. Fences, and in some cases buildings prevent access and do not allow the necessary space for regrading. The magnitude of this problem is growing virtually daily in the new sub-divisions ("Eucalyptus Grove" and "Tolosavale") in Merton, as houses are built within 12m of the top of the bank. In addition, the

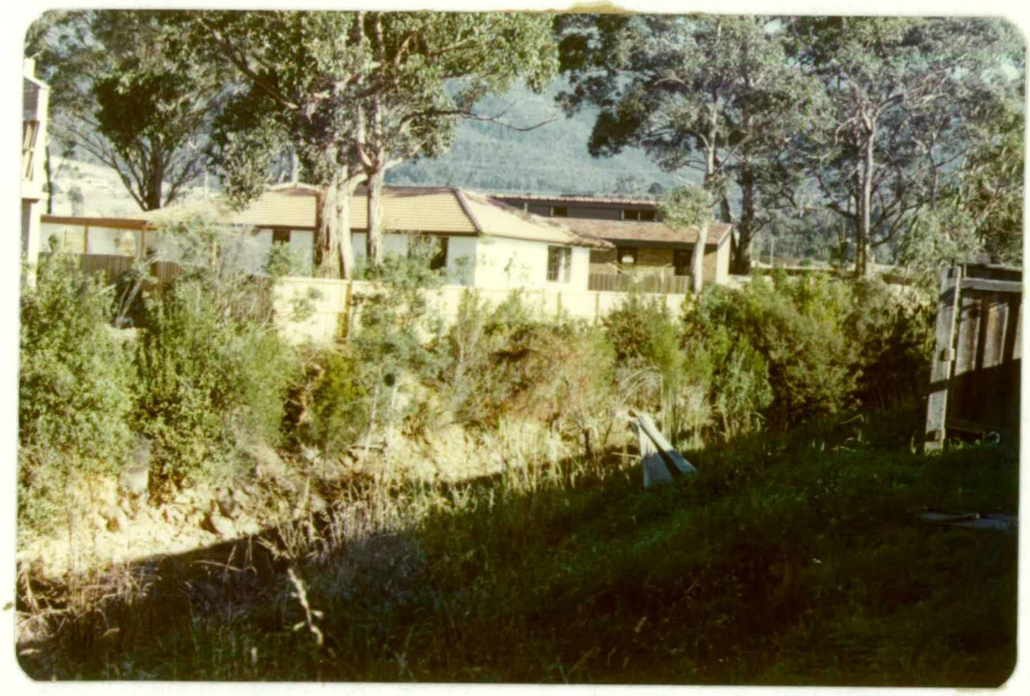


Plate 30 Accessibility for maintenance restricted as new homes are built. The far bank is steep, but is protected from erosion to a degree by indigenous vegetation. However, the land has been cleared virtually to the edge of the bank; there is no second line of defence.

Plate 31 Filling of the watercourse. Encroachment into the channel like this can result in flooding nearby as well as increase siltation and turbidity.

high, near vertical banks are vulnerable to erosion. At present, indigeneous shrubs cling to the alluvial soil, but on top of the bank the land has been cleared almost to the edge of the channel except for a few larger trees. Unless householders act on their own initiative there will be no second vegetative line of defence if the existing ground cover is torn away by floods.

Siltation, which reduces channel dimensions downstream, is also aggravated by unregulated clearing in these sub-divisions. New stormwater outlets terminate in loose soil above the stream bed, so that high velocity runoff scours the bank below. Ideally these should be provided with a rough textured outlet channel of their own, terminating at the edge or centre of the Rivulet channel. Coarse gravel set in concrete would seem to be a good solution, achieving some velocity reduction at the same time.

In order to minimize these problems and to lessen the danger from floods to property, it would seem essential that the Council not only institute a building code with regard to the Rivulet, but either acquire a strip of land or come to an agreement with developers and property owners when new sub-divisions occur. This land should be wide enough to accommodate maintenance tracks and to allow the construction of proper levee banks and/or regrading where necessary. Useful vegetation, especially indigenous species which are well adapted to prevailing conditions should be retained as a buffer zone against erosion. Some possibilities for exercising control over land use without acquisition are discussed in the last section of this chapter (p.94).

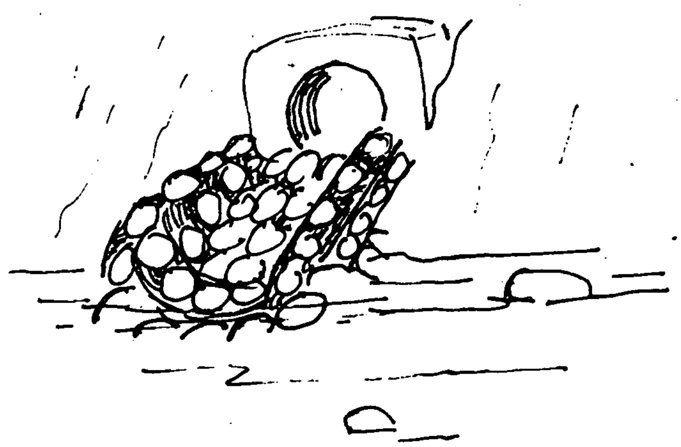


Figure 8 Idea for rough textured outlet for stormwater drain, made of stones from the Rivulet (coarse gravel) set in concrete.

WATER QUALITY

Target criteria for water quality depend on the potential use of a stream and of the area through which it flows. The parameters we have selected as of importance in the assessment of Humphrey Rivulet relate to recreational and aesthetic values of the stream, given that four reserve/ playground areas adjoin its banks and that the aim of this report is evaluation of the feasibility of building a public open space system. The reader is referred elsewhere for a summary of other parameters, such as dissolved oxygen content, and the implications of their values for aquatic life[14].

Microbiological water analyses

No available routine bacteriological examination can establish with certainty the presence in water of pathogenic micro-organisms which carry infection, but the presence of biological indicator organisms is accepted as the current most practical means of measuring the hazards associated with the use of water[15]. The most commonly used indicators are the coliform group and faecal streptococci, both usually present in human and animal excreta. Bacteriological standards for contact recreation in Australian waters have been suggested by Hart[16], as shown below.

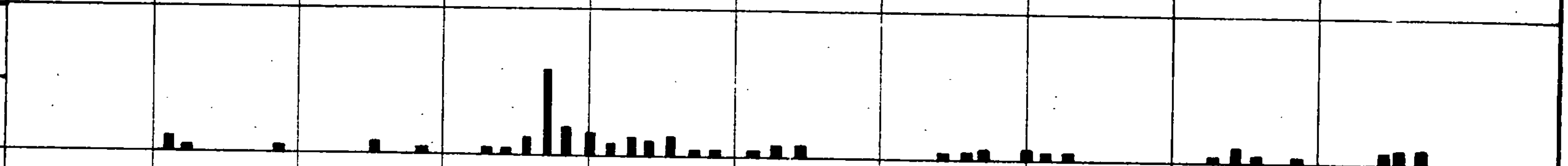
Table 3 Bacteriological quality of recreational waters
(Source: HART, B.T., 1974; *A Compilation of Australian Water Quality Criteria,* p.165; Australian Water Resources Council, Technical Paper No. 7, Australian Government Publishing Service, Canberra)

Faecal Coliform level (organisms /100 ml)	Classification
2 000	heavily polluted, water objectionable
1 000 to 2 000	distinct pollution, water suspect
50 to 200	slight pollution
50	satisfactory water

If the level of 200 faecal coliforms /100 ml is approached or exceeded regularly during the recreational season, it is recommended that action be taken by the relevant authority to assess the possible health risk. This further action will almost certainly include a full sanitary survey of the area to assess sources of pullutant input to the recreational area. Such surveys may also include the analysis of the waters for pathogenic bacteria and viruses.

With the present state of knowledge it is stressed that these bacteriological criteria are a guide based on the possibility of health hazards rather than the probability of actual danger to the health of the swimmer.

Table 4 Microbiological analysis of samples from Humphrey Rivulet at four sites (S1 to S4, indicated on Map 6). See next page for discussion of results.

Date	Site	13-7-76	20-7-76	27-7-76	3-8-76	10-8-76	17-8-76	24-8-76	31-8-76	7-9-76	14-9-76
Daily Rainfall mm (100, 50)											
Total Coliforms/ 100 ml	1	24	36	52	102	4	2	2	6	0	0
	2	94	62	174	645	235	22	258	184	30	520
	3	418	1200	790	1400	110	40	500	245	260	305
	4	172	890	290	1780	100	60	355	210	245	140
Faecal Coliforms/ 100 ml	1	0	24	24	74	6	0	0	4	0	0
	2	18	52	122	345	250	6	212	122	28	445
	3	72	690	420	920	120	5	420	155	215	240
	4	60	570	280	890	60	70	320	150	200	55
Faecal Strepto-cocci/ 100 ml	1	0	2	2	26	4	4	2	2	2	2
	2	8	75	4	256	5	2	28	14	6	174
	3	36	180	30	710	10	5	25	5	20	150
	4	22	280	30	1050	60	75	135	35	40	30

The histogram for sample bacteriological densities is plotted to a log scale.

Table 5 Microbiological analyses of samples from some pipes at point of discharge into the Rivulet (other than known stormwater drains).

Pipes	Total coliforms	Faecal coliforms	Faecal streptococci	Faecal coli./ faecal strep.
P1	2,030	1,600	290	5.5*
P2	300,000 +	300,000 +	40	7,500*
P3	4,100	3,000	30	100*
P4	94,000	97,000	12,300	7.89*
P5	6,900	6,400	1,760	3.64
P6	840	710	810	.87
P7	2,300	1,900	10	190*
P8	14,000	1,200	540	2.22

* Faecal coliform/faecal streptococci ratio indicates possible contamination from human excreta

(Location of pipes indicated in Maps on p.125 ff)

The levels obtained in samples from Humphrey Rivulet, taken over a period of ten weeks from July to September 1976 at four sites (shown in Map 6 , p. 38) are given on p. 89. These results indicate that further testing is advisable with a view to correction in the interests of public health. The following conclusions are drawn :

i) samples from the Water Catchment Reserve were of high quality bacteriologically;

ii) as faecal coliform and streptococci densities fairly regularly exceeded standards for contact recreation during the ten weeks at sites S2, 3, and 4, it seems that there are sources of recent contamination with outflows to the Rivulet within the urban area;

iii) there is some evidence that bacteria from human faeces are present in the Rivulet at times, in accord with the theory advanced by Geldreich (1972)[17], i.e., that the sources of faecal bacteria are human, rather than animal, when the ratio of faecal coliforms to faecal streptococci exceeds 4 (as Geldreich found in domestic sewage).

iv) site S3 levels definitely give cause for concern, particularly in view of the fact that the sampling site was within the Brent Street playground.

A further series of samples, taken from piped discharges (other than known stormwater drains) to the Rivulet provides some evidence of the sources of contamination (Table 5). It seems that, although the urban area is nominally sewered, some faulty septic tanks discharge into the stream. Possible other sources are discharge from the Council Disposal Area (off upper Chapel Street) or premises where animals such as horses are kept.

Aesthetic water quality criteria

According to Hart[18] :

"It is considered that to be aesthetically pleasing water should be essentially free from:

a) floating debris, oil, grease, scum or other objectionable matter;

b) substances that produce undesirable colour, odour, taste, turbidity, and foaming;

c) undesirable aquatic life such as 'water blooms' or heavy growths of attached plants or animals."

Plate 32

Humphrey Rivulet, from time to time and at varying locations which are mainly downstream from Bowden Street, fails to meet the criteria specified in (a) above under conditions of low flow. Yet, overall, the problem which probably rates the most concern is dumped solid waste, which includes rubbish discharged from stormwater drains. In our opinion, it is this situation which gives most urban reaches of the Rivulet an air of dereliction and neglect, reinforcing attitudes of disinterest and distaste.

Observation showed that the Rivulet is turbid after rain for a short time, but is commonly clear. Control of excessive erosion at a few locations and of runoff from sub-divisions where the land is being cleared for construction would imporve the situation still further. The only offensive colouring agent in the Rivulet was dark brown hard-wood lignum, discharged in reasonably small amounts from one pipe. Our only comment is that it, too, contributes to perception of the Rivulet as a dumping ground.

Algal growth on coarse gravel in the bed from Brent Street to Elwick Bay is fairly thick. We were not able to ascertain whether it could be classified as excessive, but it is quite likely there are inputs of phosphorous and nitrogen to the Rivulet, derived from fertilizers used on household and market gardens. These substances "affect rate and amount of plant growth".[19]

RESPONSIBILITY

The question of responsibility for the environment inevitably arises when consideration is being given to development work in what are traditionally areas of common ownership or which involve complex public and private interests. The local authority, which is the corporate representative of the community, has special responsibilities and duties as set out in legislation.

The legal responsibility for maintenance of natural watercourses in Tasmania is the subject of clauses in three Acts :

i) the Local Government Act 1962;
ii) the Sewers and Drains Act 1954;
iii) the Water Act 1957.

These Acts, while placing general responsibility for flood prevention, erosion, and pollution on the Local Authority are non-specific in some areas of legal duty. Legal opinions obtained by the Glenorchy City Council after the 1960 flood[20] have placed responsibility for flood mitigation in Humphrey Rivulet between the Main Road and the River Derwent on the Council (due to its ownership in title of this section of the waterway[21]), but have suggested that the property owners who abut the Rivulet or own part of it are responsible for its banks. This issue may now be confused by the numerous common drains, from highways and adjacent areas, connected to the stream. This situation could mean that the Rivulet is a common drain[22].

Common law action against nuisance, based on the ruling in *Rylands V. Fletcher* [23], introduces further legal complexities, as that case may be used as a precedent in claims for damage which results from any alteration to the natural state of a watercourse. This form of action has been widely and effectively used. An inspection of Humphrey Rivulet reveals construction works and negligence which may result in damage if severe flooding occurs. Common law action based on the above principle could prove that such irresponsibility is expensive.

Legal authority to cleanse and control pollution in streams is more definite, with legislation placing responsibility on the Local Authority[24], except for discharges from Scheduled Premises which are controlled by the Department of the Environment[25].

A general conclusion as to the duties and responsibilities in relation to watercourses, based on an evaluation of the Acts involved and legal opinions available, indicates the need for the exercise of corporate public responsibility. This of necessity should be co-ordinated by the Local Authority. It is therefore desirable that the Glenorchy City Council purchases or exercises controls over sufficient land along the banks to protect the flood plain and to carry out works necessary to mitigate erosion. Maintenance of water quality and alleviation of pollution to acceptable standards are practical problems which require the provision of alternative outfall in some cases, and enforcement of control in others. In either case, the Local Authority has the appropriate powers to execute necessary measures.

Alternatives exist for control of land use without outright purchase, and these are receiving increasing attention in Australia. A summary of these is given in a 1976 report *The Industrial Yarra : Possibilities for Change*[26]. An important principle is noted in that report, whether acquisition or agreements of varying types are envisaged: that negotiations with owners to identify and allow for their needs ought to be undertaken seriously.

Techniques for control without acquisition include :

i) assistance in return for covenants, such as provision of grants and reduction of rates and taxes if an owner agrees to accept a title covenant which protects the site for certain purposes, e.g., portion of a property classified as a scenic easement;

ii) access or right of way agreements to make a portion of private land available for public use, as is common in English National Parks;

iii) recognition of action by companies or public authorities for works such as landscaping, planting of strips of their land; this might take the form of supply of expertise and some materials.

CONCLUSION

This study of flooding, related problems, and water quality indicates that Humphrey Rivulet needs attention and will demand more attention as pressures from urbanisation in the catchment grow.

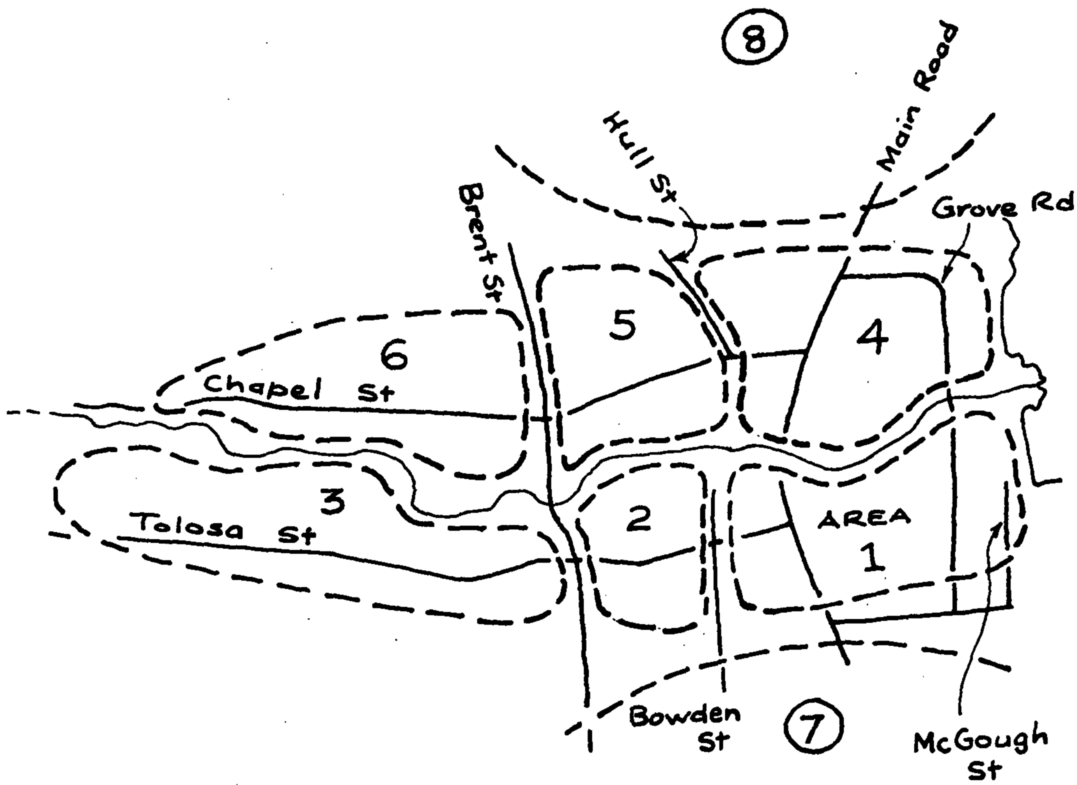
Runoff control as part of a possible future programme has not been dealt with separately in this chapter, as our comments are already summarized in Chapter 1, pp. 25-31. The next chapter discusses some of the needs of nearby residents, as interpreted from survey results. All information is then integrated and related to possible construction of an open space system in a final chapter.

1. Personal communication, G. RUUT, Clerk of Works, Glenorchy City Council, who observed the Rivulet in flood.
2. AITKEN, A. P., 1975; *Hydrological Investigation and Design of Urban Stormwater Drainage Systems;* Australian Water Resources Council Technical Paper No. 7, Australian Government Publishing Service, Canberra.
3. Glenorchy City Council records.
4. AITKEN, A.P., 1975; *op.cit.,* p.32.
5. UNITED STATES DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, 1960; *Design of Small Dams,* pp. 47-53; U.S. Government Printing Office, Washington.
6. INSTITUTION OF ENGINEERS AUSTRALIA, 1958; Stormwater Standards Committee, Report on Australian rainfall and runoff, Figure 4-7.
7. Personal communication from Mr. G.W. FEHLBURG the contractor who completed the channel work.
8. STROM, H.G., 1962; *River Improvement and Drainage in Australia and New Zealand,* p. 105; State Rivers and Water Supply Commission, Victoria.
9. PUBLIC INTEREST RESEARCH GROUP (P.I.R.G.), 1975; *The Merri Creek Study,* p. 73; Victorian Public Interest Research Group Ltd., University of Melbourne.
10. Personal communication from MR. P.E. PARSONS, Municipal Engineer of Glenorchy in 1960.
11. RITCHIE, R.F., 1967; *op.cit.,* p. 4A.
12. Ritchie drew attention to the vulnerability to flooding of the land in the vicinity of Grove Road, and also warned against the danger of floodwaters from Humphrey Rivulet and Barossa Creek joining in the vicinity of lower Tolosa Street. *Ibid.*
13. HOBART RIVULET FLOOD PROTECTION AUTHORITY, 1963; *Report on Protection against Flooding from the Hobart Rivulet,* p. 18.
14. PRESTON INSTITUTE OF TECHNOLOGY, SPECIAL PROJECT COMMITTEE, 1975; *Northern Melbourne Waterways Study,* p. 21; Preston Institute of Technology Press.
15. HART, B.T., 1974; *A Compilation of Australian Water Quality Criteria,* pp. 156, 165; Australian Water Resources Council, Technical Paper No.10, Australian Government Publishing Service, Canberra.
16. *Ibid.,* p. 165.
17. GELDREICH, E.E., 1972; Buffalo Lake recreational water quality: a study in bacteriological data interpretation, *Water Research* 6, 913-924. cited in: Hart, B.T., 1975; *op.cit.*.
18. HART, B.T., 1974; *op.cit.,*p. 47.
19. PRESTON INSTITUTE OF TECHNOLOGY, SPECIAL PROJECT COMMITTEE, 1975; *op.cit.,* p. 21.
20. Legal opinion obtained by Glenorchy City Council, dated 29 August 1960, from R.C. Wood of Piggott, Jennings, Wood, and Baker.
21. Certificate of Title; this portion of the bed of the Rivulet was accepted by the Council in lieu of rates payable.
22. Section 15, Sewers and Drains Act 1954, Tasmania.

23. (1868) LR3 HL330. Cited in: P.I.R.G., *op.cit.*, p. 58.
24. Section 553, Local Government Act 1962, and Section 79, Water Act 1957, Tasmania.
25. Section 25, Environment Protection Act 1973, Tasmania.
26. UDPA PLANNERS, 1976; *The Industrial Yarra : Possibilities for Change*, p. 41, 42; UDPA Planners, Melbourne.

RESIDENT SURVEY

CHAPTER FOUR



Map 12 For purposes of the survey, which is discussed on the following pages, the study area was divided into six sub-areas (1 - 6 above). Each sub-area extended two or three residential blocks on their side of the Rivulet. The sub-areas also represented the origin and possible destination of residents' frequent, regular journeys, while areas 7 and 8 represent destinations south of Glenorchy and north of Glenorchy respectively.

In order to predict whether an open space system along Humphrey Rivulet in urban Glenorchy and Merton might be useful to the residents in ways additional to protection from flooding, interviews seeking information in two categories were conducted in 154 homes located within two or three blocks of the Rivulet. Firstly, we wanted to establish some characteristics of the most frequent journeys which people undertook from their homes, viz., origin, destination, and purpose of trips, as well as modes of travel, thus giving a basis for deciding whether access to facilities could be improved by a Rivulet based system of footpaths and cycle tracks. Secondly, people were asked a series of questions related to usage and evaluation of existing recreational facilities for children in their immediate area, and also of the Tolosa Street Reservoir Park. Through answers to these questions, we hoped to gain an appreciation of what people wanted in the way of open spaces for recreation.

Initially, the study area was divided into six areas (Map 12 opposite) and 34 homes selected from each at random, but time and the difficulty of finding many people at home permitted interviewing in 154 of the 204 households we had hoped to contact. The 154 homes visited amounted to 13.4 per cent of all homes in the study area, and replies to questions were given normally by one, but sometimes by a few members of the household, on behalf of 489 residents. Full details of the questionnaire, sampling procedures, and processing of results are given in Appendix C, p. 145.

RESIDENTS' JOURNEYS : RESULTS FROM QUESTIONNAIRE AND IMPLICATIONS

Summary of results

Selected results from this segment of the survey are :

a. predictably, most trips undertaken at least three times weekly and once weekly from sample households were by motor vehicle, but 20 per cent were on foot or included a substantial walking component (e.g., walk one way, catch bus home); a breakdown of all trips

Table 6 Mode of travel for all trips undertaken by permanent residents of 154 households where interviews were conducted.

	Walk	*Walk +Other	Walk One Way	Cycle	Car	Bus	Taxi	Other
Daily Trips, or at least 3 times a week	129	11	4	8	392	110	3	5
Weekly Trips	121	6	3	1	478	74	3	4
TOTAL	250	17	7	9	870	184	6	9
PERCENTAGE OF TOTAL		20.3			64.3	13.6		

* WALK AND OTHER was not defined as merely walking to one's garage or to the bus stop at the front gate, but as a walk of at least a few hundred yards to a boarding point for public transport, or, for example, to a friend's place to take advantage of a lift.

Table 7 Purpose of trips within and outside the study area.

Purpose of Trip	Within Study Area	Outside Study Area	Total
Work	42	148	190
School	104	25	129
Shop	215	72	287
Recreation	216	387	603
Other	81	60	143

according to mode of travel is given in Table 6;

b. 40 percent of trips to destinations within the study area were on foot;

c. the most frequent walkers were residents over 65 years old, and young people in the 5 - 17 age range;

d. the purpose of all trips, according to whether within or beyond the study area, are shown in Table 7.

Implications for urban planning and for design of an open space system

A significant result from the point of view of assessing the layout of the urban study area, where the pedestrian network can be described as an adjunct of the road system and traffic generally takes precedence when pedestrians wish to cross roads, is that 40 per cent of all journeys recorded are, nevertheless, either completely or partially undertaken on foot. Understandably, walking trips as a proportion of all trips, that is, adding in journeys which extended beyond the study area, decreased, but still rate quite highly at 20 percent. These figures suggest that the needs of pedestrians ought to be given a great deal of attention, lending weight to arguments that undue emphasis is generally placed on the road system at the expense of pedestrians in cities where motor vehicles are heavily used. An additional factor which the results do not fully take into account is that, because the survey was carried out in winter, the regular trips people talked about were presumably those freshest in their memory. An increased rate of journeys on foot might be expected in the warmer months. However, people were asked to account for their regular summer trips if possible, largely because we were particularly interested in children's trips to the public swimming pool. The reasons for this are clear in the discussion on p.105.

Further results give added force to the case for better facilities for pedestrians. A breakdown of trips according to age groups of persons shows that the most frequent walkers, as defined by the ratio of walking trips made to all trips undertaken by a particular age group, are the aged and the young, as shown in Table 8 below.

Table 8 Mode of travel for trips within and beyond the study area according to age group

	Walk or Walking Component	Cycle	Car	Bus	Taxi	Number of Trips	% of Walking Trips
Over 65	44	2	48	16	2	112	39
45-65	63	2	251	40	2	358	17
25-44	52	-	266	29	-	347	15
18-24	10	-	112	19	1	142	<1
12-17	33	1	65	46	1	145	23
5-11	47	4	54	32	-	137	34
Under 5	13	-	62	10	1	86	15

Generally these are the people least able to cope with traffic and who ought to be shielded from conflict situations with motor vehicles as much as possible on their journeys. The elderly in particular are probably most sensitive to noise and exhaust gases, yet apparently like to be where there is much activity so that they can watch others. It is therefore reasonable that opportunities should be sought by planners to provide places for the aged to sit in comfort in shopping centres, for instance, but somewhat removed from heavy traffic. Although conflict exists between this idea and reality, in the sense that in most cities activities are centred where the traffic is heavy,there is no doubt that good design of a traffic-free precinct as part of a shopping centre can attract many people as a place to sit and watch others as well as to do their own business. Cat and Fiddle Arcade, Hobart, is a good example; the bench seats around the fountain, where children play, are always crowded on shopping days in fair weather.

Older people would also appreciate the opportunity to rest during their journeys. This could probably be most easily achieved as part of an open space system, where benches could be placed to one side of a path in attractive surroundings. On the other hand, there are alternatives which could be implemented independently or, better still, in conjunction with an open space system along the Rivulet.

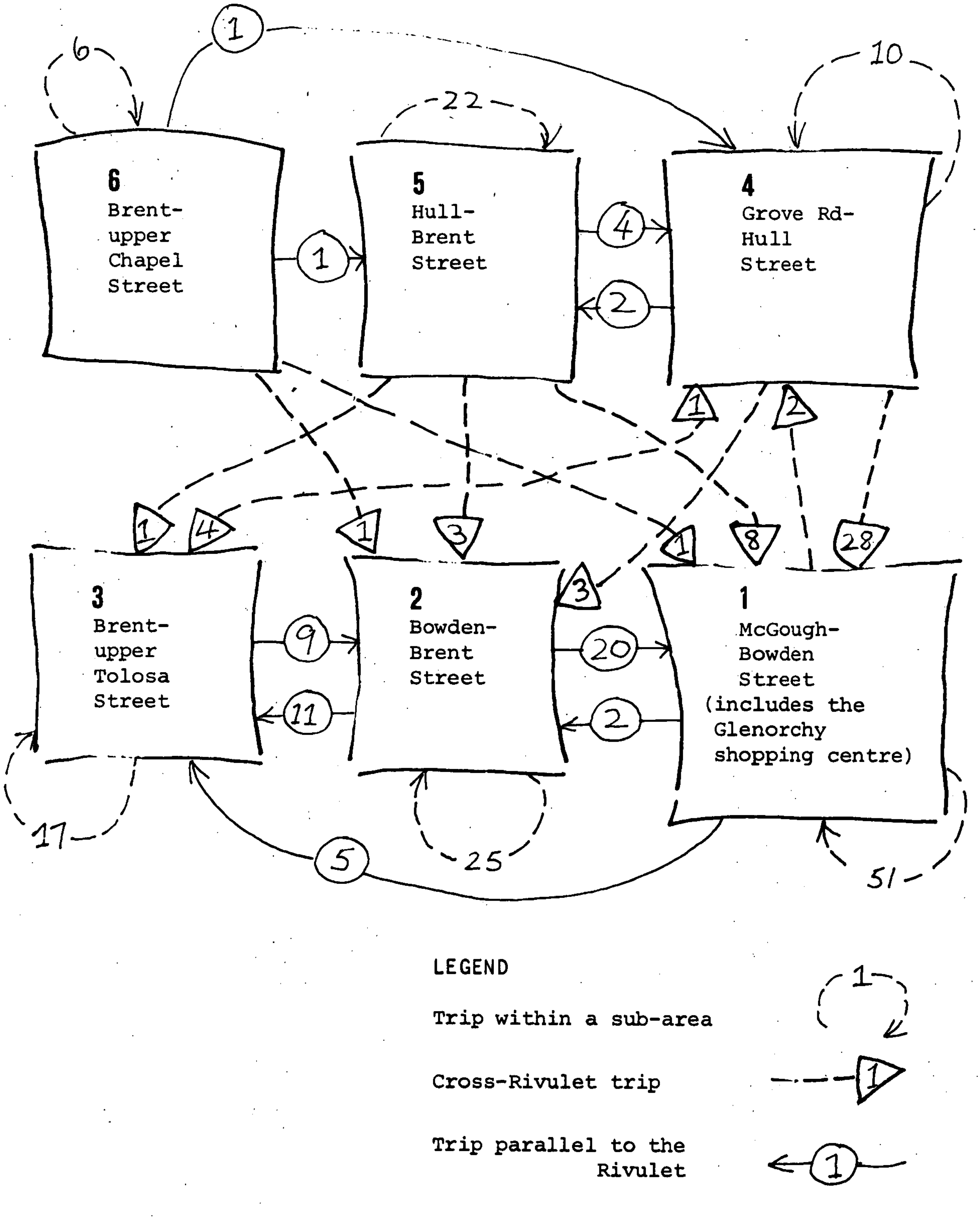


Figure 9 Walking trips, either daily or at least three times per week and once weekly within and between sub-areas of the study area around the Rivulet. Trips within the sub-areas totalled 131, parallel to the Rivulet 55, and across the Rivulet by means of the road system 52.

Roads like Tolosa and Chapel Streets could be deliberately narrowed, at least in some sections. These two streets are primarily residential, and are not through routes. The effect would be to slow the flow of traffic and at the same time provide a widened pavement where some seats could be installed and perhaps some trees grown. A change in the texture of road surfaces, such as stone cobbled strips or even strips raised about 4 inches ("sleeping policemen") could facilitate crossing, as drivers would be alerted that they are approaching a spot where pedestrians might be expected. These techniques are now fairly common in Europe, and some research and design reports on particular measures have been published[1].

Provision of these kinds of facilities could benefit all pedestrians, no matter what their age. In particular, many of the walking trips undertaken frequently within the study area (shown in Figure 9) might divert to a Rivulet pathway system when people find it a convenient route to use. Apart from the incentive of safety from traffic, residents on shopping journeys, for example, might choose these routes precisely because there are resting places along the way and because there are areas which could capture their children's interest. Thus the pathway system effectively widens the range of choices available; a journey which has an essentially routine purpose may become recreational as well.

With regard to projected usage of the path system, the following points are made:

i) Additional walking trips, some of which were not undertaken regularly at all in the past or which were normally made by car might be generated if convenient and attractive access is made available;

ii) many trips within a sub-area (55 per cent of local journeys on foot) could take advantage of a Rivulet pathway, e.g., people moving from the Grove Road portion of Area 1 to the Glenorchy Shopping Centre;

iii) trips which are essentially recreational, i.e, walking for pleasure, which, at the time of survey, mainly consisted of walking about the streets, might often transfer to the Rivulet because of its interest and contrast with the built environment;

iv) in view of the world-wide concern for energy supplies, particularly automobile fuels, it makes good planning sense to offer people alternatives to travel by car.

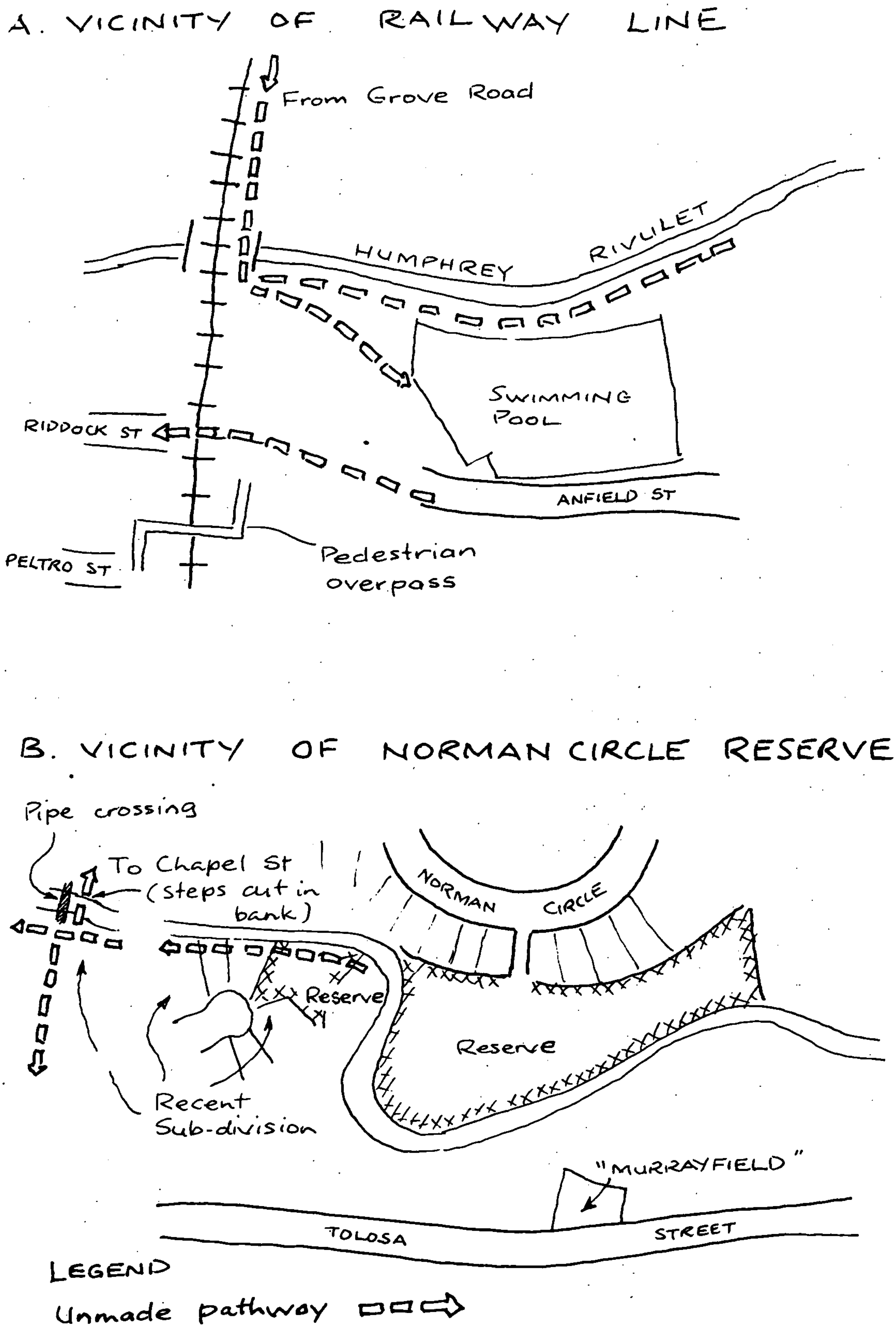
The last point, although phrased in terms of urban dwellers' future needs as the cost of motoring increases, has already been proposed in terms of current energy usage efficiency. For example, in 1974 a report from a study in the United States recommended that, because the car was a highly inefficient user of energy for short urban trips, encouragement should be given to people to travel "by energy-efficient modes, e.g., foot, bicycle, or mass transit."[2]

Particular access problems noted during survey

Observation along the Rivulet's banks showed the existence of a network of unmade paths which people use regularly, as shown in Map 13. Some of these routes are in the process of being closed off by residential development, and further restrictions will occur with additional subdivision. Provision of a Rivulet reserve with connecting links into streets would ensure that the latter are retained. Particular attention with respect to access would seem to be warranted in the cases listed below:

1) According to resident's reports, large numbers of children use railway property, including the rail bridge across the Rivulet, as a convenient means of reaching the city swimming pool in summer. This seems a potentially dangerous situation which might be helped if a lane and footbridge were provided.

Plate 33 Railway bridge across Humphrey Rivulet. Children use it to reach the public swimming pool in summer. Alternate but equally convenient access by means of a footbridge would help overcome the danger associated with trains.



Map 13 Informal path system near sections of Humphrey Rivulet. Some routes are being lost as sub-division proceeds.

Plate 34 Pathway off upper Chapel Street. Some cross the Rivulet here by means of steps cut down the bank, others go over the top along the pipe... This route will no longer be available if sub-division continues to the bank-top at the far end of the pipe.

Plate 35 People sometimes break down fences rather than go the long way. In this instance the path leads across the railway line (out of the picture in the foreground). The situation emphasizes how important convenience of access is in practice.

ii) Residents in the vicinity of Tolosa and Chapel Streets above Brent Street lack access across the Rivulet, except for the adventurous who are willing to climb steep banks. The allocation of open space as sub-division occurs, in accord with the aim of providing access, would allow later construction of a footbridge. The Council might also investigate the at present uncertain status of a public road reserve which is within industrial premises and alongside "Murrayfield". This could provide the basis for a similar link through the playground off Norman Circle. In addition, residents of upper Chapel Street have no access to the Tolosa Street Reservoir Park, except by means of a circuitous road journey, even through the park is a mere few hundred yards across the Rivulet from the end of the street.

iii) Main Road, in the vicinity of the shopping centre, has been a problem for years for pedestrians. Many people are commonly seen dashing across between cars, trucks, and buses. Inclusion of a pedestrian mall as part of plans for redevelopment of the centre would seem well worthwhile. Such a plan would have to avoid simply transferring some of the problems of shoppers on foot elsewhere if new roads for vehicular access to the centre are contemplated.

USAGE AND EVALUATION OF RECREATIONAL FACILITIES

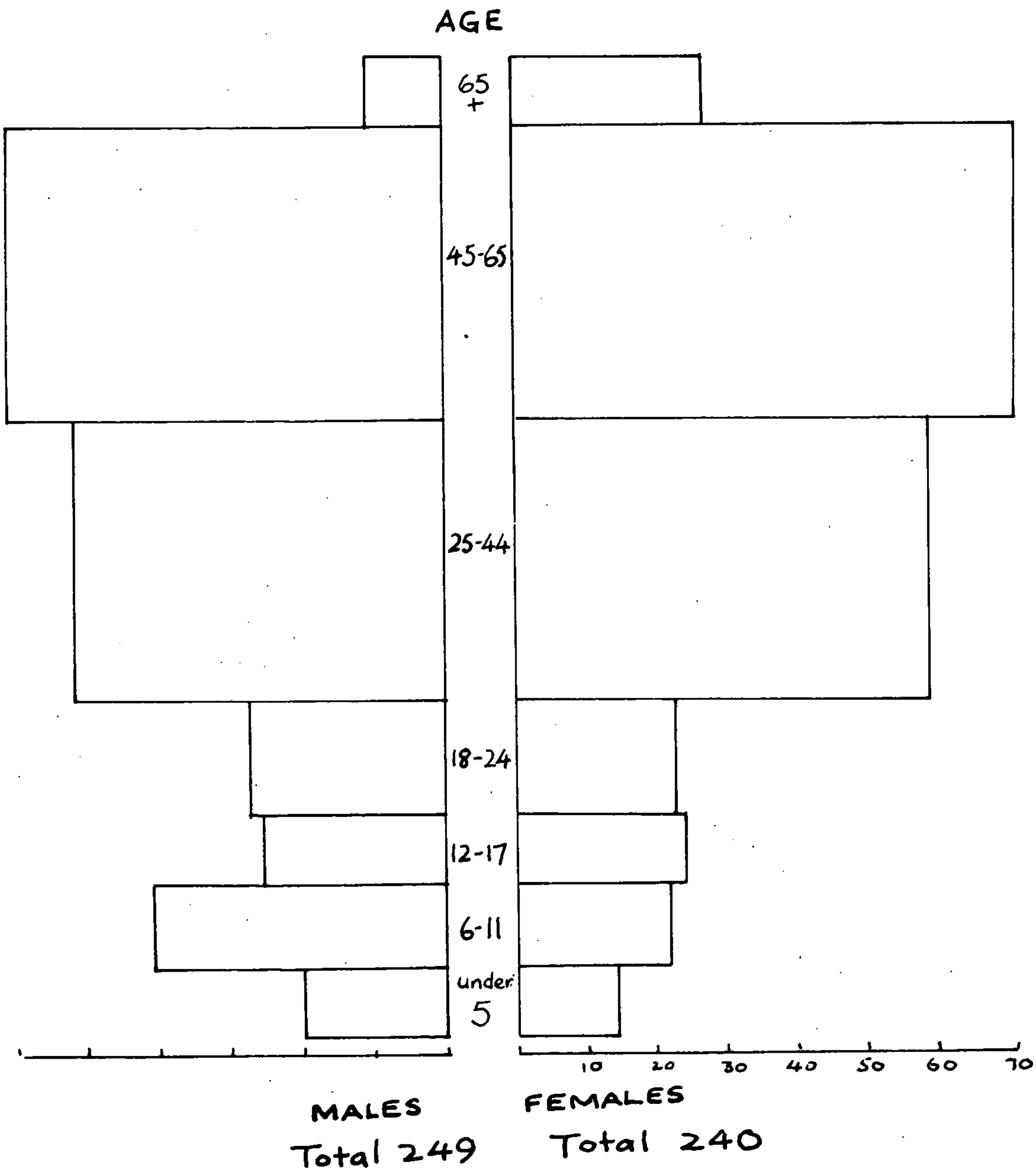
Clearly, parents in the 110 homes who were prepared to rate recreation facilities near their homes thought that provision was inadequate, as shown in Table 9. Most children (60 per cent) were reported as usually spending their free time at home, while others frequented friend's places and the street as well as their own homes. Only six children used reserves regularly. Parents often commented that there was no public open space in the vicinity of their home or that playgrounds were too far away to be useful, or that the journey was too dangerous for their young children on account of traffic on the roads. There were many suggestions that every residential block should have a large open space for children within its borders, so that parents would not be too far away from where their children play.

The reason residents often gave for rating facilities as either good or acceptable was that very few children lived in their area, so that open space was unnecessary. A profile of age groups supports their comments,

Table 9 Resident's opinions of nearby recreational facilities (for children up to age 17), according to sub-areas of the study area in which they reside.

AREA OF RESIDENCE	Excellent - Good	Acceptable	Poor - Very Poor
1 McGough - Bowden Street.	6	2	11
2 Bowden - Brent Street	3	5	8
3 Brent - upper Tolosa	5	3	10
4 Grove - Hull Street	1	4	11
5 Hull - Brent Street	1	3	16
6 Brent - upper Chapel Street	3	1	17
TOTAL	19	18	73

Figure 10 Age-sex profile, permanent residents of all homes visited in the vicinity of Humphrey Rivulet, August - September, 1976.



indicating a relatively aged population overall in the study area, as compared with more recently developed parts of the Hobart region where young people have bought homes and are often bringing up young children. There seems to be a trend, however, for younger people to move into some of Glenorchy's older established areas, and some of these people who were contacted during the survey deplored the lack of open space for children. These responses suggest a need for flexibility in open space planning, so that land is available for different recreational uses as shifts occur in the structure of the population. A reserve along the Rivulet could meet some of the aims of such planning, as a sequence of linked spaces could cater for various groups of people. In addition, since such a reserve could also provide convenient routes to other urban facilities, its prospects for receiving fairly intensive use are high in comparison with single purpose open spaces such as playgrounds.

Members of two thirds of the households interviewed had visited the Tolosa Street Reservoir Park at least once in the last twelve months; many had done so far more often. All rated it very highly. People liked its range of facilities (barbecue and picnic sites, a place for ball games, some playground equipment for younger children), the variations in its physical environment (formal gardens sheltered by trees, wider open spaces with trees interspersed, the water of the reservoir itself), and the broad landscape setting. Many people, at the time of interview, took the opportunity to remark how poorly off their own neighbourhood was by contrast. They expressed a wish for similar facilities, but necessarily on a smaller scale, closer to their homes.

Most adults who went to the park did so not only for their own enjoyment, but also to give their children the opportunity to play in a safe place that would hold their interest. Those without children of their own often joined other family groups or relatives with children and made the day a social event. People living in upper Tolosa Street near the park used it very frequently on a casual basis. Some made trips when few other visitors were about in order to allow their children to use bicycles within the park, free from worries about dangers from traffic.

A general conclusion which seems justified from the survey results with respect to the Reservoir Park is that there does exist in Glenorchy a considerable demand for open space of good quality. When such space is provided, it can serve many recreational purposes.

Clearly there is also a demand for better quality reserves close to the home. It would seem that the only way the community could afford such facilities which, at the same time, meet the criterion of accessibility, is to gain small strips of interesting land which thread through the city. From this point of view a scheme for Humphrey Rivulet could improve the position with respect to open space in the study area.

1. For example, see: BRITISH TRANSPORT AND ROAD RESEARCH LABORATORY; *Road Humps for the Control of Vehicle Speeds*, LR 597. Cited in: Bendixson, T., 1974; *Instead of Cars*, p.67; Temple Smith, London.

2. HIRST, E., 1974; Automobile energy requirements, *Proceedings*, 100 (Australian Society of Civil Engineers, 815 - 826.

MANAGEMENT AND
RECOMMENDATIONS

CHAPTER FIVE

MANAGEMENT AND
RECOMMENDATIONS

Only he who is familiar with the rules water obeys and who knows how to take them into account will succeed in creating something durable and satisfactory.

(Editorial comment, *Anthos* 1/75)

At present there are several alternatives for control of flooding and erosion in Humphrey Rivulet. The range of the available alternatives will narrow, however, as pressures on the Rivulet's drainage capacity increase. The result of no additional action in the meantime will almost certainly be the necessity for a concrete channelization or piping programme as the only viable management scheme remaining. Monetary costs will be high enough; other costs will be the loss of amenity to the community in terms of useful access routes, recreational opportunities, and a source of variety and interest in the urban landscape. Some of these values exist for local residents already; some belong to the future if the Rivulet is treated more sensitively. Nevertheless, artificial channelization does not necessarily rule out construction of an open space system. However, the system would be lacking the present physical attributes of the Rivulet which seem to function so well as a learning and play environment for children.

In this concluding chapter, sections cover a more detailed evaluation of the Rivulet management options listed in the Introduction, a concept plan for an open space system, and recommendations as to what steps would have to be taken to implement such a plan. These sections are an attempt to integrate the various data inputs from previous chapters.

EVALUATION OF LISTED OPTIONS

The four alternatives are repeated for quick reference:

1. To be content with existing circumstances, undertaking periodic removal of obstructions to flow;
2. To attempt control of flooding by means of sectional channel improvement works, such as the use of concrete and/or stone paving in the vicinity of flood-prone land, so that water rapidly escapes downstream, or construction of a concrete invert;
3. To attempt control of the entire channel within the urban area by more extensive works, such as piping below ground level or paving

of bed and banks;

4. To begin a long term programme designed to achieve: (a) flood control by means of minimal works to the Rivulet Channel and measures to limit expected increases in runoff from the urban catchment, and (b) an open space system linking homes with parks and the other urban facilities.

Our evaluation appears opposite in summary form, while further comments follow.

Option 1 : no special action

Economic costs in this case arise from probable damage to property from flooding and erosion, maintenance expenditure for work such as the removal of coarse gravels and fallen trees from the lower section of the Rivulet, particularly in the vicinity of traffic bridges, and weed control along banks. Work of this type, in the past, has not been recognized as a continuous item of municipal expenditure : hence the lack of a figure for costs. Social costs include further deterioration of the aesthetic value of the stream landscape, a consequence which adversely affects community pride and satisfaction in the urban environment, especially for the young who are forming their values. This aspect also has an economic corollary, as the value of adjacent properties could be expected to suffer. Existing recreational values will tend to be depressed also as the condition of the Rivulet channel deteriorates in response to heavier drainage loads. It should be pointed out in this context that, since the results from microbiological analysis of water quality suggest health risks for children playing in the Rivulet at present, action to remove the sources of pollution should be taken regardless of flood control policy.

Option 2 : partial channel improvements

This alternative should mitigate the effects of flooding in the specific locations where it is applied, but would have to be constructed with much skill if other consequent damage is to be avoided. For example, speeding of flow by means of a paved invert would aggravate erosion of adjacent and downstream banks, and could result in inundation downstream if the channel is in poor condition and of insufficient capacity to contain the higher flow. Similar downstream effects could follow concreting of banks in local areas (like the work done between Main Road

TABLE 10 Summary assessment of management alternatives for Humphrey Rivulet according to selected factors affecting the community.

OPTIONS	FLOOD CONTROL	EROSION CONTROL	PUBLIC ACCESS	RECREATION	LANDSCAPE QUALITY	BIOLOGICAL SYSTEMS	COST
1 no special action: some maintenance as at present	POOR: if done more systematically and scope widened, does not allow for lack of channel capacity due to added runoff from future development	POOR: to date, erosion has been virtually ignored; edges of some properties are in danger of collapsing into the Rivulet during flood flows	POOR: public access is being further restricted at present as new housing is erected	POOR: as	POOR: lack of a policy will lead to further deterioration of physical and visual attributes of landscape	POOR: i) weed growth requires application of herbicides in vicinity of Rivulet; ii) aquatic environment affected by siltation, suspect bacteriological quality	HIGH: since public pressure consequent upon flood damage could precipitate implementation of Option 2, then Option 3
2 sectional channel improvement	POOR: temporary solution in some areas only for same reasons as above; may aggravate problems downstream from works due to increased velocity	POOR: control achieved in local areas where banks lined; but erosion will worsen downstream if velocity increased as result of works, e.g., channel straightening	POOR: as above	POOR: sections of Rivulet may have to be fenced off to prevent children from falling down steep banks	POOR: works designed for flood control alone would probably display uniformity of construction seen in many other streams	POOR: much of aquatic habitat could be destroyed, e.g. if concrete invert	HIGH: $4-5 million at least for concrete invert in urban area
3 artificial channelization throughout urban area	GOOD: provided new channel designed to accommodate higher flood flows as urban area develops	GOOD: no problems if banks lined	POOR: as above; public access could be retained and improved as part of options 2 and 3, but the Rivulet would probably be less attractive to people; see:	POOR: entire Rivulet possibly fenced off if concrete fluming used	POOR: as above, but even more so	POOR: aquatic habitat for range of species normally found in streams destroyed	HIGH: $20 million cost for concrete fluming through urban area; piping more expensive; additional costs for boulder trap, trash racks
4 a. sectional channel improvement and control of runoff; b. public open space system	GOOD: provided that i) maintenance continued (but access for work improved, systematic treatment more likely); ii) channel works designed to keep velocity low	GOOD: provided conditions observed as under flood control	GOOD: designed specifically to improve public access	GOOD: designed to create recreational opportunities; children can use Rivulet for water play as at present	GOOD: preservation of many attributes of an unmodified stream; could help give urban area definite character which would blend with wider landscape	GOOD: i) use of native botanical associations could be virtually self-maintaining, would control weeds; ii) with water quality improvement, could regenerate populations and diversity of aquatic species	MODERATE: i) catchment management will save later costs of correction to drainage system; ii) improved access should reduce maintenance costs; iii) open space system costs = cost per hectare of other informal reserve developments

and the railway bridge to protect Wright Street and two homes after the 1960 flood), as velocity of flow would also be increased under these conditions. Maintenance, as in Option 1, would still be necessary. In addition, if engineers engaged in the design of these measures are given no objectives other than flood control, completed works will probably be incompatible with recreational values and landscape quality. Sections of the Rivulet currently frequented by children may have to be fenced off to avoid the danger of falls down steep, smooth banks.

Option 3 : artificial channelization (concrete paving or piping) through bulk of urban area

Costs are enormous and are probably beyond the resources of the City of Glenorchy. The sum of $20 million named in Table 10 is the cost of materials and construction for paving bed and banks (concrete fluming) to accommodate an 86 cu m/sec flow. Piping, consisting of five 1800 mm diameter pipes, would be even more expensive but is probably impractical in view of vulnerability to obstruction by flood debris. In practice, extra capacity in the new channel, whether fluming or piping, would be needed to allow for more intensive urban development if such a solution is to remain effective in the long term. Additional costs will be incurred to lessen both the risk of obstructions to flow and the maintenance required to reduce channel shrinkage due to movement of gravel and other debris. This money will be needed to build trash racks and a boulder trap, see over.

The comments made above about landscape quality and recreational values in connection with Option 2 obviously apply in this case also, but the tendency towards uniformity and sterility will be more pronounced. The entire Rivulet would probably have to be fenced off if concrete fluming is used, as the land needed for regrading of banks to give a gentler slope to the bed of the Rivulet is simply not available because of existing structures.

Option 4 : catchment management, sectional channel improvement, public open space system

Catchment management could, for example, take the form of provision of domestic tanks in new residential sub-divisions, a measure which would reduce demand for city water supplies, as water collected could be used on

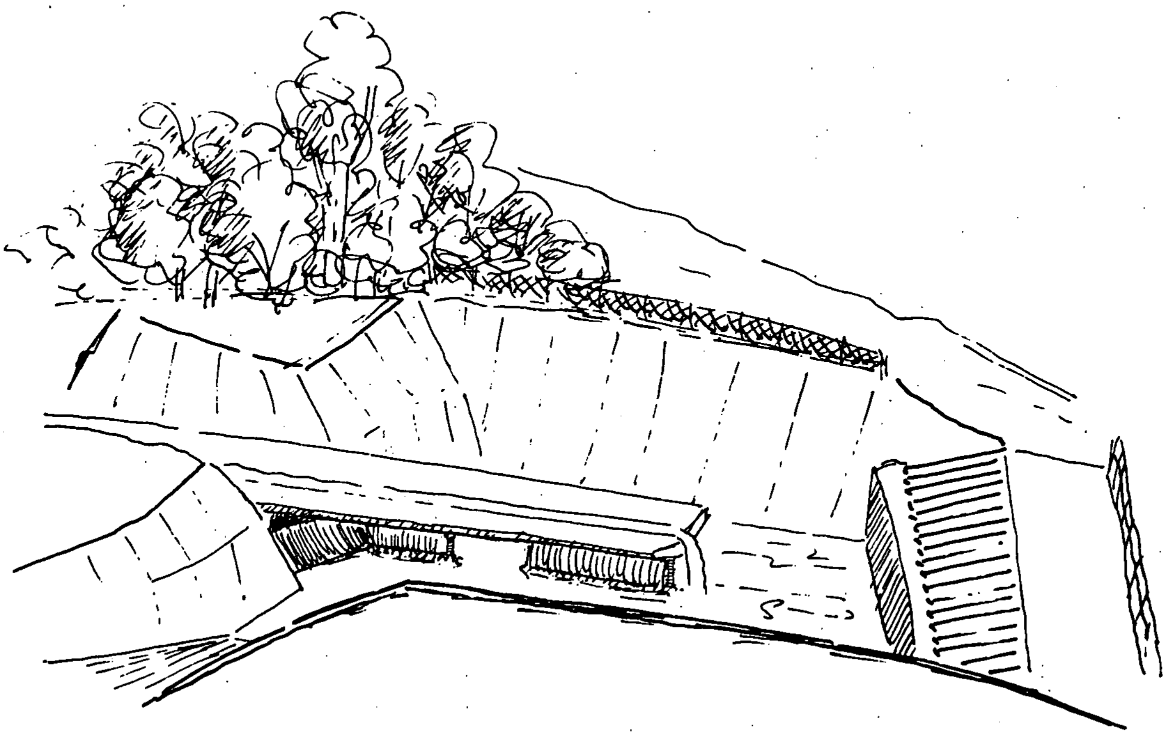


Figure 11 Boulder trap and major trash rack, Hobart Rivulet; constructed 1967-8 at a cost of $129,320. A similar structure may be necessary on Humphrey Rivulet if artificial channelization is undertaken.

lawns and gardens. Savings could be passed on to ratepayers. Residents in established areas could be encouraged to install tanks on the same basis. Another method is to plan new sub-division in accord with principles for reduction of runoff. Such layouts, since they normally imply smaller percentages of non-porous surfaces, can also cut costs, according to Brotchie[1]. A concept for such a layout proposed by that author is shown below.

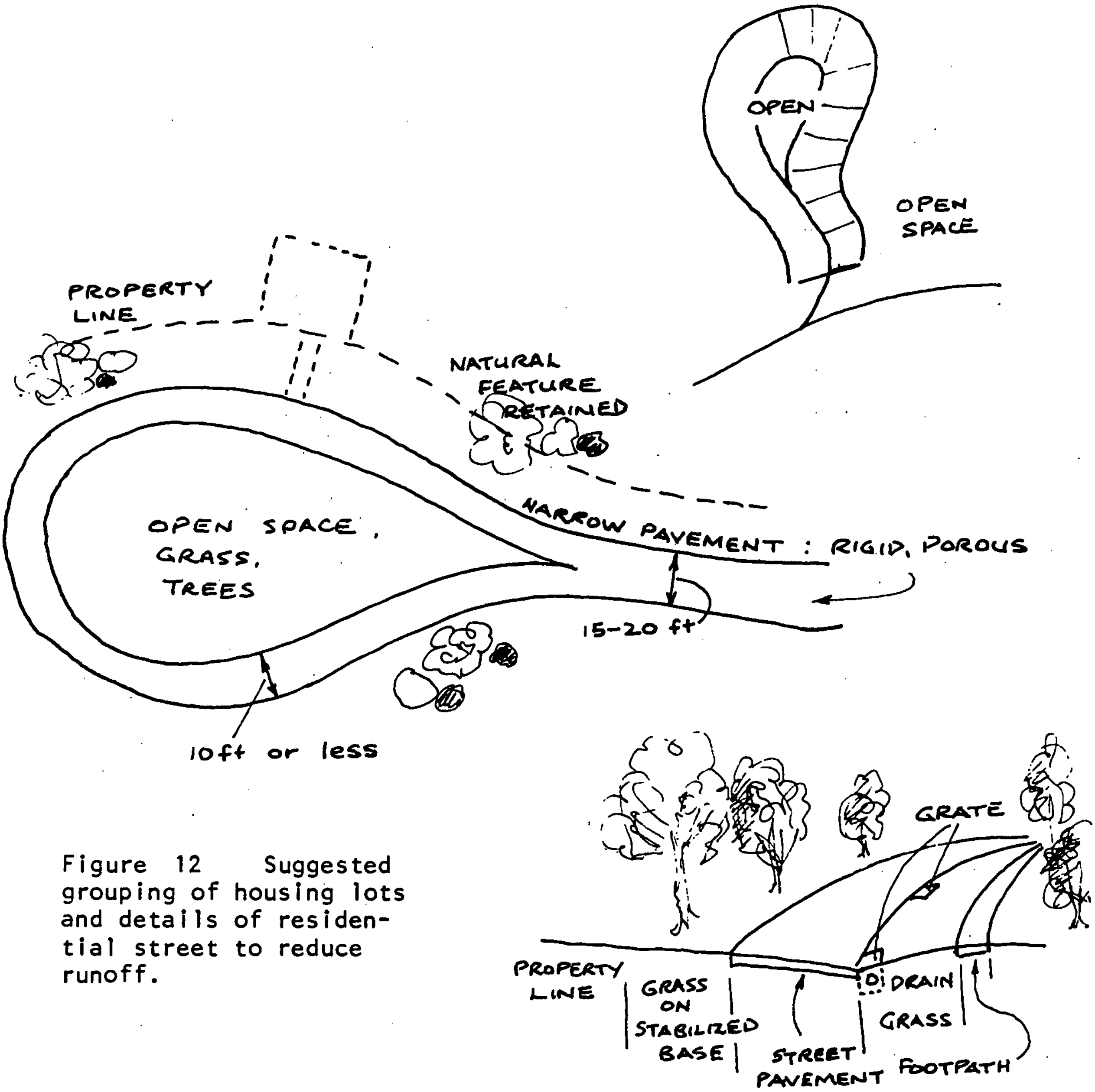


Figure 12 Suggested grouping of housing lots and details of residential street to reduce runoff.

Methods of reducing the percentage of paved surfaces in the urban area could also be investigated where redevelopment occurs. Supporting measures include restriction of development on remaining flood plains and regulation of the levels of the reservoirs in the Water Catchment Reserve in known flood danger periods. The costs of all these policies, which consist essentially of planning to prevent additions to peak flood flows, will be far less than the cost of correction once the Rivulet's capacity has been overtaxed.

Work on the Rivulet channel could be minimal, using readily available, cheap materials wherever possible, e.g., large stones from the Rivulet itself for stabilization of badly eroded banks. The ponding capacity of the flood plain below Brent Street could be increased by removal of accumulated debris, gravel, and soil and much of the material then used to raise the existing levees downstream (vicinity of Grove Road).

Pathway construction and planting would be added items of expenditure for the Council, but could reduce other costs. Access routes for regular maintenance are needed anyway, and tracks doubling as paths would make work more efficient. Planting with selected species and rough mowing of open areas would keep down introduced weeds and greatly reduce the fire risk.

Acquisition of land for a Rivulet reserve, where necessary, is another item of municipal expenditure. In view of the wide resident dissatisfaction with provision of open spaces in Glenorchy, as indicated in the survey results (Chapter 4), such expenditure may be overdue.

With the exception of much needed flood control measures (see recommendations, p.134), Option 4 has the advantage of allowing costs to be spread over a long period rather than involving the Council and the community in massive capital expenditure. It does not require costly engineering design studies or site investigations to demonstrate feasibility before work can begin. The basic simplicity of the open space system lends itself to involvement by community service organisations and business firms whose properties adjoin the Rivulet. However, there would need to be some evidence of general understanding and acceptance of the design guidelines by the community before the Council could embark upon the project with confidence.

One matter not given space in the evaluation summary is that of the significance of the old buildings and flood wall for which the Rivulet provides the setting. Apart from the obvious practical function of the wall and the possibility of putting some of the buildings to community use at a later date, these structures are a resource because they are a focus for a sense of history and continuity in community life. A reserve along the Rivulet could be designed to enhance their characteristics and relevance. Efforts to present a case for acceptance of the Rivulet and parts of its surrounds as a segment of the Australian Natural Heritage would be well worthwhile.

Conclusion

It could well be argued that our clear preference for the fourth option, preservation and enhancement of the Rivulet's characteristics, amounts to an emotional plea for retention of a more or less natural feature in an urban environment where, in our opinion, utilitarian values often seem overriding. This is the case. But we maintain that this stance is also supported and more than justified when the relevant social, economic, and environmental factors are taken into account.

Plate 36 The Rivulet, although polluted, degraded in many ways, and hedged in by development, still has many attractive areas. Its positive attributes would be retained and reinforced for enjoyment by present and future residents. (View downstream from Grove Road bridge).

CONCEPT PLAN

The concept plan we have devised for Humphrey Rivulet is shown on the foldout maps (Sheets 1, 2, 3) following. A legend, common to each, is below. Suggestions for landscape treatment are given in subsequent pages.

LEGEND

Proposed path/cycle track routes

Land suggested for purchase or agreement

Open space in public ownership

Footbridge: Proposed

Existing

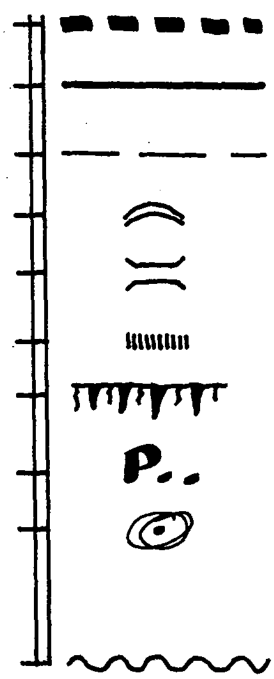
Temporary

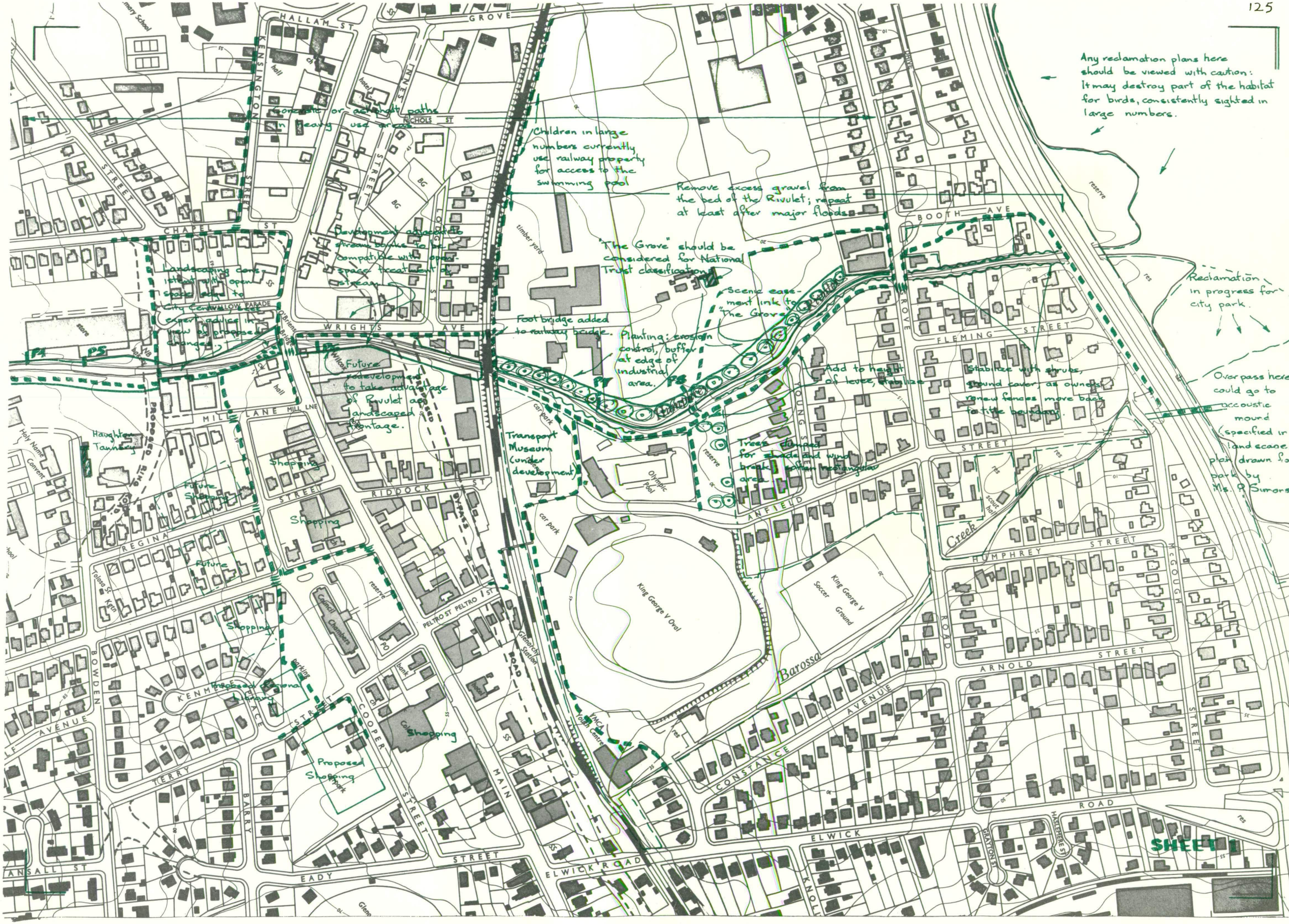
Areas requiring erosion protection

Piped discharge sampling sites (see p.)

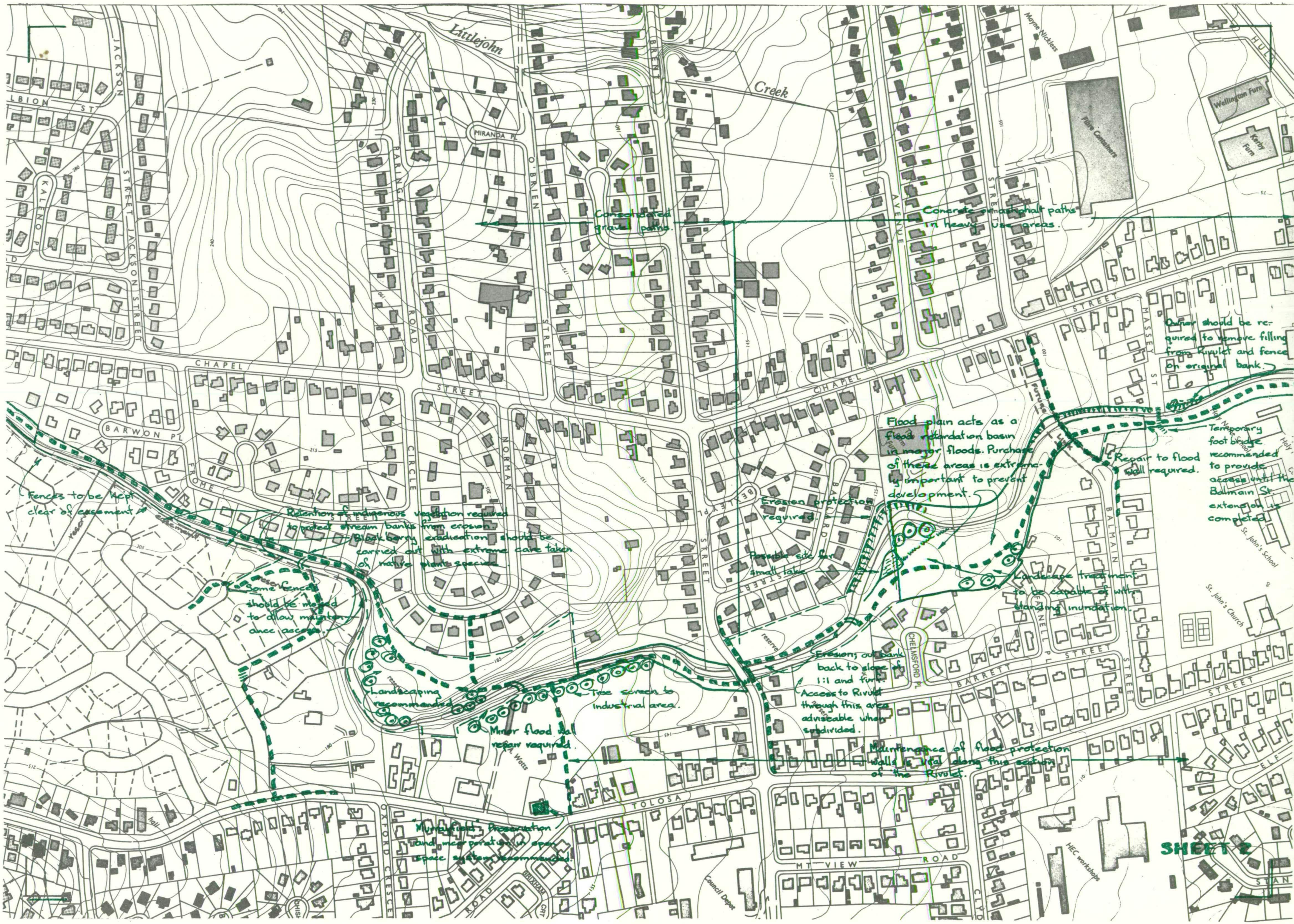
Recommended tree planting

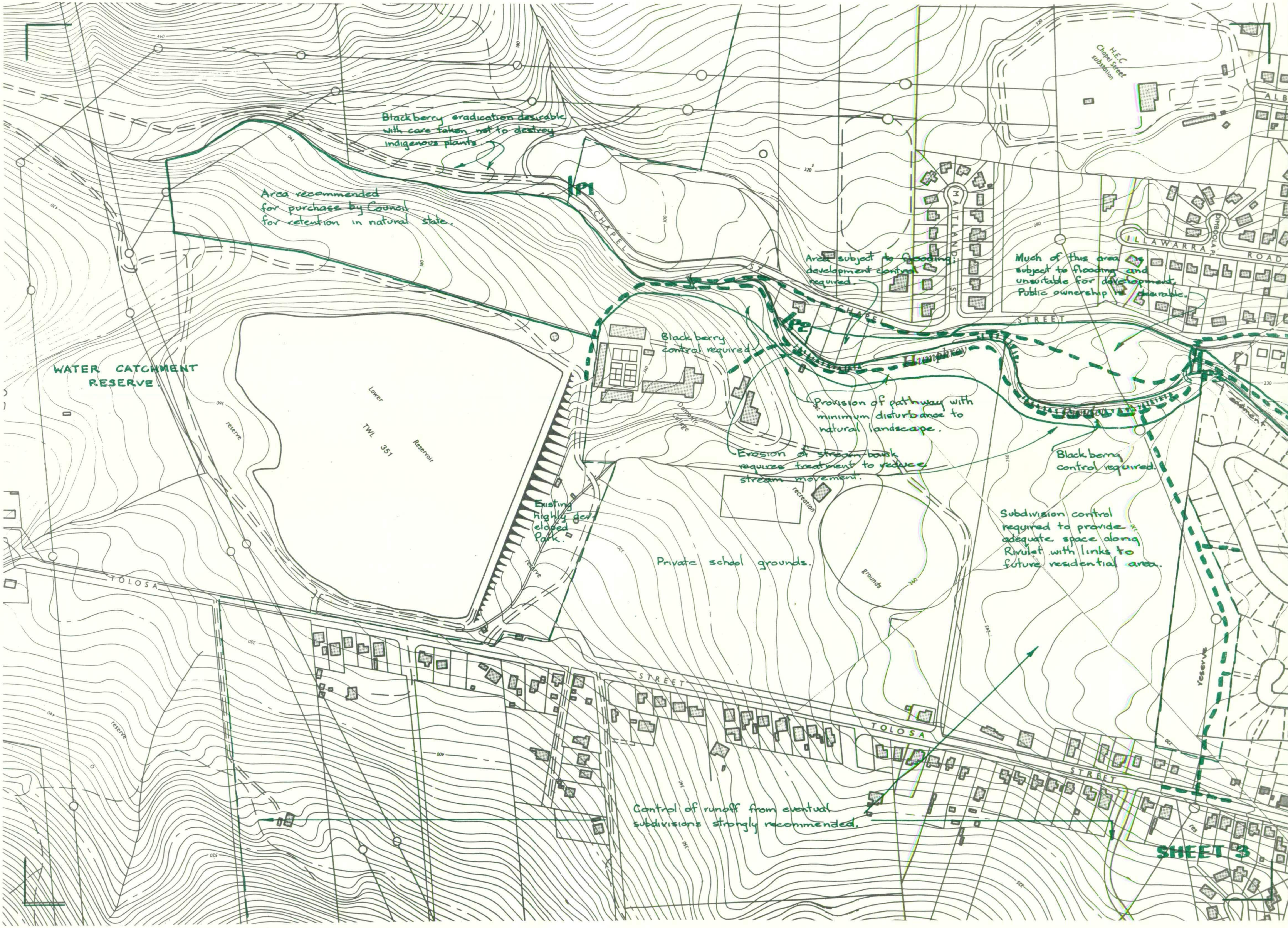
Planting (shrubbery, ground cover) for bank stabilisation, weed control





Any reclamation plans here should be viewed with caution: It may destroy part of the habitat for birds, consistently sighted in large numbers.
Children in large numbers currently use railway property for access to the swimming pool
Remove excess gravel from the bed of the Rivulet; repeat at least after major floods
"The Grove" should be considered for National Trust classification.
Scenic easement link to "The Grove"
Foot bridge added to railway bridge.
Planting: erosion control, buffer at edge of industrial area.
Add to height of levee, stabilize
Reclamation in progress for city park.
Overpass here could go to accoustic mound (specified in landscape plan drawn for park by Ms. P Simons)
Future redevelopment to take advantage of Rivulet as landscaped frontage.
Transport Museum (under development)
Haughton Tannery
Shopping
Future Shopping
Future
Proposed Shopping Park
SHEET 1
HALLAM ST
GROVE
KENSINGTON
INNES
NICHOLS ST
STREET
CHAPEL ST
WRIGHTS AVE
BOOTH AVE
FLEMING STREET
MILL LANE
RIDDOCK ST
ANFIELD
REGINA
PELTRO ST
HUMPHREY STREET
ARNOLD STREET
BOWDEN
KENMORE PLACE
COOPER STREET
MAIN ROAD
CONSTANCE AVENUE
Barossa
TERRY
BARRY
EADY STREET
ELWICK ROAD
ANSALL ST
McGOUGH STREET
Creek
King George V Oval
King George V Soccer Ground
Olympic Pool
Council Chambers
Glenorchy Station
YMCA Youth Centre
timber yard
car park
reserve
store
hall
school
Holy Name Convent


SHEET 2
Concrete or asphalt paths in heavy use areas.
Consolidated gravel paths.
Owner should be required to remove filling from Rivulet and fence on original bank.
Temporary foot bridge recommended to provide access until the Balmain St. extension is completed.
Repair to flood wall required.
Flood plain acts as a flood retardation basin in major floods. Purchase of these areas is extremely important to prevent development.
Erosion protection required.
Possible site for small lake.
Landscape treatment to be capable of withstanding inundation.
Erosion cut bank back to slope of 1:1 and turf.
Access to Rivulet through this area advisable when subdivided.
Maintenance of flood protection walls is vital along this section of the Rivulet.
Tree screen to industrial area.
Minor flood wall repair required.
Landscaping recommended.
Myrtlefield Preservation and incorporation in open space system recommended.
Some fences should be moved to allow maintenance access.
Retention of indigenous vegetation required to protect stream banks from erosion. Blackberry eradication should be carried out with extreme care taken of native plant species.
Fences to be kept clear of easement.
Littlejohn
Creek
Mayne Nickless
Fibre Containers
Wellington Furn
Kerby Furn
HEC workshops
Council Depot
St. John's Church
St. John's School
JACKSON STREET
ALBION ST
KALENO PL
CHAPEL STREET
BARINGA ROAD
MIRANDA PL
O'BRIEN STREET
BRENT
AVENUE
NORMAN CIRCLE
BARWON PL
FROME
BEDDOME PL
BALLARD
MASSEY ST
BALMAIN STREET
CHELMSFORD PL
BARRETT STREET
TOLOSA
OXFORD CRESCENT
MT VIEW ROAD
CLYDE
BRIXHAM CRT
FUTURE


WATER CATCHMENT RESERVE.
Blackberry eradication desirable with care taken not to destroy indigenous plants.
Area recommended for purchase by Council for retention in natural state.
P1
Lower Reservoir TWL 351
reserve
CHAPEL ST
MAITLAND ST
ILLAWARRA ROAD
DIMBOOLA PL
H.E.C. Chapel Street substation
Area subject to flooding: development control required.
Much of this area is subject to flooding and unsuitable for development. Public ownership is desirable.
Blackberry control required.
P2
Humphrey
Existing highly developed Park.
Domestic College
recreation
grounds
Provision of pathway with minimum disturbance to natural landscape.
Erosion of stream bank requires treatment to reduce stream movement.
Private school grounds.
Blackberry control required.
Subdivision control required to provide adequate space along Rivulet with links to future residential area.
reserve
TOLOSA STREET
Control of runoff from eventual subdivisions strongly recommended.
SHEET 3

Landscape suggestions

Our thoughts on the urban Rivulet are that it would be best treated as one means of fostering the visual impression that the characteristics of the surrounding forested hills penetrate into the town, so that Glenorchy fits into its physical environment rather than clashes with it. To some extent this effect exists already upstream from the Norman Circle playground, although trees are being felled as development proceeds, whereas closer to the city centre, it has largely disappeared with the removal of native vegetation. For this reason the task of landscaping involves different sorts of problems in the two distinct sectors.

Downstream from Norman Circle, treatment can be more formal in accord with space restrictions and the more intensely urban character of the Rivulet's surrounds. Even here, however, the visual theme arising from the clumps of eucalypts upstream and the forested catchment can be made continuous by careful siting of small numbers of tall trees with spreading crowns such as manna gums, blue gums, and stringybarks. Other low growing native species, especially those able to stabilize banks, can reinforce the theme. Mr. Allan Gray, who can be contacted at the Department of Environmental Design, Tasmanian College of Advanced Education (T.C.A.E.), Mt. Nelson, has a particular interest in the use of Tasmanian trees and shrubs for this purpose and has indicated willingness to assist in any work on the Rivulet. Staff of the College have also formally approached the Council to seek project work in the Glenorchy area, and presumably could also be approached to give advice.

With respect to the existing vegetation in this area, action should be taken to pollard willows, remove some which occupy the channel, and replant where trees have died for the sake of bank stabilization. Blackberry and other weed control is necessary, but banks must be quickly stabilized, preferably with fire resistant shrubs and ground cover. A report by Hackett[2] (held by the T.C.A.E.) describes techniques for stabilizing steep banks, although in a British context. The ground creeper *Vinca major* is an excellent (introduced) species for stabilizing soil, and is fire resistant. It grows along the Rivulet at several sites already.

Where erosion is more serious, batters could be constructed with rocks from the Rivulet, giving a rough texture to reduce velocity, or bush poles stood on end. These materials would fit in well with the existing landscape. The flood plain between Brent and Bowden Streets will need special treatment with hardy species, as periodic inundation must be expected. In any case, from the point of view of preservation of a somewhat wild environment currently enjoyed by children, landscaping of this site should not be too formal.

It may be necessary to build concrete or asphalt paths where most intense use occurs (probably between Brent Street and Grove Road, either side of the city centre). In this case, drainage from paths will have to be treated with special care because of the proximity of the paths to the Rivulet banks. Paths ought to be highly visible from streets at their point of entry into the street system. Good landscaping of these areas could do much to attract attention and interest in the open space system.

Upstream from Norman Circle playground, control of blackberries will be needed rather than replanting. Paths could be surfaced with consolidated gravel and follow the contours of the land.

1. BROTCHIE, J.F., 1974; Some systems concepts for urban planning, *Royal Australian Planning Institute Journal* 12, 43 - 50.

2. HACKETT, B., 1972; *Landscape Development of Steep Slopes;* Oriel Press, Newcastle upon Tyne.

RECOMMENDATIONS

The suggested programme of action is not exhaustive; it serves to indicate areas of concern where work can begin. Priorities have been given to the recommendations to indicate the importance of time in the execution of these tasks. Priorities are grouped under the following headings:

a. Urgent action
b. Routine operations
c. Long term considerations

a. Urgent Action

Action as indicated below is required to assure safety of life and property during flooding:

1. Removal of coarse gravel deposits from the bed of the Rivulet between the River Derwent and the railway bridge; particular attention should be given to improvement of channel capacity at the Grove Road bridge;

2. Re-investigate the question of the adequacy of the height of the dam wall at Knight's Creek Reservoir, as originally suggested by R.F. Ritchie in 1967 (see p. 83);

3. Prevent further development of flood plains, by acquisition if necessary;

4. Remove broken limbs and other debris likely to dam the stream under flood conditions;

5. Advise property owners along the Rivulet of the value of the stone flood protection walls and suggest restoration at the sites where breaches have occurred;

6. Prevent persons carrying out filling and construction which reduce the capacity of the Rivulet to contain flood flows.

b. Routine operations

Regular maintenance, control of development, and water quality protection are essential elements in a comprehensive Rivulet management programme. The following requirements are necessary for effective management of Humphrey Rivulet by the Glenorchy City Council:

1. The need for removal of coarse gravels and debris to be a matter for regular appraisal;

2. Prevent further development within a strip of land extending at least 15 m from the bank of the Rivulet;

3. Control and progressive eradication of polluting discharges to the stream;

4. Control over blackberries and other noxious weeds in the vicinity of the Rivulet.

c. Long Term Objectives

Flexibility is possible in the implementation of the long term objectives of option 4 but, the creation of a viable recreational facility will depend on appropriate action being taken for this purpose. The following action is recommended:

1. Adoption in principle of option 4 by Glenorchy City Council;

2. An appropriate resolution being passed by Council to purchase the suggested area of land as it becomes available, or alternatively, to arrange agreements with property owners, e.g., scenic easement, public right of way;

3. Allocation of finance to allow for the progressive development of access routes along the Rivulet in accord with the spirit of the concept plan included in this report; it would be best to initiate action where demand is greatest;

4. A detailed landscape plan being prepared by a skilled professional for the area between Bowden and Brent Streets (the Department of Environmental Design at the T.C.A.E. has indicated interest in such a project);

5. Listing of the Rivulet with the Australian Heritage Commission as an area appropriate for financial assistance from the Federal Government;

6. The project being brought to the attention of local service organisations as worthy of their adoption as a community development activity;

7. Investigation by Council staff of practical methods of reducing urban stormwater runoff.

APPENDIX A

DETAILS OF FLOW CALCULATIONS FOR HUMPHREY RIVULET

As stated in the text (p. 74), the R.F.D.M. was used to assess maximum flows on a 15 year flood frequency basis, in conjunction with a stream flow formula for calculating times of concentration. This section gives more details of how the formulae were applied. The R.F.D.M. is repeated below for easy reference:

$$Q = \frac{1}{360} CIA$$

where Q = peak rate of runoff in cubic metres per second;
C = coefficient of runoff;
I = mean storm rainfall intensity for the catchment time of concentration in millimetres per hour;
A = catchment area in hectares.

The rainfall intensity component of the formula is based on flood frequency data and time of concentration (that is, the time taken for flow from the furthest point of the catchment upstream to reach the point under consideration). The time of concentration can be calculated by various methods; the alternatives considered were graphs produced by the Institution of Engineers[1] and a U.S. Department of the Interior stream flow formula used in the design of small dams[2]. The Institution of Engineers Graph Fig. 2-3 is more applicable to short catchments with a high proportion of overland or surface flow. The stream flow formula was preferred because of the steep terrain of the catchment of Humphrey Rivulet. The slopes probably have the effect of concentrating surface flow into stream flow over a very short distance, producing an overland flow which has the general characteristics of a stream for the purposes of calculating time of concentration. The catchment of Knights Creek and Humphrey Rivulet are also over 6,000 metres in length, and more accurate results could be expected from the time of concentration formula from the U.S. Department of the Interior as follows:

$$tc = \frac{3.63(.621\ L)}{H}^{3} \quad \text{(metricated from the imperial formula)},$$

where tc = time of concentration in hours;
L = length of longest watercourse in kilometres;
H = altitude difference between highest point in catchment and point at which flow is calculated, in metres.

Flood frequency or the statistical expectancy of a storm of a

Table 11 Calculation of run-off co-efficient C for urban sections of Humphrey Rivulet's catchment. The areas for different types of surface are taken from Ritchie (1967), who plotted them from a map of a Glenorchy residential area of 9.98 ha overall.

Type of Surface	Area	C	Percentage of Total Catchment
Impervious streets	1.87 ha	0.95*	
Impervious house etc.	1.96 ha	0.95	38.3%
Pervious lawns, gardens	6.15 ha	0.40**	61.7%

Weighted mean C for typical urban area = 0.61 (rounded to 0.60 for calculation of storm flows in this report).

* C of 0.95 for impervious surfaces is the maximum allowed for by the Institution of Engineers, Australia (Figure 5-2)[5].

** C of 0.40 is described as applicable to conditions of "medium soil, close crop" and mean rainfall intensity of 25 mm/hr by the Institution of Engineers.

particular intensity which may occur at a frequency of once in ten years, or fifty years etc., is known as a once in ten year or fifty year flood or storm. This information, based on rainfall records over a number of years, is plotted as a graph by the Institution of Engineers, Australia, for the Hobart metropolitan area[3]. A fifteen year flood frequency has been used in the Glenorchy area for some years by consultants and Council staff to determine the design capacity of pipes and waterways in the city's drainage system.[4]

The coefficient of runoff C varies significantly with the perviousness of the land surface. This coefficient has also been defined for various surfaces by the Institution of Engineers[5]. The co-efficient for the rural segment of the catchment of Humphrey Rivulet was selected as 0.45 on the basis of medium soil and close crop, and a mean rainfall intensity of 30.5 mm per hour. Results obtained by using this coefficient for portion of the catchment checks with actual runoff (see p. 140, over). C for a typical urban segment of the catchment was estimated by Ritchie in 1967 by calculation of pervious and impervious surfaces in a Glenorchy residential area of 9.98 hectares, for which large scale detail plans are available showing streets, paving and buildings[6]. His results and our application of them to the total projected urban portions of the catchment are given in Table 11 opposite.

The magnitude of the flows at various points in the catchment and in the Rivulet, as determined by the methods stated, is included in the text as Table 2, p. 76. Map 11 on the same page shows the subdivided catchment and the points at which flow was calculated.

To test the reliability of the R.F.D.M. for at least part of this application, the catchment of Knight's Creek was plotted, flow calculated and compared with actual flow during the 1960, fifty year flood observed by P.E. Parsons, Municipal Engineer at the time. His observation gives the height of flow over the Knights Creek Dam spillway as 2.027 metres at the peak of the flood[7]. Francis' weir formula with end and velocity of approach corrections[8] has been utilised in the following section for purposes of comparison. The use of empirical units in this calculation has been necessary, due to the unavailability of a metric rainfall intensity diagram for Hobart.

Peak flow from the Knight's Creek Dam Catchment (R.F.D.M.):

Time of concentration[9]

$$tc = \left(\frac{11.9L^3}{H}\right)^{0.385}$$

$$= \left(\frac{11.9\left(\frac{21000}{5280}\right)^3}{2887}\right)^{0.385}$$

$$= 36 \text{ mins.}$$

(L = length of flow = (21000/5280) miles; H = altitude difference = 2887 ft.)

Flow[10]

$$Q = CIA$$

$$= 0.45 \times 1.28 \times 1835$$

$$= 1057 \text{ cusecs.}$$

(A = area of catchment = 1835 acres; I = rainfall intensity = 1.28; C = coefficient of runoff = .45)

Using the previous flow data for a 15 year frequency flood, the following calculation can be made for a 50 year flood frequency, based on the amended rainfall intensity (I) of 1.6 from Figure 4-7 from the Institution of Engineers:[7]

$$Q = CIA$$

$$= 0.45 \times 1.6 \times 1835$$

$$= 1321 \text{ cusecs}$$

Knights Creek Dam spillway discharge in 1960 (50 year flood):

Using Francis' formula for weirs with end correction:

$$Q = 3.33\,(L - 0.1nH)H^{3/2}$$

(L = length of nappe = 26.75 ft; H = depth of flow = 6.65 ft; n = no. of ends = 2)

$$\text{Thus } Q = 3.33\,(26.75 \times 1.33)\,6.65^{3/2}$$

$$= 1452 \text{ cusecs}$$

Adding correction for velocity of approach:

$$V = \frac{Q}{A}$$

$$= \frac{1452}{26.75 \times 6.65}$$

$$= 8.16 \text{ ft.}$$

Francis' formula with end and velocity of approach corrections:

$$Q = 3.33\,(L - 0.1nH)\left(H^{3/2} - \left(\frac{v^2}{2g}\right)^{3/2}\right)$$

$$= 3.33 \times 25.42\,(17.15 - 1.03)$$

$$= 1364 \text{ cusecs.}$$

Thus the calculation of discharge or flow from the catchment on a 50 year flood frequency basis compares well at 1321 cusecs, and appears to justify the use of the selected coefficient and method for this particular catchment. In the absence of records of flows in other parts of the Rivulet, it is not possible to test R.F.D.M. results for other segments of the total catchment.

1. INSTITUTION OF ENGINEERS, AUSTRALIA, 1958; Stormwater Standards Committee, Report on Australian rainfall and runoff, Figure 2-3.
2. UNITED STATES DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, 1960; *Design of Small Dams,* p.47; U.S. Government Printing Office, Washington.
3. INSTITUTION OF ENGINEERS, AUSTRALIA, 1958; *op.cit.,* Figure 4-7.
4. RITCHIE, R.F., 1967; *Report on Flooding - Glenorchy Creeks,* p. 1A; unpublished report to Glenorchy City Council.
5. INSTITUTION OF ENGINEERS, AUSTRALIA, 1958; *op.cit.,* Figure 5-2.
6. RITCHIE, R.F., 1967; *op.cit.,* p. 1A.
7. *Ibid,* p. 4A
8. LEWITT, E.H., 1956; *Hydraulics and the Mechanics of Fluids,* p. 121, Pitman, London.
9. UNITED STATES DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, 1960; *op.cit.,* p. 47.
10. SEELYE, E.E., 1962; *Design,* p. 18-20; John Wiley and Sons, New York.
11. INSTITUTION OF ENGINEERS AUSTRALIA, 1958; *op.cit.,* Figure 4-7.
12. LEWITT, E.H., 1956; *op.cit.,* p. 118.
13. *Ibid,* p. 121.

APPENDIX B
DETAILS OF CALCULATIONS
OF CHANNEL CROSS-SECTIONS

The following account gives the methodology by which various theoretical channel cross-sections for the Rivulet were calculated. The aim was to predict the channel dimensions necessary to pass downstream the 86 cubic m/sec 15 year flood flow at a velocity compatible with minimal erosion and nil movement of course gravels. A number of trials were made to achieve a good "fit" between all variables affecting flow within this constraint. Unfortunately the critical velocity which results in movement of the heavier gravels is not known; the velocity level we have specified may be unnecessarily low.

Combining the empirical formula ($Q = AV$) with Manning's formula, flow or discharge is given by:

$$Q = A \frac{R^{2/3} S^{1/2}}{N}$$

where Q = flow in cubic m/sec;
A = cross-sectional area of flow in channel in square m;
S = channel slope (fall/length);
R = hydraulic mean depth in m
$= \frac{A}{P}$ (P is the wetted perimeter in feet);
K = rugosity coefficient of channel (Kutter's N).

The value of Kutter's N chosen for all calculations is 0.05, as recommended by Seelye[1] for natural, winding channels with some pools, shoals in the lower stages of flow, and the channel in fair, i.e., unobstructed condition.

To determine an approximate cross-section:

$$Q = AV \text{ (V is velocity of flow in m/sec)}$$

If desirable velocity is 2.5 m/sec. then:

$$A = \frac{Q}{V} = \frac{86}{2.5} = 34 \text{ m}^2$$

Allowing a margin for error, a cross sectional area of 37 m^2 has been selected for the first trial, keeping in mind that 2m is the design height of the existing Grove Road bridge structure. Using the combined formula for flow, with

$$A = 37m^2,$$
$$P = 22\ 15m,$$
$$R = \frac{37}{22.16} = 1.67,$$
$$S = \frac{1}{50} = .02,$$

and $N = 0.05$, three trials are outlined below.

Trial 1.

$$\text{Discharge } Q = \frac{37 \times 1.40 \times 0.1414}{0.05} = 146.5 \text{ cubic m/sec.}$$

Channel capacity in this case exceeds that required for an 86 cubic m/sec flow. However, velocity would be 3.96 m/sec: probably too high to restrict erosion and gravel movement satisfactorily.

$$\text{Velocity } V = \frac{1.40 \times 0.1414}{0.05} = 3.96 \text{ m/sec.}$$

Velocity is a function of depth of flow and slope of the stream. To reduce velocity, a series of steps and ponds in the Rivulet bed which reduce effective slope are necessary.

Trial 2. With a slope of 1 in 500:

$$\text{Discharge } Q = \frac{37 \times 1.40 \times 0.04472}{0.05} = 46.33 \text{ cubic m/sec.}$$

$$\text{Velocity } V = 1.25 \text{ m/sec.}$$

Comparison with the first trial indicates the magnitude of the changes in discharge and velocity which can result from variations in slope.

Trial 3. With a slope of 1 in 150:

$$\text{Discharge } Q = \frac{37 \times 1.40 \times 0.0816}{0.05} = 84.59 \text{ cubic m/sec.}$$

$$\text{Velocity } V = 2.29 \text{ m/sec.}$$

Results from this trial appear to comply with desirable criteria for flow in the Rivulet. Yet, since the material of the Rivulet's banks is mainly of a loose alluvial type, its angle of repose or stability cannot be guaranteed at a greater slope than 1:1 or 45^{o}[2]. Even at this angle, such friable material will require protection until ground cover is established[3].

1. SEELYE, E.E., 1962; *Design*, pp. 18-68; John Wiley & Sons, New York.
2. This is an accepted engineering standard for earthworks.
3. Overlaying with straw and wire netting pegged down to retain soil after sowing with suitable grasses is advisable where channel work is carried out. Ground cover can be planted later through this protection.

APPENDIX C
HOUSEHOLD SURVEY METHODS

Procedures adopted for the household survey are outlined in this appendix.

QUESTIONNAIRE

A copy of the form is given, p. 147. ~~It~~ was prepared to give the following information and coded so that replies to questions could be punched for processing by computer, using the Statistical Package for the Social Sciences (SPSS) :

a) age groups and sex of sample resident population;
b) destination, purpose, and mode of travel of journeys undertaken on a very frequent (i.e., 3 times or more) and on a weekly basis; up to three trips per person were allowed for within each trip frequency;
c) most frequent play or recreational venues of children up to the age of 17 years;
d) evaluation (according to household, rather than by individual members of a household) of play/recreational facilities in the immediate area;
e) local usage of the Tolosa Street Reservoir Park; purpose of visit; mode of travel; evaluation of the Park.

SAMPLING METHODS

The study area was divided into six sub-areas, three on either side of the Rivulet. Each sub-area extended 2-3 blocks from the Rivulet (refer Map 12, p. 98). Thirty-four homes in each sub-area were selected by means of random numbers (total homes for interview: 204) and using Southern Metropolitan Master Planning Authority maps (scale: 200 ft. to 1 inch). Sub-areas contained unequal numbers of homes, ranging from 166 to 234, on account of variations in allotment sizes and patterns of land use.

INTERVIEWING

The survey was conducted at varying times during all days of the week and on some evenings by four interviewers. Almost all of the 204 selected houses were visited at least once. Even so, 154 households only were successfully contacted. This number represents 13.4 per cent of all homes in the study area. Table 12 below shows a breakdown, according to sub-area, of numbers of homes visited and persons for whom answers were given.

Table 12 The number of homes visited in each sub-area for survey purposes, together with a breakdown of numbers of persons in each sub-area for whom responses to the questionnaire were recorded.

	1 McGough-Bowden St	2 Bowden-Brent St	3 Brent St-upper Tolosa St	4 Grove Rd-Hull St	5 Hull-Brent St	6 Brent-upper Chapel St
No. of homes visited	24	26	28	25	23	28
No. of persons for whom responses were given	70	80	115	65	82	77

PROCESSING OF DATA

Processing was done at the Computer Centre, University of Tasmania (BC 700 Computer), using programmes offered in the SPSS. Frequencies of responses to alternatives within variables and cross-tabulation of selected variables were printed. Print-outs may be inspected at the Resource Centre, Environmental Studies, University of Tasmania.

INTERVIEWER ____________ STREET & HOUSE NO. ________ AREA col 1 [ ]

CASE NO. 2 3 4

Q1. I would like to know the age group of each person living here. Is there anyone

PERSON col 5
1. over 65
2. 45 - 65
3. 25 - 44
4. 18 - 24
5. 12 - 17
6. 5 - 11
7. under 5

As each person's age is given, enter sex of that person as well, entering 1. MALE 2 FEMALE

AGE col 6
SEX col 7

Q2. Can you give me some details of the trips each person undertakes from the house at least three times a week? For example, trips to work, shops, school.

PURPOSE
1. Work
2. School
3. Shop
4. Entertainment, sport, play
5. Other (specify)

DEST'N
1 - 8 as per map att.

Trip 1. D PURPose 1 col 8
D DEST'n 1 col 9
D MODE 1 col 10

Trip 2. D PURPose 2 col 11
D DEST'n 2 col 12
D MODE 2 col 13

Trip 3. D PURPose 3 col 14
D DEST'n 3 col 15
D MODE 3 col 16

LEAVE AS A GAP 17 18 19

Q.3. I would now like the same sort of information about the places each person usually goes to about once a week.

MODE
1. Walk
2. Walk + other
3. Walk one way
4. Cycle
5. Car
6. Bus
7. Taxi
8. Other (specify)

Trip 1. W PURPose 1 col 20
W DEST'n 1 col 21
W MODE 1 col 22

Trip 2. W PURPose 2 col 23
W DEST'n 2 col 24
W MODE 2 col 25

Trip 3. W PURPose 3 col 26
W DEST'n 3 col 27
W MODE 3 col 28

LEAVE AS A GAP 29 30 31

Q.4. Where do each of the children play most often?

1. At home
2. Street
3. Friend's place
4. Combination 1 - 3
5. Schoolyard
6. Park
7. Creek
8. Entertainment: Glen.
9. " : Hobart
10. Other (specify)

PLAY cols 32,33

Q.5. What do you think of children's play facilities in this area? Would you say they are

1. Excellent
2. Good
3. Acceptable
4. Poor
5. Very Poor

col 34
RATE PL [ ]

Any comments on play facilities:

LEAVE AS A GAP 35 36 37 38 39

Q.6. Have people from this house visited the Reservoir Park (at the top of Tolosa Street) during the last year? 1. Yes 2. No

col 40
VISRES [ ]

If "No" go to Q.10.

If "Yes"

Q.7. Did both adults and children go?

1. Adults
2. Adults and Children
3. Children alone

col 41
FAMRES [ ]

Q.8. How did you/they travel there?

1. Walk
2. Car
3. Cycle
4. Other (specify)

col 42
MODRES [ ]

Q.9. Did you do anything in particular there?

1. Picnic
2. Walk
3. Play with the children
4. Other (specify)

col 43
ACTRES [ ]

Q.10 What do you think about the Reservoir Park?

1. Excellent
2. Good
3. Acceptable
4. Poor
5. Very Poor

col 44
RATRES [ ]

Any comments on the Reservoir Park:

Humphrey
Rivulet at Glenorchy's
urban fringe