THE CMPS&F GROUP OF COMPANIES

MELBOURNE WATER

DRAINAGE SURVEY 1996/97

CITY OF STONNINGTON

March 18, 1998

CMPS&F

1. INTRODUCTION AND BACKGROUND

1.1 Introduction

Melbourne Water commissioned CMPS&F Pty Limited in November 1996 to undertake a Drainage Survey Consultancy covering the Corporation's main drainage systems across much of metropolitan Melbourne. Excerpts from the Consultancy Brief are reproduced as Appendix A.

This document is one of a series of twenty seven reports, each covering one municipality, and covers drainage systems assigned to the City of Stonnington as follows:

- Yarra Street Drain (4801) ← council drain
- Prahran Main Drain (4811)
- Essex Street Main Drain (4812)
- Williams Road Diversion (4814)
- Beatty Avenue Main Drain (4815)
- Canberra Road Main Drain (4816)
- Moonga Road Main Drain (4821)
- East Malvern Drain (4844)

It should be noted that some reaches of these drains may lie outside the municipal boundary, and are included in this report only so that complete drainage systems are covered within a single document. Conversely, some reaches of drains that lie within the municipal boundary may be described in other reports in the series.

It should also be noted that not all of Melbourne Water's drainage systems, or all reaches of the drains listed, are included in the Consultancy.

1.2 Overview

The requirements of the Consultancy are:

- preparation of plans showing the extent of inundation resulting from flows in excess of the capacity of Melbourne Water's drainage systems in 100, 50 and 20 year average recurrence interval flood events;
- identification of all buildings subject to flooding to above floor levels in events up to the 100 year event;
- identification of the risks associated with leaving properties during a flood event; and
- preliminary assessment of works required to prevent flooding of residential buildings to above floor level in the 100 year event, and associated costs.

Table 2.1
Catchment Summary Statistics

Major Drainage Catchment		Tributary Drainage Catchments		Suburb(s)	Topography	Total Area (ha)	Residential (ha)	Schools (see note 1) (ha)	Commercial (ha)	Industrial (ha)	Reserves / Open Space (ha)
4801	Yarra Street Drain			South Yarra	Flat (upper), steep (lower)	97.3	59.3	4.3	15.6	16.9	1.2
4811	Prahran Main Drain	4812 4814 4815	Essex Street main Drain Williams Road Diversion Beatty Avenue Main Drain	South Yarra, Prahran, Toorak, Armadale	Generally steep, flat to the extreme west	732.2	519.3	18.8	81.7	87.8	24.5
4816	Canberra Road Main Drain			Toorak	Steep	74.7	71.4	0.1	0.5	2.5	0.2
4821	Moonga Road Main Drain			Toorak	Steep	132.8	117.8	0.0	6.7	7.9	0.4
4844	East Malvern Drain			Malvern East	Flat (upper and lower), steep (mid)	96.4	74.3	0.7	1.5	11.1	8.7

Note 1: Includes hospitals and similar institutions.

Table 2.2
Drainage System Characteristics

Major Drainage Catchment	Drain No.	Drain Type	Notes/Comments
Yarra Street Drain	4801	Piped	
Prahran Main Drain	4811 4812 4814 4815	Piped Piped Piped Piped	Storages across Toorak Rd at River St and in Como Park
Canberra Road Main Drain	4816	Piped	
Moonga Road Main Drain	4821	Piped	
East Malvern Drain	4844	Piped	

2.2 Hydrology

Peak 100, 50 and 20 year average recurrence interval flood flows under proposed future landuse conditions were determined using the hydrological model RORB. Full details of the methodology are presented in Appendices C and D.

Peak flows are summarised in Table 2.3.

4801 COUNCIL SYSTEM — MAPPING WRONG ANYWAY. STORAGES IN U/S CATCHMENT NOT MODELLED D.F

Table 2.3
Peak Flows

Major Drainage Catchment	Drain No.	Location	Peak Flows (cumecs)			
			20 Year	50 Year	100 Year Piped	100 Year Overland
Yarra Street Drain	4801	Cnr Toorak Rd & Yarra St	7.3	8.8	8.8	1.6
		Outlet to Yarra River	8.3	9.9	8.6	3.1
Prahran Main Drain	4811/15	High St	11.7	14.2	14.5	2.3
		Cnr Orrong Rd & Lambert Rd	19.4	24.5	15.0	11.0
	4811	Mathoura Rd	21.5	27.5	13.1	15.7
		Williams Rd (near Cassell St)	21.3	26.3	25.6	3.7
		Cnr Toorak Rd & Tivoli Rd	10.4	17.7	11.1	10.6
		Outlet to Yarra River	9.2	15.2	14.5*	-
	4812	Cnr Williams Rd & Erica St	4.9	6.0	5.2	1.9
		Cnr Bendigo St & Murray St	7.3	8.8	4.0	5.0
		Cnr Surrey Rd & Simmons St	11.5	15.5	8.8	9.3
	4814	Outlet to Yarra River	20.4	22.7	23.0	-
Canberra Road Main Drain	4816	Top of drain	6.4	7.8	6.4	2.8
		Outlet to Yarra River	6.1	6.9	7.5	1.0
Moonga Road Main Drain	4821	Cnr Moonga Rd & Glyndebourne Av	5.8	7.1	4.7	3.7
		Outlet to Gardiners Creek	10.1	12.4	11.0	3.9
East Malvern Drain	4844	Top of drain	5.2	6.5	7.8	-
		Outlet to Gardiners Creek	6.3	7.7	6.5	2.1

* Flow is less than the 50 year flow due to diversions along the railway line.

3. EXTENT OF FLOOD INUNDATION, AND FLOOD AND SAFETY RISK ASSESSMENT

3.1 Introduction

Hydraulic modelling was used to determine flood levels and velocities in each of the 100, 50 and 20 year average recurrence interval events. Flood levels were then used in conjunction with survey data to determine extents of inundation. Floor levels of all potentially flood prone buildings were surveyed to determine severity of flood risk. Full details of the methodology are presented in Appendices C and E.

3.2 Extent of Inundation

Extents of inundation, and flood and safety risks are shown on the Drainage Survey Plans. All information is based on surface topography at the date of survey as indicated on the Plans. Peak flows are based on proposed future landuse conditions. Definitions of flood and safety risk adopted by Melbourne Water are presented in Sections 3.3 and 3.4 respectively.

3.3 Flood Risk

Property flood risk is defined by Melbourne Water in terms of frequency of inundation to above floor level as follows:

Category 1 - Property affected in 100 year event, but floor flood free
Category 2 - Flooded to above floor level in 50 to 100 year event
Category 3 - Flooded to above floor level in 20 to 50 year event
Category 4 - Flooded to above floor level in more frequent than 20 year event

Flood risk data are summarised in Table 3.1. As proposed and adopted by CMPS&F and Melbourne Water, the flood risk has been assessed by comparing the maximum flood level on each property, with the lowest habitable floor level on that property. No account has been taken of the coincidence or otherwise of the position of the building relative to the location of the maximum flood level. In some cases, particularly on steep blocks, this may result in properties being assessed as having a higher flood risk than is actually the case.

Table 3.1
Summary Flood Risk Statistics

Flood Risk Category	Number of Properties
1	973
2	51
3	135
4	246

3.4 Safety Risk

Property safety risk is defined by Melbourne Water in terms of the velocity and depth of floodwaters along the egress path from the property to high ground in the 100 year event, as follows:

High risk: velocity*depth greater than 0.8 m^2/s, or depth greater than 0.8 metres;

Medium risk: velocity*depth between 0.4 and 0.8 m^2/s, or depth between 0.4 and 0.8 metres;

Low risk: velocity*depth less than 0.4 m^2/s, or depth less than 0.4 metres.

The higher of the velocity*depth and depth criteria along the "safest" path governs. All egress was assumed to be via the street frontage, along roads only.

Safety risk data are summarised in Table 3.2.

Table 3.2
Safety Risk Data

Risk Category	Number of Properties
Low	736
Medium	365
High	91

3.5 Drainage System Flooding Characteristics

Drainage system flooding characteristics are summarised in Table 3.3.

Table 3.3
Drainage System Flooding Characteristics

Major Drainage Catchment	Drain No.	Extent of Inundation	Flood Risk *	Safety Risk	Notes/Comment
Yarra Street Drain	4801	Widespread inundation	Many properties affected in Claremont St. Depths up to 2000mm	High risk in Claremont St. Depth of 1600mm in road.	
Prahran Main Drain	4811	Widespread around Toorak, Williams, Canterbury & Northcote Rds & Mandeville Cr. Generally minor elsewhere	Large proportion of properties affected, particularly in the areas mentioned in the previous column. Depths of over 500mm common	High risk in River St, Surrey Rd North, Lambert St, Gordon St & Woodside Cr	
	4812	Widespread inundation	Large number of properties affected along pipe alignment & Chapel St	High risk in Surrey Rd North. Medium risk in Chapel St & Malvern Rd. Low risk elsewhere	
	4814	Nil	Nil	Nil	
	4815	Generally contained within road & pipe	Few properties affected.	Low risk only	
Canberra Road Main Drain	4816	Minimal inundation	2 properties affected, by 100 year event only	Medium risk in Winifred Cr	
Moonga Road Main Drain	4821	Minimal inundation	Category 1 only	High risk in Moonga Rd near Warra St	
East Malvern Drain	4844	Minimal inundation	Inundation through golf course only	Nil	

* Depths refer to depths of floodwaters above property floor levels in 100 year event.
* "Affected" properties defined as subject to flooding to above floor level in 100 year event.

4. FLOOD MITIGATION OPTIONS

4.1 Introduction

Conceptual flood mitigation options were developed for all areas in which residential buildings were identified as being subject to inundation to above floor level in the 100 year event.

The adopted design standard for these options is that all floors should be at least 300 mm above the 100 year flood level. It should be noted however that flood mitigation options were not developed for properties not subject to inundation to above floor level in the 100 year event, even if the flood level was identified as being within 300 mm of the floor level. Further, if the property floor is less than 300 mm above ground level, the adopted freeboard in the 100 year event is the height of the floor above ground level.

All options were developed using the same assumptions used to determine flood flows and levels described in Chapters 2 and 3, including:

- land use based on zonings as described in Appendix D. No account was taken of existing landuse. In some instances, flood mitigation options have been developed for areas that may not be subject to inundation with existing landuse; and

- surface topography at the date of survey as indicated on the Drainage Survey Plans, and drainage system details as provided by Melbourne Water. No account has been taken of drainage works not shown on plans collected from Melbourne Water, or of modifications to surface topography after the date of survey.

4.2 Flood Mitigation Options

4.2.1 Introduction

The range of flood mitigation options considered was as follows:

- retarding basins;

- piped drainage works:

  - duplication of existing works;
  - replacement of existing works;
  - construction of new works;

- open channel works:

  - augmentation of existing works;
  - lining of existing unlined channels;
  - construction of new works;

- flow diversion. This can often be achieved at relatively low cost by minor works such as speed humps;
- construction of levee banks and flood walls; and
- property acquisition.

4.2.2 Proposed Works

Proposed works are described below, and shown on Figure 4.1(a).

(a) **Yarra Street Drain Catchment (4801)**

No flood mitigation options have been developed.

(b) **Prahran Main Drain Catchment (4811)**

Details of proposed mitigation works within this catchment are shown on Figure 4.1(a) and described below.

Prahran Main Drain (4811)

The proposed mitigation works for this drain include additional pipes as follows:

- Along Northcote Road from Elm Grove to the corner of Rose Street and Turner Street.
- Downstream from the low point in Malvern Road to Williams Road where the flows are diverted north along Williams Road and discharge to the Yarra River.
- A piped continuation of the drain 4812 augmentation (see below) from Surrey Road North, along Toorak Road and into River Street, through the easement to Chapel Street, along Forest Hill to Claremont Street, along Yarra Street, across Alexandra Avenue and into the Yarra River.

Essex Street Main Drain (4812)

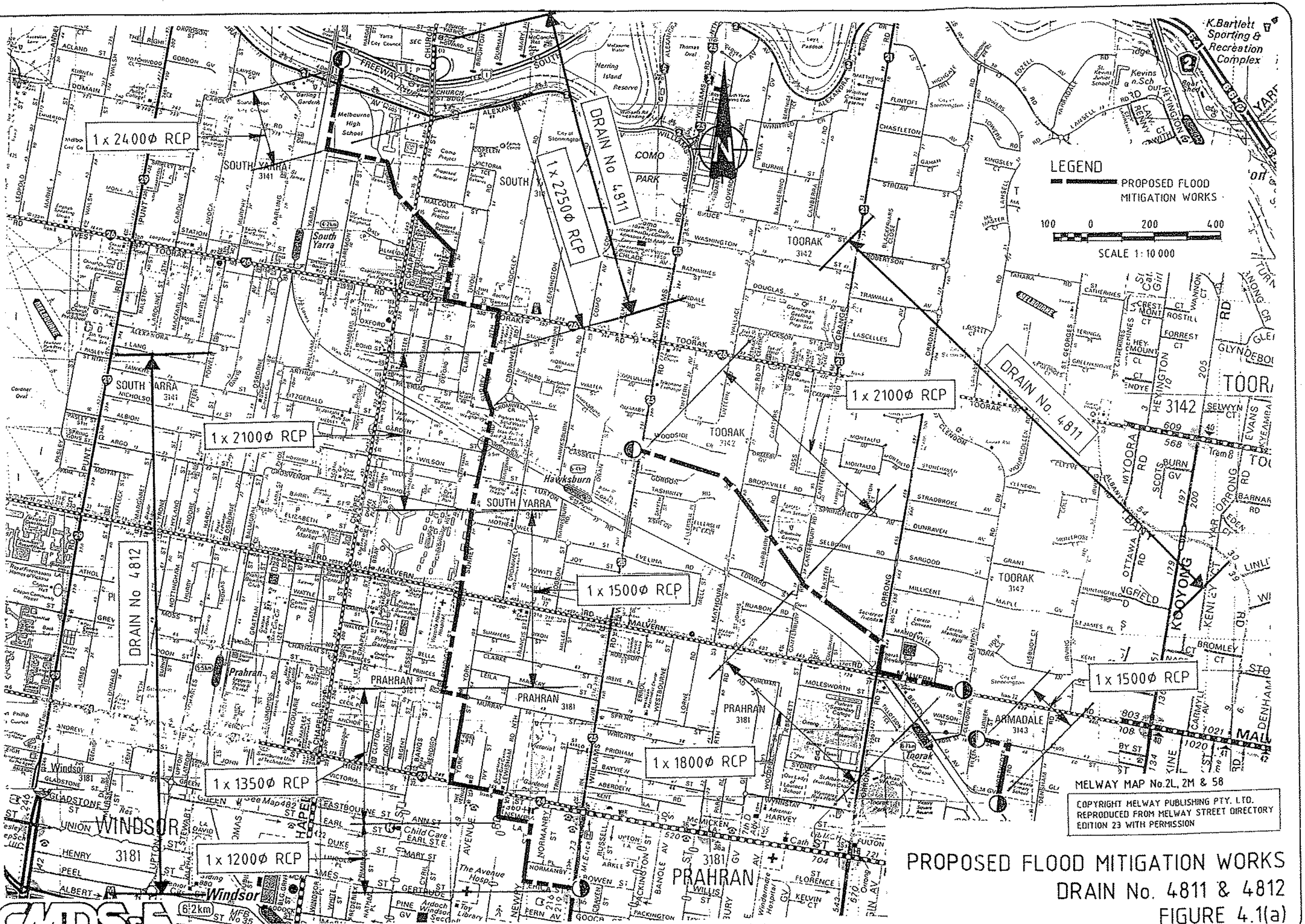
The proposed mitigation works along this drain comprise piping the majority of the overland flow. The proposed pipe extends from the corner of Erica Street and Williams Road to Bendigo Street and then north to drain 4811.

Williams Road Diversion (4814)

No flood mitigation options have been developed.

Beatty Avenue Main Drain (4815)

No flood mitigation options have been developed.



PROPOSED FLOOD MITIGATION WORKS
DRAIN No. 4811 & 4812
FIGURE 4.1(a)

CMPS&F

(c) Canberra Road Main Drain Catchment (4816)

Only two residential property floors along this drain are subject to inundation, and by the 100 year ARI event only. Consequently not flood mitigation option have been developed. Relatively inexpensive local detailing and reshaping may reduce the likelihood of these properties being inundated.

(d) Moonga Road Main Drain Catchment (4821)

No flood mitigation options have been developed.

(e) East Malvern Drain Catchment (4844)

No flood mitigation options have been developed.

4.3 Costs of Proposed Works

Preliminary costs estimates were developed for all proposed works. Much of this was based on standard unit rates presented in Appendix F. Proposed works and associated cost estimates are summarised in Table 4.1.

Table 4.1
Summary of Proposed Works and Cost Estimates

Drain No.	Drain Name	Proposed Works	Estimated Cost ($)	Total ($)
4811	Prahran Main Drain	Recommended drain augmentation requires:		
		• 180 metres of 1500mm diameter RCP	$ 200,000	
		• 600 metres of 1800mm diameter RCP	$ 1,090,000	
		• 670 metres of 2100mm diameter RCP	$ 1,785,000	
		• 935 metres of 2250mm diameter RCP	$ 2,880,000	
		• 235 metres of 2400mm diameter RCP	$ 790,000	$ 6,745,000
4812	Essex Street Main Drain	Recommended drain augmentation requires:		
		• 130 metres of 1200 mm diameter RCP	$ 105,000	
		• 670 metres of 1350 mm diameter RCP	$ 725,000	
		• 535 metres of 1500 mm diameter RCP	$ 595,000	
		• 460 metres of 2100 mm diameter RCP	$ 1,050,000	$ 2,475,000

5. REFERENCES

1. Monash University Department of Civil Engineering, in conjunction with Montech Pty Limited (1995), "RORB - Version 4, Runoff Routing Program, User Manual", by E.M.Laurenson and R.G.Mein, incorporating RORB Windows Interface by Hydro Expert Software in conjunction with T.Wong, June 1995.

2. Institution of Engineers, Australia (1987), "Australian Rainfall and Runoff, A Guide to Flood Estimation".

3. Melbourne Water (1993), "Water Industry Technical Standards, Technical Standards Manual".

4 BACKGROUND INFORMATION

The information contained in this document is confidential and should not be disclosed to third parties without the written consent of R. Young, General Manager, Waterways and Drainage.

4.1 Introduction

Melbourne Water has a requirement to know the flooding risk that exists over the drainage system. The majority of the major waterways have been flood mapped over the years and these flood inundation plans are made available to the public for information. However, very little detail knowledge is available on the flood risk over the underground drainage system.

The flood information from these mapping projects will be used to give flood advice on properties affected by flooding along Melbourne Waters' drains, and by identifying relative flood risks for sections of drains will set the priority for the capital works program. The information is also required for land development issues and therefore may be questioned by an AAT panel hearing.

The mapping projects are now based on a municipality, each with a number of Melbourne Water drains to be flood mapped. Annexure 4 shows the extent of work for each municipality.

The completion of these mapping projects will need to complement the changes each municipality is proposing to reform their planning schemes using the Victorian Planning Provisions. It is Melbourne Water's intension to include the 100 year ARI inundation area as a flood inundation overlay on the new planning schemes, therefore it will be critical for Melbourne Water to supply the overlay information to match each municipality's reform timetable.

The aims of these Projects are:

- To identify all properties that are flood prone up to the 100 year ARI standard along all Melbourne Water Drains in each specific municipality;
- To identify all property floors that are flood prone to three levels of risk;
- To identify flood prone properties that have unacceptable safety risk from overland flow;
- To identify preliminary flood mitigation options to give 100 year ARI protection to residential flooding identified above.

4.2 Terms of Reference

This document is an invitation to your organisation to present, in detail, the services that you can provide for flood mapping services in the required project areas. The work may be staged with specific milestones. You should feel free to comment on how to best progress each project as you see fit. Components of your proposal envisaged by Melbourne Water include :

- Demonstrate the methodology of how each project is to be completed, including :
  - ⇒ the design models, their assumptions, and quality control checks to ensure that a consistent approach is used for all projects;
  - ⇒ survey methods, control level measures and associated level of accuracy of reduced natural surface levels;
  - ⇒ the support capability and experience of personnel for this project

- Provide a project plan of all significant milestones including :
  - ⇒ project initiation, surveys, hydrologic modelling, pipe capacities, overland flow modelling, flood plan preparation, flood risk/ safety assessment, flood mitigation assessment and final report;
  - ⇒ program, schedule, resources, and costs.

- Provide a bid to complete all work based on each Municipality specified in Table below. Bids for combinations of municipalities are welcomed.

Staging	Municipality Project	
Pilot Councils	Port Phillip	Brimbank
Stage 1	Banyule Darebin Glen Eira Hume Yarra	Moonee Valley Moreland White Horse Yarra Ranges Casey
Stage 2	Bayside Boroondara Hobsons Bay Kingston Manningham Maribyrnong	Maroondah Melbourne City Monash Stonnington Whittlesea Knox

- Respondents should include specific answers to the points raised below :

  A detailed description of the work proposed and a municipal based project plans.

  A statement of deliverable's to be produced.

  Details of survey data methodology.

  An explanation of project initiation and management methodology.

  Structure of the project team to complete the project(s)

Time frames and detailed costing of each municipal based project proposal.

Information on their organisation, including quality accreditation, and relevant expertise in the development, implementation and support of such a large flood plain mapping exercise. Melbourne Water needs to be assured that checks are made at the completion of each stage before proceeding to the next step.

Curriculum vitae on principal personnel nominated to undertake the proposal work, and the details of the total workload to be carried by each principal.

- The following specific outputs are required for each project
  a) Written Report;
  b) Paper prints of plans showing inundation areas;
  c) Safety/ Risk assessment in digital form (ie. spreadsheet);
  d) Hydrologic and Hydraulic models in digital format;
  e) Extent of the 100 year ARI flood inundation area in digital format;
  f) Aerial photographs and survey data used.

Notes on the output requirements and suggested modelling techniques is attached in Annexure 3. It is proposed that any progress payments for each project would be based on these milestones being completed.

4.3 Melbourne Water's Existing Information Sources

The following information may be useful to complete these projects:

- catchment plans and some subarea area data where this is available.
- reduced Yarra 2500 series plans with 1 metre contours (actual scale 1:5000 and A3 size). The contours on these plans have been estimated from aerial photography and can not be relied upon to give actual point surface levels and should be verified by the proposer.
- the above 2500 plans are also available in digital form if required (eg. DFX format). The transfer cost of this data from Dataflow is to be payed by the proposer.
- design drawings of the drainage systems, including drain size and shape, invert level, and drain construction material. This material can be viewed at our office and relevant photocopies may be taken.
- recent work done by Melbourne Water on all of these catchments have identified a broad band of area that may be subject to flood inundation. These plans can only be used as an initial guide to the extent of the flood plain and is available in digital form.
- access to old 1" to 160 feet and 1" to 40 feet plans in some areas can show spot levels along roads. (These levels may not represent the current levels and should be verified by the proposer). This material can be view at our office and relevant photocopies may be taken.

A lot of the above information is available from a number of Melbourne Water held sources. It is intended for the proposer to determine what is required to complete these projects and to obtain copies of this information. Some assistance will be given to allow access to the material.

APPENDIX C
OVERVIEW OF TECHNICAL METHODOLOGY

Design flows were assessed using the RORB hydrologic model. Design flood levels were then calculated using the EXTRAN hydraulic model.

Recorded flow data were not available for any of the drainage systems under investigation. The RORB models were therefore "calibrated" to the 100 year peak discharge calculated using the rational method. It was generally assumed in the "calibration" process that the pipe systems were capable of accommodating the full 100 year peak discharge. In some of the larger systems, particularly those with significant lengths of "natural" streams, the calibration process also took account of typical RORB parameters provided by Melbourne Water. These were determined based on calibration of some of the larger streams around metropolitan Melbourne for which recorded flow data are available.

The calibrated RORB models were then adjusted such that only flows up to the capacity of the pipe system were routed through the pipe system, with the balance being routed overland.

The EXTRAN modelling was undertaken in two stages as follows:

(a) Preliminary EXTRAN models were developed to determine:

- the approximate capacities of the pipe system for use in the RORB modelling as outlined above; and

- pipe system velocities for calculation of times of concentration to be used in the rational method calculations.

The preliminary EXTRAN models generally incorporated full available details of the piped systems, but only approximate details of overland flow paths.

(b) Final EXTRAN models included full details of overland flow cross sections and levels determined from aerial survey.

Although EXTRAN has fully transient capabilities, it was only used in steady state mode, using peak flow calculated using RORB. Peak levels in retarding basins were generally calculated using RORB. In cases where retarding basin outlet capacity is significantly reduced by tailwater effects from downstream drainage systems, stage discharge relationships for use in RORB modelling were estimated using EXTRAN.

All field survey was based on aerial photography, with ground survey generally used only for levelling of control points for photogrammetric interpretation of aerial photography, and building floor level survey.

Digital terrain models, based on the aerial survey, were developed for all overland flow paths, and used:

- to extract flow cross sections for use in the EXTRAN modelling; and

- in conjunction with flood levels determined from the EXTRAN modelling, to prepare plans showing the extent of inundation along each drainage system.

Ground survey was used to determine floor levels of all buildings likely to be subject to inundation in a 100 year event. This information was then used, in conjunction with calculated flood levels, to determine which properties would be subject to inundation to above floor level in 20, 50 and 100 year events.

The digital terrain models were then used in conjunction with flood levels and velocities determined using EXTRAN to map areas corresponding to defined ranges of depth, and depth * velocity, in the 100 year event.

APPENDIX D
HYDROLOGY

D.1 INTRODUCTION

A series of hydrological investigations was undertaken to determine:

- peak flows resulting from; and
- peak levels in retarding basins and other storages in

20, 50 and 100 year average recurrence interval storm events under proposed future landuse conditions.

D.2 HYDROLOGIC MODEL RORB

D.2.1 Model Overview

RORB (ref.1) is a non linear rainfall runoff and streamflow routing model for calculation of flow hydrographs in drainage and stream networks.

The model requires catchments to be subdivided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network.

Each reach is assumed to have storage characteristics as follows:

$$S = 3600kQ^m$$

where

S is storage (m^3);
Q is outflow discharge (cumecs); and
k and m are dimensionless parameters.

The coefficient k is the product of two factors:

$$k = k_c . k_r$$

where

k_c is an empirical coefficient applicable to the entire catchment, and
k_r is the relative delay time applicable to each reach.

The relative delay time for each reach, k_{ri}, is determined as follows:

$$k_{ri}=F_i*(L_i/d_{av})$$

where

L_i is the reach length (km),
d_{av} is the average distance along the reach network from each subareas centroid to the catchment outlet (km), and
F_i is an empirical factor, and a function of reach type as follows:

for natural reaches, $F_i=1.0$,
for excavated but unlined reaches, $F_i=1/(3S_c^{0.25})$,
for lined or piped reaches, $F_i=1/(9S_c^{0.5})$, and
for drowned reaches, $F_i=0.0$,

where S_c is reach slope (%).

The model is also able to simulate:

- lakes, retarding basins and similar storages; and
- concentrated and distributed inflows and outflows.

D.2.2 Model Application and Parameters

In this study, all flows in excess of the capacity of drainage systems subject to investigation were routed overland, and separately to flows contained within the defined drainage system. For the purposes of assigning a reach type, overland flow along roads was generally assumed to be "lined or piped". The one exception to this was in flat areas of shallow sheet flow, in which case the reach type was assumed to be "excavated but unlined". The natural reach type was generally assigned only to heavily vegetated creeks in flat areas, as distinct from engineered drains.

RORB's initial loss/runoff coefficient model was used throughout the study. Adopted parameters for pervious areas were as follows:

- initial loss - 15 mm; and
- runoff coefficient - 0.6.

The model sets these parameters for impervious areas as follows:

- initial loss - 0 mm; and
- runoff coefficient - 0.9.

A value of 0.8 was adopted for the model exponent, m, throughout.

D.3 RATIONAL METHOD

D.3.1 Overview

The rational method is the simplest and most widely used method for calculation of peak discharge from a catchment. The basic equation is as follows:

$$Q = C.I.A/360$$

where

Q is peak flow in cumecs, corresponding to the average recurrence interval under consideration;

C is runoff coefficient;

I is rainfall intensity in mm/hour, corresponding to t_c, the time of concentration of the catchment, and the average recurrence interval under consideration; and

A is catchment area in hectares.

Time of concentration, t_c, was generally calculated using:

- actual flow velocities in Melbourne Water drains, calculated using preliminary EXTRAN models, as outlined in Appendix C;
- flow velocities in Council drainage systems, generally calculated assuming:
  - a Colebrook White roughness coefficient of 1.5mm;
  - pipe diameters of 600mm; and
  - pipe friction slope equal to 50 to 100% of ground slope; and
- an allowance of seven minutes for runoff to reach the upstream limit of the piped drainage system.

The runoff coefficient was assessed using the method prescribed in Chapter 14 of the 1987 Edition of "Australian Rainfall and Runoff" (ref.2). This relates the runoff coefficient to:

- the impervious percentage of the catchment;
- design recurrence interval; and
- 10 year 1 hour design rainfall intensity.

Standardised impervious percentages for each major landuse were adopted as follows:

- residential 48.5%. This is derived from the assumption that existing residential areas are generally 45% impervious, but 10% of this will be converted to dual occupancy with an 80% impervious fraction;

- schools - 45%;
- commercial - 75%;
- industrial - 80%; and
- reserves/open space - 10%.

Landuse was generally based on zonings extracted from the pData planning database provided by Stratagem Infobase on 28 November 1996. Where necessary, additional information and adjustments were based on hard copy planning scheme maps.

All landuse categories included in the database or hard copy planning scheme maps were assigned to one of the five major landuses listed above. Some further adjustments were sometimes necessary to correct obvious anomalies associated with this process. For example, golf courses are sometimes assigned a commercial landuse. This impervious percentage of a golf course, however, will clearly be significantly less than 75%, and adjustment is therefore required.

D.3.2 Parameters and Peak Discharges

Rational method parameters and resultant peak flows are summarised in Table D.1.

Table D.1
Summary of Rational Method and RORB Parameters and Peak Flows

Major Drainage Catchment/ Drain No.	Drain Name	Tributary or Diversion Drain No.	Tributary or Diversion Drain Name	Catchment Area (ha)	Impervious Percentage	Rational Method				Undiverted RORB Model			Diverted RORB Model		
						Runoff Coefficient	Time of Concentration (mins)	Rainfall Intensity (mm/hr)	Peak 100 Year Flow (cumecs)[1]	K_c	d_{av}	Peak 100 Year Flow (cumecs)[1]	K_c	d_{av}	Peak 100 Year Flow (cumecs)[1]
4801	Yarra Street Drain			97	58	0.69	27	78	14.7	2.21	1.0	14.8	2.21	1.0	11.7
4811	Prahran Main Drain	4812 4814 4815	Essex Street Main Drain Williams Road Diversion Beatty Avenue Main Drain	702 [2]	54	0.67	44	58	74.7	6.66	2.6	74.7	5.79	2.3	36.3
4816	Canberra Road Main Drain			75	50	0.62	15	110	14.2	3.07	0.7	14.2	3.07	0.7	7.4
4821	Moonga Road Main Drain			133	52	0.64	15	109	25.7	2.72	0.8	25.8	2.72	0.8	14.9
4844	East Malvern Drain			96	49	0.62	26	80	13.1	3.89	0.9	13.1	3.89	0.9	8.6

1. At outlet of Drain listed in first two columns.
2. Rational Method parameters for the Prahran Main Drain catchment were developed based on partial area effects.

D.4 DESIGN RAINFALL INTENSITIES

Design rainfall intensities were determined based on the methods prescribed in the 1987 edition of "Australian Rainfall and Runoff" (ref.2), and are presented in Table D.2.

Table D.2
Design Rainfall Intensities (mm/hr)

Duration	20 Year	50 Year	100 Year
10 min	92.3	115	134
15 mins	75.6	93.7	109
20 mins	64.8	80.1	92.8
30 mins	51.5	63.3	73.1
45 mins	40.2	49.3	56.8
60 mins	33.5	41.0	47.1
90 mins	25.8	31.4	36.0
2 hrs	21.4	25.9	29.6
3 hrs	16.3	19.7	22.4
6 hrs	10.3	12.3	13.9
8 hrs	8.46	10.1	11.4
12 hrs	6.46	7.68	8.66
18 hrs	5.0	5.99	6.77
24 hrs	4.17	5.0	5.67
36 hrs	3.19	3.85	4.39
48 hrs	2.62	3.18	3.63
72 hrs	1.94	2.37	2.72

D.5 CATCHMENT MODELS - LAYOUT, CALIBRATION AND RESULTS

RORB catchment models were developed for each of the rational method catchments detailed in the previous section. At this stage of the process, all flows were routed together, and no account was taken of drain capacities.

The models were each calibrated to the results of the 100 year rational method flow at the catchment outlet, by adjusting K_c. Resultant model parameters and flows are also summarised in Table D.1.

D.6 FINAL CATCHMENT MODELS

The calibrated models were then adjusted to include:

- separate routing of flows in excess of drain capacity;
- diversions into and/or out of the catchment; and
- any retarding basins, lakes or storages. This included any areas where large volumes of runoff would pond during a major storm event, even if this was not a lake or designated retarding basin.

The introduction of diversions into the models will often result in changes to d_{av}. Any significant changes to dav were compensated for by also adjusting K_c, such that K_c/d_{av} was the same as for the calibrated model. Final model parameters are also presented in Table D.1.

Catchment specific RORB model features are summarised in Table D.3.

Table D.3
Catchment Specific RORB Model Characteristics

Major Drainage Catchment	Modelled Storages	Modelled Diversions
Prahran Main Drain	• across Toorak Rd & River St • in Como Park (Williams Rd)	• Williams Road Diversion (4814)

<u>Prahran Main Drain Catchment (4811)</u>

Sub-areas AB and AC were omitted from the RORB model for calibration purposes as these sub-areas contribute to the Williams Road Diversion only.

APPENDIX E
HYDRAULIC MODELLING

E.1 INTRODUCTION

The aims of the hydraulic studies were to determine:

- peak 100, 50 and 20 year flood levels; and
- peak 100 year velocities

at all required locations.

E.2 HYDRAULIC MODEL EXTRAN-XP

All hydraulic modelling was undertaken using EXTRAN-XP. EXTRAN is a transient quasi-two-dimensional hydraulic flow model, capable of simulating both piped and open channel systems. Other capabilities and features of particular relevance include:

- simulation both subcritical and supercritical flow regimes;
- simulation of interchange between surface and subsurface flows through manholes; and
- simulation of branched and looped networks, incorporating both convergent and divergent flows, and multiple tailwater conditions.

EXTRAN is a link node model. Flood levels are calculated at model nodes, which are linked by a series of links with defined hydraulic characteristics. Flows and velocities are calculated within the links.

Typical values of Mannings roughness coefficients used in the modelling are shown in Table E.1

Table E.1
Typical Values of Mannings Roughness Coefficient

Material/Surface	Typical Mannings Roughness Coefficients
Concrete	0.015
Roads with grassed nature strips	0.020
Grassed Floodways	0.03 to 0.04

Typical values adopted for other hydraulic parameters were as follows:

- expansion/contraction coefficients (surface flows) - 0.2 to 0.5
- culvert entry loss coefficient - 0.2 to 0.7;
- culvert exit loss coefficient - 0.2 to 1.0;
- manhole diameter - 1.2 metres
- manhole inlet loss coefficient ("pipe end") - 1.0; and
- manhole exit loss coefficient ("surface end") - 1.0.

It was assumed in all hydraulic modelling that drainage system capacity is unconstrained by inlet capacity, and that drains will not be blocked during flood events. No account was taken of the capacities of any underground drainage systems other than those requiring investigation as part of this study.

Tailwater levels were generally adopted as the greater RL +0.3 m AHD and:

- piped systems - downstream pipe obvert level; and
- open channel systems - normal flow depth.

A tailwater level of RL +0.3 m AHD was generally applicable only to drains discharging to Port Phillip Bay.

The flood levels and velocities calculated in this Study correspond to a storm event on the catchment of the drain under consideration without any allowance for a coincident event on either the outfall stream of the drain or Port Phillip Bay. It is entirely likely, particularly along the lower reaches of drainage systems, that higher flood levels than those calculated in this study will result from a flood event on the outfall stream, or an extreme high tide or storm surge event on Port Phillip Bay, either alone or coincident with a storm event in the catchment of the drain in question.

E.3 FINAL EXTRAN MODELS

The Yarra Street Drain and the Prahran Main Drain were included in a single EXTRAN model.

APPENDIX F
UNIT COST RATES FOR FLOOD MITIGATION WORKS

F.1 INTRODUCTION

Standard unit cost rates were developed for a range of possible flood mitigation works, and used to develop the cost estimates presented in Chapter 4.

F.2 PIPED DRAINAGE WORKS

Estimates for piped drainage works were based on:

- Melbourne Water's Water Industry Technical Standards (ref.3); and
- recent tender prices.

All rates are approximate only, and all include a contingency allowance to account for items that have not been assessed at this stage, including:

- relocation of underground services;
- excavation in rock; and
- miscellaneous additional works such as manholes, inlet pits and bends.

Adopted rates are presented in Table F.1.

Table F.1
Standard Rates for Piped Drainage Works

Diameter (mm)	Reserves and Open Areas ($/m)	Roads ($/m)	Developed Private Property/Major Roads/ Boring ($/m)
900	360	530	700
1050	430	670	900
1200	500	800	1100
1350	600	950	1300
1500	710	1110	1500
1650	870	1340	1800
1800	1100	1650	2200
1950	1310	1960	2600
2100	1560	2280	3000
2250	1780	2670	3560
2400	2030	3070	4060
2700	2350	3520	4700
3000	2700	4050	5400