CLAISEBROOK INLET
PUBLIC ENVIRONMENTAL REVIEW

ALAN TINGAY & ASSOCIATES
&
EAST PERTH REDEVELOPMENT AUTHORITY

FEBRUARY 1992
REPORT NO: 91/24
AN INVITATION TO COMMENT ON THIS PER

The Environmental Protection Authority (EPA) invites people to make a submission on this Public Environmental Review (PER).

The East Perth Redevelopment Authority (EPRA) propose to develop an Inlet along the existing alignment of Claisebrook Drain in East Perth to provide a focus for urban redevelopment in the area. In accordance with the Environmental Protection Act 1986, a PER has been prepared which describes this proposal and its likely effects on the environment. The PER is available for a public review period for 8 weeks from 7 March, 1992 and finishing on 4 May, 1992.

Following receipt of comments from Government agencies and the public, the Environmental Protection Authority (EPA) will prepare an assessment report with recommendations to government, taking into account issues raised in public submissions.

Why write a submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless confidentiality is requested, and may be quoted either in full or in part in each report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people) please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a submission

You may agree or disagree with, or comment on, the general issues discussed in the PER or the specific proposals. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the PER:

0 clearly state your point of view;
0 indicate the source of your information or argument if this is applicable; and
0 suggest recommendations, safeguards or alternatives.
Points to keep in mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

0 attempt to list points so that the issues raised are clear. A summary of your submission is helpful;

0 refer each point to the appropriate section, chapter or recommendation in the PER;

0 if you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering;

0 attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

0 Please indicate whether your submission can be quoted in full or in part by the EPA in its Assessment Report.

Remember to include:

0 your name;
0 address; and
0 date.

The closing date for submissions is:

4 May 1992

Submissions should be addressed to:

The Chairman,
Environmental Protection Authority
GPO Box S1400
PERTH WA 6001

Attention:  Mr N Wimbush

or for hand delivery

9th Floor
Westralia Square
38 Mounts Bay Road
PERTH WA 6000
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SUMMARY

1. Introduction

The East Perth Project is an ambitious urban renewal program which is designed to rejuvenate a substantial part of the inner city suburb of East Perth. It is the largest urban renewal project in Perth's history and involves 140ha of land. The Claisebrook Inlet is an important development feature of the East Perth Project and is the subject of this Public Environmental Review (PER). The East Perth Redevelopment Authority (EPRA) is the Proponent for the Claisebrook Inlet. Management of the Inlet and the surrounding landscaped areas including the islands will remain the responsibility of EPRA for the Authority's lifetime.

2. Description Of Existing Environment

Setting

The Claisebrook Inlet will be constructed at the base of a shallow valley within East Perth which contains the Claisebrook Drain. Substantial areas of the proposed Inlet location contain loose fill and rubble as a result of excavation and filling from past industries.

A large portion of the East Perth area is owned by the State Government and is mostly land acquired for public purposes or land which has been used by public agencies. The number of buildings actually affected by the construction of the Inlet are few and are mainly old sheds, which are either vacant or in poor condition.

Hydrogeology

A groundwater study was commissioned to evaluate the hydrogeological conditions that exist in and around the proposed location for Claisebrook Inlet. Groundwater flow occurs into the Swan River and Claisebrook Drain and these control the level of groundwater in the immediate vicinity. Groundwater analysis indicates that groundwaters are generally of good quality.

Claisebrook Drain

The Claisebrook Drain receives stormwater drainage from an urbanised catchment area. It is mostly piped until it discharges into a relatively poorly maintained open drain near East Parade. A low flow pipe designed to carry summer flows discharges into the river just south of the existing Claisebrook Drain.

Investigations established that some sediments within Claisebrook Drain are contaminated with heavy metals, hydrocarbons and pesticides. Elevated levels of heavy metals were detected above what would be considered normal for soils in the area. These elevated levels are confined to the uppermost sediments in the drain.
Waters of the Claisebrook Drain samples are typical of an urban drain. Review of water quality data and comparison with Water Quality Criteria has shown that they are moderately clear and generally of good quality. However, two parameters are of concern, these being high faecal coliforms, and elevated levels of nutrients.

**Former Gasworks Site**

The former Gasworks site owned by SECWA is located adjacent to the mouth of the proposed Claisebrook Inlet. Past industrial activities on this site have resulted in its pollution with chemicals that have the potential to impact on the general environment and to affect human health. The state of this site has implications with regard to the future quality of water within the Inlet.

Contamination consists of wastes generated by gas production of which coal tar is considered to be the most important. A portion of the Gasworks is required for the construction of the Claisebrook Inlet and drilling has found it to be free of coal tar contamination. The groundwater beneath the Gasworks site is polluted as a result of leaching of wastes and the dumping of liquids.

3. **Description Of The Development**

**The Inlet**

The Claisebrook Inlet will be the focal point of redevelopment within the East Perth Redevelopment Project. The Inlet design has 3 main components, a main section with an area of 1.5ha, two channels which connect the main section to the Swan River and which collectively have an area of 0.5ha, and a channel at the westernmost end which is at a higher level than the main section.

The ultimate location and shape of the Inlet and the connecting channels were determined after taking into account the constraints offered by the site with regard to topography, existing services, trees and the presence of the former East Perth Gasworks site and because of poor ground conditions adjacent to the Claisebrook Drain between Trafalgar Road and Plain Street.

**Inlet Excavation**

The construction of the Claisebrook Inlet will be carried out by excavators loading into trucks. It is expected that 140000m$^3$ of material will be excavated in the construction of the main body of the Inlet. Excavation of the channel at the western end of the Inlet and its adjacent promenade will involve removing 90000m$^3$ of material.

**River Deepening**

Two areas of the bed of the Swan River adjacent to the connecting channels of the Inlet will be deepened to enhance the exchange of water between the Inlet and the river.
Associated Engineering Works

The design of the Inlet includes a number of bridges which will allow motorised and pedestrian access either around or through the development area. Two road bridges will cross the channel at the western end while four footbridges will allow pedestrian and bicycle access through and around the development centred on the main section of the Inlet.

Works Associated with the Former Gasworks Site

The northern connecting channel of the Claisebrook Inlet runs alongside the former Gasworks site. Dewatering for the construction of the Inlet and the creation of the Inlet itself have the potential to introduce contaminated groundwater from the site into the Inlet thereby affecting its water quality. In order to prevent this a barrier wall will be constructed along that portion of the northern channel that borders the Gasworks site.

Associated Urban Design and Landscaping

The Inlet can be divided into three separate design zones, the foreshore, the main basin and the perched water system west of Plain Street. The foreshore area will retain its existing parkland character of roughly slashed, unirrigated grass and native riverine trees. Islands created by the construction of the Inlet will be in keeping with this theme. The maintenance of public access to and along the river has been a priority in planning the foreshore areas.

The main basin of the Inlet will measure approximately 120 metres by 70 metres and will have an average depth of 2 metres. Landscape vegetation around the major basin will comprise indigenous species in order to give the project Western Australia flavour. West of Plain Street, the Inlet becomes a closed system of elevated ponds with water flowing back towards the river. Hard edged pavements will cover the remainder of the pedestrian areas between the water and buildings.

4. Environmental Issues And Management

Inlet Construction

The water that initially fills the Inlet will exchange with river water when connection is made to the Swan River. This represents a release of water to the Swan River. It is expected that this water will be of good quality however it may contain suspended sediments as a result of the construction activities. Should there be a need, the potential impact related to the release of this water will be managed by timing the connection so that the suspended sediment levels are as low as can be practically achieved and the impact of any suspended sediments is minimised.

Dewatering will be required to some degree in the construction of the Inlet. This action has the potential to lower the groundwater table and cause contaminated groundwater to flow from the gasworks. A groundwater flow cutoff wall designed to
prevent the flow of contaminated groundwaters into the Inlet during construction therefore will be installed prior to dewatering. The EPRA will produce an Environmental Management Program which will give full details relating to the disposal and handling of groundwaters from dewatering.

Investigations indicate it is unlikely that contaminated waste may be present on the Inlet site itself. Despite this there is a minor potential for small quantities to be present. If unidentified waste of suspect nature is uncovered during excavations a specific procedure for dealing with these materials will ensure that worker and public health is protected and that the wastes are properly disposed of. The EPRA will produce an Environmental Management Program which will give full details relating to disposal and handling of any contaminated materials.

**Claisebrook Drain Sediments**

Investigations have established that the sediments of the Claisebrook Drain are contaminated with a range of chemical compounds. SECWA proposes to excavate sediments contaminated by gasworks pollutants from the drain and the Swan River. However, some of these sediments will be excavated for the construction of the Inlet. It is proposed that SECWA will retain responsibility for these, however if this is not the case EPRA will be responsible.

Elevated but low level heavy metal contamination has been identified within the sediments that line the drain in areas which will be excavated as part of the Inlet construction. The levels of heavy metals are considered not to be high enough to warrant special treatment and it is proposed that the material be treated as normal spoil.

**Dust**

The wet nature of the excavation will serve to reduce the risk of dust generation, however the excavation will still have minor potential to generate dust. The construction of the Inlet was determined as having a medium risk with regard to the generation of nuisance dust as defined by EPA Dust Control Guidelines. Dust suppression measures as detailed in the EPA guidelines for medium risk category sites will be implemented to minimise this potential nuisance.

**Noise**

Excavation of the Inlet is expected to generate noise over the construction period. The noise has potential to disturb residents and workers; however, this potential is lessened by the noisy nature of the area and the absence nearby residents. However, work practices and limited working hours will limit prevent unacceptable impacts from occurring.

**Deepening of the Swan River**

Deepening has the potential to cause short term changes to the Swan River which relate to the suspension of fine particulate matter into the water column. This could affect
filter feeding organisms and reduce the available light for aquatic plants. However, the area of mussel habitat nearby is relatively small and seagrasses are not present in this stretch of the Swan River. The suspension of sediments may promote the release of pollutants found in the river sediments. Given the existing need for removal of these sediments it is considered that the excavation will pose little or no additional impact to the river biota.

**Inlet Water Quality**

A study was commissioned to determine the degree of water circulation and exchange within the Inlet. The rates of water exchange between the proposed Inlet and the Swan River were calculated and these indicate that good exchange rates will be maintained. As a result it is concluded that exchange will be sufficient to prevent the build up of pollutants and the stagnation of the Inlet waters.

It is possible that water quality criteria relating to faecal coliforms may be exceeded occasionally in the Inlet despite water exchange. As a result, management techniques will be implemented to minimise the level of faecal coliform in the Inlet.

**Groundwater**

A study was commissioned to analyse the impact that Inlet construction would have on the groundwater table in the area and the potential for migration of saline water inland from the Swan River. The results show a drop in the water table of between 1.8m and 0.2m will occur. The majority of this area will be under the control of the EPRA and therefore will not affect private bores. Modelling has indicated the lowering will be insufficient to cause intrusion of saline waters from the Swan.

**Existing Human Usage**

Existing use of the development area is limited to passive recreation on the foreshore including use of the cycleway. Construction will be planned to limit any inconvenience to cycleway users. The net impact with regard to use of the area will be a positive one, as the development will greatly enhance the attractiveness of this area of foreshore.

5. **Conclusions**

The proposed Claisebrook Inlet is a key element in the rejuvenation of East Perth. The Claisebrook Inlet will effectively improve the recreational features of the area, promote the removal or control of sources of water pollution, the clean-up of adjacent polluted land, and will generate a program to improve the water quality of Claisebrook Drain.

It is concluded that the potential benefits of this proposal to the people of Perth and the general urban environment outweigh the minor potential impacts identified in this PER. Given this and the commitments made by the Proponent to minimise these impacts, it is concluded that the proposed Claisebrook Inlet does not pose an unacceptable impact to the environment.
1. INTRODUCTION

1.1 Background

The East Perth Project is an ambitious urban renewal program which is designed to rejuvenate a substantial part of the inner city suburb of East Perth. It is the largest urban renewal project in Perth's history and involves 140ha of land. The project area is located less than 2km away from Perth's centre and will form a new eastern gateway to the central city as it is strategically located between the city and the airport.

The Claisebrook Inlet is an important development feature of the East Perth Project and is the subject of this Public Environmental Review (PER). It has been referred to the Environmental Protection Authority (EPA) so that its potential environmental impact can be assessed. The Claisebrook Inlet is within one of a number of development areas which the East Perth Project has been divided into for design and management purposes. These design areas are referred to as the Claisebrook, Trafalgar, Eastbridge and Gladstone Precincts (Figure 1.1). The Trafalgar Precinct has been further subdivided into North Trafalgar and South Trafalgar. The Claisebrook Inlet is within the North Trafalgar Precinct.

As structure planning for each of the precincts has been finalised they have been referred by the East Perth Redevelopment Authority (EPRA) to the EPA as required under the provisions of the Environmental Protection Act, 1986. These referrals have provided the EPA with opportunities to consider whether these plans warrant detailed assessment.

The Claisebrook Precinct and the southern part of the Trafalgar Precinct were referred to the EPA in 1990. However, as redevelopment in these areas involves only the demolition and construction of buildings and the upgrading of services, the EPA decided that formal assessment was not warranted.

North Trafalgar was initially referred to the EPA in early 1991. At that time the EPA indicated that two components of this area were of particular interest to it, namely the East Perth Gasworks site which is contaminated with industrial wastes and the proposed Claisebrook Inlet. Therefore, the EPA determined that it would formally review proposals for this area. However, it did not set a level of assessment as the Gasworks site was owned by the State Energy Commission of Western Australia (SECWA) and not by the EPRA. The EPA believed it inappropriate for the EPRA to propose remedial works for a site which it did not own.

Therefore, the original referral was subsequently withdrawn and a new referral was made which referred only to the Claisebrook Inlet and not the Gasworks site. The Inlet itself was also redesigned for this new referral in order to minimise its overlap with the Gasworks site. Construction of the Inlet will now involve only a small part of the Gasworks site and this part is virtually free of industrial contaminants. The EPA decided that this new proposal for the Claisebrook Inlet warrants assessment in more detail and has required the EPRA to prepare a PER to provide the basis for that
DEVELOPMENT PRECINCTS OF THE EAST PERTH PROJECT

FIGURE 1.1
assessment. The issues involved are specified in guidelines prepared by the EPA (see Appendix 1) and a PER has been prepared to conform with those guidelines.

The proposed clean-up of the East Perth Gasworks also has now been independently referred to the EPA by SECWA. In turn the EPA has decided to assess this proposal at a PER level of assessment and the appropriate documentation is being prepared by SECWA (as at February 1992). The SECWA proposal is not related to or dependant on the construction of the Claisebrook Inlet in any way.

The PER process which is described more fully in Section 1.3 below, provides an opportunity for public comment on the Claisebrook Inlet proposal through an 8 week public review period. Interested persons are encouraged to make written submission to the EPA during this period and a guide to the preparation of a submission is given at the front of this PER.

In general, the present PER describes the Proponent and the proposed Claisebrook Inlet along with its associated urban design and landscaping. Descriptions and analyses of the environmental issues relevant to the Inlet and its construction also are provided together with environmental management strategies which will be carried out to minimise potential environmental impacts.

1.2 The Proponent

The Proponent for the Claisebrook Inlet is the East Perth Redevelopment Authority (EPRA) which was established by Parliament to plan and manage the redevelopment of East Perth. The powers and operations of the EPRA are specified by East Perth Redevelopment Authority Act, 1991.

1.3 The PER and the Assessment Process

This PER has been requested by the EPA in order to enable it to assess the environmental implications of the construction of the Claisebrook Inlet. It has been prepared with the following objectives in mind:

- To promote public understanding of the proposal and to facilitate public comment to the EPA.
- To provide a mechanism whereby public authorities and the general public can raise environmental issues which may not otherwise be addressed.
- To address all environmental and design issues in one concise and definitive report.

The PER Assessment Process is illustrated in Figure 1.2. The PER is available for a period of 8 weeks during which submissions can be made to the EPA. At the end of the review period, comments submitted by the public and others will be forwarded to the
THE ENVIRONMENTAL ASSESSMENT (EIA) PROCESS
(Under the Environmental Protection Act, 1986)

**STATUTORY TIMING**

- Report (advise within 28 days) (Section 40)
- EPA DECISION ON ASSESSMENT LEVEL (Section 40)*
  - EIA by EPA not required - report

**INFORMATION ABOUT APPEALS, INQUIRIES ETC**

1. 2nd & 3rd party appeals to Minister within 14 days on level set (but process not held up) (Sections 100-110)
2. Minister may direct higher level of assessment but not vice versa (Section 43)

**FORMAL PROCESS**

- Public Environmental Report (PER)

**PROPOSAL**

- Decision Making
  - Minister may refer
  - Public authorities shall refer
  - Proponent may refer
  - EPA calls in

**PROPOSED, DMA, REFEREE ADVISED** (Section 40)

**PROPOSENT PREPARES DOCUMENTATION**

**EPA EXAMINES DOCUMENTATION FOR SUITABILITY FOR PUBLIC REVIEW**

**PUBLIC REVIEW**

- Additional points are:
  - Public inquiries (with Minister's approval)
  - Proponent to respond to public comments

**EPA UNDERTAKES ASSESSMENT**

(Under broad powers. Details in Administrative Procedures for flexibility (Section 40))

**EPA REPORTS TO MINISTER** (Section 44)

**MINISTER PUBLISHES EPA REPORT** as soon as possible (Section 44)*

**MINISTER ENSURES SETTING OF AND IMPLEMENTATION OF ENVIRONMENTAL CONDITIONS** (Section 45-48)*

* Appeal Point
EPRA and the EPRA will provide written responses to any issues raised. The EPA will then prepare an Assessment Report which will provide advice and recommendations to the Minister of the Environment as to the environmental acceptability of the proposal and what conditions should apply to it. Members of the public and others may lodge appeals with respect to the recommendations in the EPA Assessment Report. The Minister will then determine any appeals and will inform the EPRA whether the proposed Claisebrook Inlet development is acceptable and what conditions will apply to its construction and management.

The PER has been written to provide a concise, accessible description of the proposal, its setting, its potential environmental impacts, and the management strategies that will be carried out to minimise these potential impacts.

The main body of the PER comprises (9) sections.

1. Introduction
2. Need for the Development
3. Assessment of Alternatives
4. Description of the Development
5. Description of the Existing Environment
6. Assessment of Environmental Impacts
7. Environmental Management
8. Conclusions
9. References

1.4 Legislative Framework

In the early stages of the East Perth Project it was recognised that an innovative approach would be necessary for the efficient and effective redevelopment of the area involved. The benefits of such an approach could be seen internationally through urban renewal projects such as the London Docklands and the False Creek housing project in Vancouver; and in Australia by projects such as Sydney’s Darling Harbour, the South Bank development in Brisbane and the Docklands project in Melbourne. In each case, special planning and management processes were necessary to realise comprehensive redevelopment.

In Western Australia, the Government considered that the level of integrated planning & management needed for the East Perth Project could best be achieved by a single authority which had the full range of necessary resources and expertise. Therefore, the East Perth Redevelopment Authority was established through the proclamation of the East Perth Redevelopment Act, 1991, to provide sufficient management focus and control over development while deferring to other Authorities or established processes on specialist matters.

The East Perth Redevelopment Act, 1991 generally enables the Authority to undertake:

- overall planning, urban design and development co-ordination,
o land assembly, site preparation and property management,
o arrangement for the provision of service infrastructure and community facilities, and
o disposal or leasing of land in accordance with the approved development scheme.

The Board of the Redevelopment Authority is made up of two representatives from the Perth City Council and five others with knowledge or experience in urban planning, business management, property development, financial management, engineering, transport and community affairs. The operations of the Redevelopment Authority are subject to Ministerial policy directions and are fully accountable under the Financial Administration and Audit Act, 1985.

1.5 Statutory Requirements and Approvals

Part of the East Perth Redevelopment Act, 1991 provides that a Redevelopment Scheme be introduced for the whole or part of the redevelopment area defined in the Act. A Draft Redevelopment Scheme for the Claisebrook Valley is being prepared by the EPRA in consultation with the City of Perth to meet this requirement. In preparing this Scheme consideration has been given to public and other submissions to the Outline Development Plan for East Perth which was released in October 1990. The Scheme will be advertised for public comment prior to its approval by the Minister for Planning.

The Redevelopment Scheme outlines intentions for future development in the Scheme area through a series of objectives and planning policies. Detailed plans are being prepared for a number of sectors within the scheme area and these include specific development policies, performance criteria and general design guidelines. All development applications will be assessed according to these criteria.

Where the EPRA is acting as developer, as in the construction of the Claisebrook Inlet, and associated roads and services, it is bound by legislation and must act in accordance with its own Redevelopment Scheme. The Minister for Planning is required to give development approval when the Authority is the developer.

Part 5 of the Act allocates a development control function to the EPRA in addition to that currently undertaken by the City of Perth and the State Planning Commission. Therefore when the proposed Redevelopment Scheme is gazetted the Authority will be the principle development control agency in consultation with other government departments and the City of Perth.
1.6 Major Issues

This PER gives an assessment of the potential environmental impacts that may be posed by the construction of the Claisebrook Inlet. These can be broadly broken down into impacts that may occur during the construction of the Inlet and those that may occur after its completion.

Potential impacts such as noise and dust generated by the Inlet excavation, initial water quality within the Inlet, and the effect of dewatering on groundwater levels are considered to be important but of a temporary nature.

Long term potential impacts relate to such issues as water quality within the Inlet, permanent groundwater level reductions, and the impact of the deepening of parts of the Swan River.

1.7 Timing of the Proposal

The East Perth Redevelopment Authority aims to commence substantial development in the 1992-1993 financial year and has several major programming schedules underway in order to meet this objective. These schedules relate to the whole development area as well as the construction of the Claisebrook Inlet. They include a programme for the establishment of a Redevelopment Scheme, land assembly and securing of the necessary environmental approvals.

Project planning consultants in conjunction with the project's environmental scientists have set the target date for the Inlet PER approval for the second half of 1992. Construction of the Inlet will commence as soon as approvals are obtained from the Minister for the Environment and the Redevelopment Scheme is gazetted. It is expected that the actual completion of the Inlet would occur in the first half of 1993.

One of the primary constraints on the timing of the project are the financial obligations which the EPRA must meet in order to satisfy State and Federal funding programmes. These require the expenditure of certain moneys on urban infrastructure within each financial year of the project. It is therefore of great importance that these approval schedules are met.

1.8 Management

Management of the Inlet and the surrounding landscaped areas including the islands will remain the responsibility of the East Perth Redevelopment Authority for the Authorities' lifetime which is expected to be at least the short to medium term. In reality many of the maintenance activities that will need to be performed will be carried out by other agencies with the EPRA being responsible for the financing of these activities. At some time in the future the State Government will decide that the objectives of creating the Authority will have been met and the Authority will be
dissolved. Any remaining management responsibilities will then be passed onto other relevant authorities.

1.9 Public Participation and Consultation

On 11 October 1990 an "Outline Development Plan" for East Perth was released by the Premier. The plan established a planning and management framework for the redevelopment of East Perth. During this design phase, consultation was undertaken with other Government Agencies with major interests in East Perth. Public submissions on previous plans for the development of the area were also considered.

The Plan detailed recommendations for the redevelopment of East Perth and it was widely advertised in both the electronic and written media that the Project would welcome submissions from all sources on the proposals. Two major public meetings were held to discuss the plan and a formal public comment period was held open for five months.

An important part of this public participation process was a day long meeting held by the Project Co-ordinators half way through the design process. This meeting was attended by representatives of most affected government agencies, community groups, professional groups and the design consultants directly involved in the project. The valuable feedback from this day was subsequently interpreted into the proposed redevelopment plan.

Since that time, more detailed planning has required further consultation with agencies and government interested groups and numerous groups that represent various community interests. This process of consultation will continue throughout the life of the Project as design and development is undertaken for all areas of East Perth.

The revised plans for the development of the Claisebrook and Trafalgar Precincts will be subject to a 3 month public comment period as part of the planning process to introduce the Redevelopment Scheme for the area. It is proposed that this Scheme be released for Public comment in April 1992 along with a series of information bulletins designed to encourage public comments and inputs to the project.

1.10 Aboriginal Heritage Issues

The files of the Aboriginal Sites Department contain three ethnographic listings within the Project area. The Project therefore appointed consultants to undertake a study into Aboriginal heritage and interests in the area.

The study involved an examination of archival material and previous research reports on the Project area and its environs, together with archaeological and ethnographic field surveys. Aboriginal people having associations with and who are knowledgeable of Aboriginal heritage in East Perth were interviewed and detailed site inspections were undertaken with key informants having association with the area.
The final report recommended that the East Perth Project be permitted to proceed with development; that consultation with Aboriginal people and their respective organisations continue throughout the planning and development phases of the project; and that further consultation be undertaken with Nyungars concerning recognition of Aboriginal heritage.

The report was submitted to the Aboriginal Sites Department and application to develop the land was made in accordance with Section 18 of the Aboriginal Heritage Act, 1972-1980. Ministerial approval to develop has subsequently been received.

It is the Authorities intention to continue consultation with Aboriginal people and agencies concerning development within the Project area and to recognise Aboriginal history and culture.
2. NEED FOR THE DEVELOPMENT

The redevelopment of East Perth will have major benefits through:

- urban consolidation,
- conversion of former industrial and other under utilised land to residential, commercial, open space, and other socially beneficial uses,
- economic stimulation generated by expenditure, and
- construction and permanent employment.

Urban consolidation involves the provision of housing and associated community facilities in locations close to the central city area. This provides the means of reducing the demands for new housing in outer suburbs and of restricting urban expansion. Unrestricted urban expansion inevitably leads to increased costs for the provision of services, roads and other infrastructure over larger and larger areas.

The East Perth Project will provide a range of medium density housing through the development of what is known as an "urban village". This in turn will stimulate similar residential development in other areas nearby and collectively this development will lead to greater vitality and diversity within inner Perth and economic stimulation of the city itself.

In addition, the urban consolidation benefits to the East Perth Project will be achieved by new development of former industrial and commercial sites, old warehouses and factories rather than the displacement of existing residents. The conversion of this under utilised land and associated services will have important economic as well as social benefits.

It is envisaged that public and private sources will spend several hundred million dollars in residential and commercial development associated with the East Perth Project. This will result in approximately 15500 person years of employment taking into account the multiplier effect on employment.

The success of the EPRA in achieving the economic rejuvenation of East Perth is dependent to a considerable extent on the construction of the Claisebrook Inlet. The Inlet has been designed so as to connect much of the development area with the Swan River, one of the most valuable natural assets the area has to offer. This, in combination with other initiatives designed to utilise the attributes of the area, will ensure that land values are sufficiently enhanced so as to sustain the costs of redevelopment.
The area involved has tremendous potential with its proximity to the Central Business District (CBD), accessibility by rail, varied topography, contiguity with the Swan River and proximity to Burswood, Maylands and Ascot Peninsulas. It is within a valley which can be exploited to provide a degree of topographic enclosure and identity and some of the existing warehouses and other buildings are distinctive and can be used as the basis for an architectural theme.
3. ASSESSMENT OF ALTERNATIVES

The development of concepts for the rejuvenation of East Perth began in the early 1980's and since that time numerous development options have been prepared, exhibited and tested financially. The composition of the early concepts varied with some giving emphasis to commercial, others to residential. Each was shaped by market forces and public opinion at the time and have in effect been part of the evolutionary process that has resulted in the current design.

The consideration of the constraints offered by the site is an important factor in deciding the ultimate land use for the development area. This is especially the case with the decision to site Claisebrook Inlet at the base of the valley in which Claisebrook Drain is located. A large area at the base of the valley once consisted of a series of swamps and lakes known as Tea Tree Lagoon. Subsequently these were filled with rubble from various industries such as tile and pipe factories and brick making works which has made the area unsuitable for the construction of buildings. The cost of excavation and disposal of this rubble plus the filling and compaction of the resulting excavation is considered to be too great to be practically achievable.

The Claisebrook Drain also complicates decisions relating to land use at the base of the valley. Even if the drain could be fully piped through the development area an easement would be required on which no development would be allowed for reasons of access and maintenance. As a result it was concluded that the area around the Claisebrook Drain could only be used as public open space.

There are several options for the incorporation of this area into the development. They are as follows:

- retain the area in its current condition,
- formal sporting facilities such as ovals,
- open grassed and landscaped areas including the opening of the Drain as a flowing brook (this was rejected partially because the waters of the drain are a health hazard),
- construction of a lake, and
- the opening up of the Drain to form an Inlet of the Swan River.

Economic analysis of each development option showed that the construction of an Inlet would result in the greatest appreciation of surrounding land values. The Inlet had the added attraction of returning the area to a water body which reflects its earlier form as Tea Tree Lagoon.

Therefore the construction of an Inlet is considered to be the best development option for practical, cost and aesthetic reasons.
4. DESCRIPTION OF EXISTING ENVIRONMENT

4.1 Topographic Setting

The topography of the development area is shown in Figure 4.1. The Claisebrook Inlet will be constructed at the base of a shallow valley which slopes upwards in a westerly direction away from the Swan River. The Claisebrook Drain flows along the base of the valley. Land to the south rises relatively steeply up to Cemetery Hill which has a maximum elevation of about 30m. Haig Park which is an area of flat land, is also immediately to the south of the proposed Inlet and is cut into the base of Cemetery Hill.

To the north, the land steeply rises at first but then flattens out to a maximum elevation of about 12m.

Land along the foreshore of the Swan River is mostly low lying flood plain which has been elevated to about 4m above the level of the river as a result of land filling. Only a small wedge-shaped portion of land immediately south of the existing mouth of the Claisebrook Drain would now be flooded by the water level associated with a 1 in 100 year flood event of the Swan River.

4.2 Ground Conditions

The ground conditions beneath the proposed Inlet were assessed as part of a broad study designed to consider the suitability of the redevelopment area with regard to building foundations (Sinclair Knight, 1989). This study involved a review of previous work together with investigations into the history of the site.

Parts of the location of the proposed Inlet were previously used by a number of industries such as a Bristile brick and pipeworks factory and an early stoneware pipe and tile factory. Clay was excavated for use in these factories from the immediate vicinity of Claisebrook Drain and waste materials were backfilled into these excavations.

Borehole investigations have encountered loose fill and inert fill such as broken clay piping and rubble throughout the site. Some boreholes encountered no fill but only sandy clay. Other areas have concrete residues from the cleaning of concrete trucks. Residue from brick kilns and other general rubbish is also to be expected on the site. Foundations of the brickworks building still remain and some areas are covered with concrete slabs and footings.

The study concluded that substantial areas of the proposed Inlet location contains loose fill and rubble to a depth of 5m to 6m. Any buildings considered in such areas would require piled foundations or the rubble would need to be excavated and replaced. Both of these options would involve substantial cost.
4.3 Hydrogeology

A groundwater study was commissioned to evaluate the hydrogeological conditions that exist in and around the proposed location for Claisebrook Inlet. The results of this study are provided in full in Appendix 2. The information gained from this study was used to predict the potential inflow of groundwater into the Inlet for water exchange studies and the impact that construction of the Inlet would have on groundwater levels.

A total of 15 holes were drilled into the unconfined aquifer to assess its physical characteristics and the quality of groundwaters contained within it. This was done by hydraulic testing, water table mapping, and groundwater sampling and analysis. The locations of drill holes are shown in Figure 4.2.

The unconfined aquifer beneath the proposed Inlet consists of a 1m to 2m thick layer of medium sized sand underlain by interbedded sands of the Tamala Limestone Formation and clays. The Haig Park area is dominated by a clayey layer whereas elsewhere sands dominate. Vacant land between Claisebrook Drain and Brown Street to the north is made up of fill toward the surface consisting mostly of building rubble.

Groundwater contained within the unconfined aquifer originates from direct infiltration of rainfall. The water table which exists at the surface of the unconfined groundwater system is defined mainly by topography (Figure 4.3). This water table fluctuates seasonally by about 1m to 1.5m. Hydraulic testing indicated a variable permeability of between 0.1m and 2.5m/day, however, a maximum of 15m/day was measured in coarse quartz sands.

Groundwater flow occurs toward the Swan River and Claisebrook Drain with an average gradient of 0.002. Claisebrook Drain has a significant impact upon groundwater levels and flow directions. Groundwater discharges into this drain and the drain controls the level of groundwater in its immediate vicinity.

Two groundwater samples were collected from each bore for chemical analysis. These were analysed for a range of chemical parameters including common dissolved solids, selected heavy metals and phenols. The concentration of total dissolved solids ranged from 260 to 2450mg/kg. Heavy metals and phenols were below detectable limits at most locations close to the proposed Inlet indicating generally good water quality. Elevated levels of zinc were found at one site (EP3), however, this water would be suitable for drinking purposes (Hart, 1974). Phenols were detected at the north western corner of Haig Park (EP15) and possibly this indicates some localised pollution of the aquifer.

4.4 Buildings

A large portion of the East Perth area is owned by the State Government and is mostly land acquired for public purposes (such as road reserves) or land which has been used by public agencies. Privately held land is generally used for commercial or service industries. A small number of residential properties are located around Constitution
LOCATION OF GROUNDWATER MONITORING BORES

FIGURE 4.2

SOURCE: MACKIE MARTIN & ASSOCIATES, 1991
EXISTING GROUNDWATER LEVELS

FIGURE 4.3

LEGEND

- Cadastral Boundary
- - - - Drainage
- - - - River
- - - Railway
- - - - Trafalgar Precinct
- - - - Proposed Claisebrook Inlet
+ Monitoring Bore

Water Level Contour (mAHDD)

SOURCE: MACKIE MARTIN & ASSOCIATES, 1991
Street to the south of the Inlet area. The number of buildings actually affected by the construction of the Inlet are few and are mainly old sheds, which are either vacant or in poor condition.

The only building of any consequence which is indirectly affected by the Inlet's construction is the pump house of the East Perth sewage pumping station. The pump house was built in the 1930's and is not sound-proofed. The pumping station also has a large concrete storage tanks which are in a poor condition. The station is regularly maintained but needs major mechanical and electrical upgrading. The entire facility will be upgraded as a result of the proposal including the provision of an airtight roof over the storage tanks and chemical scrubbers to provide odour control.

4.5 Claisebrook Drain

4.5.1 General

The Claisebrook Drain receives stormwater drainage from an urbanised and industrial catchment area in excess of about 12km² north of the City of Perth. Drainage is received from much of the City of Perth and Northbridge, to as far north as Dianella. Land use within the catchment is mostly medium density residential but it also contains high density business and restaurant areas and small amounts of light industry. The majority of the catchment is sewered.

The Claisebrook Drain is mostly piped until it discharges into a relatively poorly maintained open drain near East Parade. A low flow pipe designed to carry summer flows commences at Brook Street and discharges into the river just south of the existing Claisebrook Drain (Figure 5.7). The Drain has a small weir near its mouth below which the drain water mixes with river water.

4.5.2 Sediment Contamination

Investigations associated with the study of the former Gasworks site conducted by SEC WA have established that some sediments within Claisebrook Drain are contaminated with heavy metals, hydrocarbons and pesticides (Camp Scott Furphy, 1990). This study concluded that the hydrocarbons originated from the gasworks site while the heavy metals were the result of discharges into the drain further upstream. This is consistent with the findings of the Swan River Trust which has identified heavy metal contamination in a number of the drains discharging into the Swan River (Thurlow et al, 1986). The pesticides may have originated from both the general catchment area and the Gasworks site.

The sampling of Claisebrook Drain sediments for the Gasworks study was confined to the lower reaches of the drain adjacent to the Gasworks site. Therefore, the remainder of the unpiped section of the Claisebrook Drain was sampled in a further study designed to examine the level of pollutants in sediments that would be excavated for Claisebrook Inlet. In this study cores were drilled at six locations to a maximum depth of 2.1m. The locations of the cores are shown in Figure 4.4. Samples from the first
CLAISEBROOK DRAIN CORE LOCATIONS

FIGURE 4.4
and last 15cm of each core were extracted and analysed for a range of heavy metals. Selected surface samples were analysed for pesticides and phenols.

The results of the analyses show that the sediments sampled above the weir do not contain detectable levels of pesticides or phenols. However, elevated levels of heavy metals were detected above what would be considered normal for soils in the area. This is especially true of lead, copper and mercury. The results of heavy metal analyses are presented in Table 4.1 and comparison can be made with the normal range of heavy metals found in Australian soils and published background levels. These elevated levels are confined to the uppermost sediments in the drain as samples taken from the base of the cores did not show similarly elevated levels.

The presence of contamination within the drain has implications with regard to disposal of sediments from the Inlet excavation. This is discussed in Section 6.1 and in an Environmental Management Program on materials handling to be produced at a later date.

### TABLE 4.1

**HEAVY METAL LEVELS IN SEDIMENTS OF THE CLAISEBROOK DRAIN**

<table>
<thead>
<tr>
<th>Arsenic</th>
<th>Chromium</th>
<th>Copper</th>
<th>Lead</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLO01A</td>
<td>6</td>
<td>38</td>
<td>52</td>
<td>120</td>
</tr>
<tr>
<td>CLO01B</td>
<td>4</td>
<td>15</td>
<td>&lt;1</td>
<td>3</td>
</tr>
<tr>
<td>CLO02A</td>
<td>6</td>
<td>40</td>
<td>49</td>
<td>170</td>
</tr>
<tr>
<td>CLO02B</td>
<td>2</td>
<td>19</td>
<td>&lt;1</td>
<td>&lt;2</td>
</tr>
<tr>
<td>CLO03A</td>
<td>10</td>
<td>68</td>
<td>15</td>
<td>48</td>
</tr>
<tr>
<td>CLO03B</td>
<td>6</td>
<td>35</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>CLO04A</td>
<td>2</td>
<td>34</td>
<td>120</td>
<td>155</td>
</tr>
<tr>
<td>CLO04B</td>
<td>8</td>
<td>42</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>CLO05A</td>
<td>4</td>
<td>40</td>
<td>31</td>
<td>135</td>
</tr>
<tr>
<td>CLO05B</td>
<td>8</td>
<td>42</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>CLO06A</td>
<td>18</td>
<td>78</td>
<td>32</td>
<td>170</td>
</tr>
<tr>
<td>CLO06B</td>
<td>14</td>
<td>78</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Australian Soils ANZEC 1990</td>
<td>0.2-8</td>
<td>N.A.</td>
<td>1-190</td>
<td>2-200</td>
</tr>
<tr>
<td>Background Levels (Cairney, 1987)</td>
<td>N.A.</td>
<td>500</td>
<td>200</td>
<td>500</td>
</tr>
</tbody>
</table>

**Note:** Samples with Prefix A are surface samples, samples with Prefix B are from the base of the core. N.A. indicates not available.

### 4.5.3 Water Quality

Water quality in the Claisebrook Drain has been assessed by the Swan River Trust (SRT) and the Water Authority of Western Australia (WAWA) over at least the past
decade as part of an assessment of potential pollution of the Swan River. This research has involved the periodic collection and analysis of water from the drain for heavy metals, nutrients and faecal pollution. A typical analysis of the drain water is presented in Table 4.2 along with selected draft Water Quality Criteria (EPA, 1990b). Comparison of this analysis with those from other drains that empty into the Swan (Thurlow et al, 1986) show that the Claisebrook Drain samples are generally typical for an urban drain.

Review of the WAWA and SRT water quality data and comparison with EPA draft Water Quality Criteria (1990b) has shown that the waters of Claisebrook Drain are moderately clear and generally of good quality with satisfactory levels of pollutants and concentrations of oxygen. However, two water quality parameters are of concern with regard to the potential quality of water in the proposed Inlet. These are the high faecal coliform count (which indicates faecal pollution), and elevated levels of the nutrients phosphorus and nitrogen. These are discussed below.

**Faecal Coliforms**

Faecal coliforms levels are a measure of pathogenic microorganisms. Their presence is used as an indicator that faecal pollution has occurred.

The faecal coliform levels recorded in past studies of Claisebrook Drain are among the most elevated of any drains entering the Swan (Thurlow et al, 1986). However, few recent faecal coliform counts were available from either the SRT or WAWA so a program of water sampling and analysis was conducted to assess current levels. The locations of water sampling within the Drain are shown in Figure 4.5 The results have confirmed that faecal coliforms levels continue to be high (see Appendix 3).

One of the aims of the sampling program was to determine whether the sewage pump station adjacent to the Claisebrook Drain, near where the drain meets the Swan River, was responsible for the elevated faecal coliform levels. The conclusion of the study was that leakage from the pump station was not the cause and that the likely sources of faecal pollution were throughout the catchment of the drain. These sources probably consist of illegal sewage connections to stormwater drains, leaking sewage systems and septic tanks, and pollution from parks and streets originating from animals.

**Nutrients**

Phosphorus and nitrogen are important to the productivity of aquatic plants. When waters become enriched with these nutrients the growth and reproduction of algae and other aquatic plants is enhanced. Excess growth can lead to a condition known as eutrophication in which plant growth actually results in the depletion of oxygen levels in the water resulting in the death of aquatic animals. Populations of algae can "bloom" as a result of nutrient enrichment causing odours and death of fish and waterfowl.

Nitrogen and phosphorus levels in the Claisebrook Drain were found to exceed EPA water quality criteria (EPA, 1990b) and are considered to be sufficient to promote
CLAISEBROOK DRAIN WATER SAMPLING LOCATIONS

FIGURE 4.5
excessive aquatic plant growth. However, the concentrations are at levels that are typical of drain waters entering the Swan River from urbanised areas.

**TABLE 4.2**

**TYPICAL CLAISEBROOK DRAIN WATER QUALITY**

<table>
<thead>
<tr>
<th>Analysis 28/5/90</th>
<th>EPA Criteria (1990b) Schedules 1(1) &amp; 1(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.45</td>
</tr>
<tr>
<td>Total Nitrogen mg/L</td>
<td>0.29</td>
</tr>
<tr>
<td>Total Phosphorus mg/L</td>
<td>0.091</td>
</tr>
<tr>
<td>F.E. Coli (organisms/100ml)</td>
<td>6400</td>
</tr>
<tr>
<td>Chromium ug/L</td>
<td>12.5</td>
</tr>
<tr>
<td>Copper ug/L</td>
<td>60</td>
</tr>
<tr>
<td>Nickel ug/L</td>
<td>150</td>
</tr>
<tr>
<td>Lead ug/L</td>
<td>≤100</td>
</tr>
<tr>
<td>Zinc mg/L</td>
<td>0.08</td>
</tr>
</tbody>
</table>

4.6 **Former Gasworks Site**

4.6.1 **Introduction**

The former Gasworks site owned by SECWA is located adjacent to the mouth of the proposed Claisebrook Inlet. Past activities on this site have resulted in its pollution with chemicals that have the potential to impact on the general environment and to affect human health. The state of this site has placed constraints on the design and location of the Inlet and has implications with regard to the future quality of water within the Inlet.

The site and its pollution have been the subject of a number of studies by SECWA and EPRA over the past few years which have aimed to define the extent of the contamination and to formulate a remedial plan to reduce the potential environmental impacts posed by the site to an acceptable level. The chosen remedial plan is the subject of a separate Public Environmental Review prepared by SECWA.

4.6.2 **History**

Construction of the gasworks began in 1915 when the first gasholder was erected on the southernmost portion of the site. Prior or soon after this, the Claisebrook Drain was re-routed from the north to its current discharge point into the Swan. This allowed the construction of other plant elements such as retorts in which coal was heated to produce volatile gas and solid coke. The plant reached full production in 1924 and it remained in service until the 1970's.

Alan Tingay & Associates
The raw gas produced in the retorts was passed through a series of condensers to remove impurities such as tars, and ammonia related compounds. Tars which consisted mostly of the heavier hydrocarbons were condensed and then treated by distillation to produce useful chemical compounds such as creosote, pitch and road tar. Ammonical liquor was removed by a gas scrubber.

After treatment the gas was passed into gas holders for storage. A total of five gas holders were installed, three of which were relief holders used to store raw gas prior to cleaning. Some further condensation of heavy tars and liquors probably occurred in these holders. Purified gas was distributed to customers from the two operational holders located in the south western corner of the site.

### 4.6.3 Ground Conditions

Contamination of the former gasworks site has resulted from work practices that would be considered environmentally unsound by today's standards. Wastes were spilled, leaked from storage containers and piping, and used as fill around the site. Essentially contamination over the site consists of wastes generated by gas production. These wastes are described below.

**Liquid Tar**

Tar is considered to be the most important contaminant occurring on the site. Its distribution generally matches the locations of Gasworks buildings where tars were extracted, treated and stored. In addition, it is known that condensation of tars from raw gas occurred in the three relief gas holders. Two of these holders were in the southern section of the Gasworks site immediately adjacent to the existing mouth of the Claisebrook Drain and tar has been identified at their former locations.

A portion of the Gasworks is required for the construction of the Claisebrook Inlet. This area has been drilled intensively and has been found to be generally free of coal tar contamination. The locations of the drill holes are shown in Figure 4.6. Drill logs of selected holes are presented in Appendix 4.

**Solid Wastes**

Spent oxides, a solid waste produced in the process of removal of impurities from the gas, have been used as fill over the site. However much of this material was taken offsite during the operation of the plant. Other solid wastes such as clinker and burnt coal from boilers and the carburetted gas water plant, and excess coal and coke, occur in filled areas and as the base of roads and buildings.

Considerable filling along the foreshore of the Swan River occurred during the 1940's to 1960's especially along the northern part of the foreshore and associated low lying areas. It is likely that wastes from the gasworks were used as fill, along with building rubble and sand from offsite.
ZONE FREE OF COAL TAR CONTAMINATION

LEGEND:
- Drill Hole
- Previously Drilled Hole
- Foundation of Gas Storage Tanks

ALAN TINGAY & ASSOCIATES

LOCATION OF TEST DRILL HOLES OVER FORMER GASWORKS SITE

FIGURE 4.6
4.6.4 Groundwater Quality

The groundwater beneath the Gasworks site is polluted as a result of leaching of non-aqueous wastes and the dumping of liquids. As the groundwater discharges to the Swan River, this pollution could have implications to the existing aquatic environment. It also has the potential to affect water quality in the proposed Claisebrook Inlet.

Groundwater investigations on the site were conducted by drilling holes to various depths beneath the water table and extracting water samples for chemical analysis. A range of hydrocarbons, heavy metals and other chemical compounds such as cyanide and ammonia nitrogen were analysed for in these samples.

The highest concentrations of hydrocarbons in the groundwater were detected in samples from near the southern gas holders and just north of these holders. High concentrations of some hydrocarbons also were detected at the site of the tar plant.

Groundwaters over the site were also analysed for the heavy metals copper, chromium, cadmium, lead, arsenic and mercury. Generally the samples had lower than detectable limits for these metals with the exception of groundwater from bores in the northern part of the gasworks site that are well away from the site of the proposed Inlet.

Ammonia Nitrogen is a generic name for a group of chemicals that include ammonia and other nitrogenous species. All groundwaters samples had elevated levels of these chemical species, however, the highest levels were found along the front of the gasworks site beneath the foreshore of the Swan River.

4.6.5 Proposed Remedial Treatment

The proposed remedial treatment by SECWA for the former Gasworks site is described in detail in a separate PER relating to that site. The treatment is designed to prevent the migration of contaminants in the soil and groundwaters from the site generally and at isolating this contamination from the surrounding environment. The proposal involves the containment of groundwater by in-ground cut-off walls strategically located on the southern and eastern margins of the site. A similar wall is proposed in the present PER to prevent the migration of contaminated groundwaters into the proposed Claisebrook Inlet (see Section 5.1).

4.7 Swan River

The Swan River is a typical estuary of the south-west region of Western Australia with large seasonal variation in river flows and thus significantly different hydrological characteristics between summer and winter. The mean tidal range at Barrack Street Jetty is approximately 0.5m and would be essentially the same at East Perth.

In the area of the proposed Inlet and the former Gasworks site the river consists of a channel but a relatively short distance to the south beyond the Causeway, it expands into a broad estuary in front of the Perth Esplanade.
Waterflows and Salinity

In winter, river flows flush the estuary and, at East Perth, the surface water is essentially fresh for approximately four months. During periods of high run-off, flow turbulence minimises stratification of the water column, and the fresh water usually extends to the river bed. A gradual decrease in fresh water flow through spring and summer increases the salinity of the surface water through to mid-Autumn.

Also in spring, when river flow decreases due to reduced run-off or due to incoming astronomic or barometric tides, saline water can intrude upstream beneath the outflowing river water. As a result the river becomes stratified with fresh water at the surface and saline water at depth. Maximum surface water salinity at East Perth is typically around 25g/L, while the bottom water salinity may reach 30g/L.

This simple characterisation is complicated by the very high variability that occurs in the river with time and location. Variable winds, tides, barometric conditions and river flows can often result in a stratified water column being established or broken down within a few days, and may result in rapid large scale changes in salinity at the bottom of the river.

Sediments

The river bed sediments vary from fine sediments (predominantly clay size fractions) within the central channel to silts, sand, mussel shell and rubble near to the shores. Dredged areas of the river form deeper basins and appear to act as depositional area for fine sediments.

Bathymetry

The bathymetry of the Swan River immediately adjacent to the proposed mouths of the Claisebrook Inlet is shown in Figure 5.6. Relatively shallow water occurs at the mouth of the Claisebrook Drain and over a bank just south of the proposed southern entrance to the Inlet.

The section of river near the East Perth Gasworks has been dredged previously, and the central depth is now 2 to 4m below chart datum or approximately -3 to -5m AHD (the difference between Australian Height Datum and Chart Datum is about +0.76m). The river is shallower upstream from Bunbury rail bridge and downstream from Heirisson Island, where it is generally 1 to 2m below chart datum.

Fauna

The distribution and life history of fauna within the Swan River estuary is strongly influenced by the salinity regime. Other environmental factors such as temperature, dissolved oxygen, available food and shelter also influence the manner in which different species utilise the river. Forty-two benthic fauna species were identified in the deep and shallow waters of the Middle and Upper Swan estuary in a study during
March and April, 1977 (Wallace, 1977). The large majority of these species inhabit the shallow depths and are of marine origin.

Based on the distribution of benthic molluscs, three biotype regions have been distinguished for the Swan River estuary (Chalmers et al., 1976), namely the Upper, Middle and Lower Estuary. The Upper Estuary extends from Heirisson Island to Ellen Brook, including the stretch of River adjacent to East Perth. This region has only two species of bivalves and four species of gastropods that are continuously resident. The penetration of marine and estuarine species in the Upper Estuary is dependent on the previous winter's rainfall and rainfall during successively earlier years.

Fish in the Swan Estuary include both estuarine species (cobbler, southern anchovy, flathead, black bream, Perth herring, yellow-tailed trumpeter), and marine species (mulloway, tailor, mullet). The life cycles and distributions of each of these species varies in relation to the salinity regime, but both estuarine and marine species would occur seasonally in the river at East Perth.

Vegetation

The dominant aquatic macrophytes of the Swan River are the seagrass *Halophila ovalis* and a member of the lily family, *Potomogeton pectinatus*. The main beds of seagrass occur in the lower Swan River Estuary and these end abruptly at the Narrows Bridge (Thurlow et al., 1986). There are no beds of seagrass in the Swan River adjacent to East Perth. *Potomogeton* is the dominant macrophyte of the upper Swan but it does not extend into areas that experience elevated salinities such as those found in the Swan River at East Perth.

Contaminated Sediments

Studies conducted on behalf of SECWA have established that hydrocarbons which originated from the Gasworks site have found their way into the Claisebrook Drain and the Swan River. A part of the site near the mouth of the Drain is known to be a particular source of contamination. This has resulted in relatively high levels of contamination in the lower reaches of the Drain below the weir and in the sediments of the Swan River immediately adjacent to the Drain mouth. The full distribution of the contamination is described in SECWA's PER on the Gasworks site.
5. DESCRIPTION OF THE DEVELOPMENT

5.1 The Inlet

5.1.1 General Description

The Claisebrook Inlet will be the focal point of redevelopment within the East Perth Redevelopment Project. In a planning sense the Inlet has been designed to connect and identify East Perth with the Swan River, one of the most valuable natural assets the area has to offer.

The Inlet design has 3 main components as follows:

- A main section with an area of 1.5ha.
- Two channels which connect the main section to the Swan River and which collectively have an area of 0.5ha, and
- A channel at the westernmost end which is at a higher level than the main section. Water will be pumped from the main section into this channel and then will flow back to the main section over a weir.

These components are shown in Figure 5.1

The Inlet will be set in a surrounding of buildings and parklands and will have a variety of edge treatments depending on the topography and the proposed use of the adjacent land. The edge treatments will range from sandy beaches adjacent to parklands through to hard edged walls near development areas. A number of footbridges and road bridges will cross over the Inlet to facilitate easy passage around and through the development area. It is proposed that some powered boating be allowed but otherwise the Inlet will primarily be an ornamental feature and other water based recreational activities such as swimming will be prohibited.

Two areas in the Swan River adjacent to the mouths of the connecting channels will be deepened to facilitate water circulation in the Inlet. This deepening will also allow the berthing of river ferries at the mouth of the southern channel where a jetty will be built.

5.1.2 Location and Shape

The location and shape of the Claisebrook Inlet has been determined through a design process which has sought to take advantage of the attributes of the area but which has also recognised the constraints posed by the development site.

The location of the Inlet was chosen primarily because of poor ground conditions adjacent to the Claisebrook Drain between Trafalgar Road and Plain Street. These ground conditions have resulted from the filling in of a wetland known as Tea Tree Lagoon through which Claise Brook used to flow and the excavation and filling of clay.
pits nearby. Geotechnical studies have shown this area to be unsuitable for the construction of substantial buildings without considerable expenditure on foundations or alternatively the excavation and replacement of substantial amounts of material. However, by excavating the fill material to create an Inlet the original watercourse can be artificially recreated, the development constraints can be overcome and the site converted to a major urban design asset which will be the feature of the East Perth Project.

The ultimate shape of the Inlet and the connecting channels were determined after taking into account the constraints offered by the site with regard to topography, existing services, trees and the presence of a polluted industrial site nearby (the former East Perth Gasworks site). The spatial relationship of the features that have had an impact on the shape of the Inlet are shown on Figure 5.2.

Options for the location of the connecting channels between the main section of the Inlet and the Swan River are very restricted. To the north, the former gasworks site contains pollutants which have the potential to be transported into the Swan River. Any excavation of polluted parts of this site would therefore involve difficulties associated with the disposal of contaminated soil and potentially high costs. It was decided therefore that the site should be avoided as far as possible. Site investigations, however, have identified a section of the Gasworks site that is free of contamination (see Section 4.6) and the Inlet will partially impinge upon this area in order to maximise the width of the connecting channel. This will facilitate water circulation in the Inlet and water exchange with the Swan River.

A sewage pump station is located to the south of the Gasworks site. This station is critical to the operations of the Water Authority of Western Australia (WAWA) and cannot be relocated without incurring very high costs (see Section 4.4). The only option, therefore, for a connecting channel between the main section of the Inlet and the Swan River is between the southern limit of the former Gasworks site and this sewage pump station.

Immediately west of the pump station, it is possible to excavate a southern connecting channel but options for the alignment of this channel are limited by steeply rising ground toward Cemetery Hill. There are also constraints imposed by the design objective of attempting to retain as many of the well established trees in the area adjacent to the Swan River as possible.

5.1.3 Edge Treatments

The Inlet and channels combined will have a total perimeter of 1160m. Most of this will have hard edge walls as it will have either a promenade or building development adjacent to it. Some areas of parkland including the island toward the mouth of the Inlet will have a "soft edge" treatment consisting of soil and grass. The types of edge treatments are shown in Figure 5.3 while Figure 5.4 shows the location along the Inlet of each edge treatment type. The height of the edge treatments has been selected to exceed water levels in the Swan River during a 1 in 100 year flood event.
5.1.4 Construction Methods

The construction of the Inlet will occur in a number of stages as follows:

- excavation of the Inlet area to the north of the existing Claisebrook Drain between Trafalgar Road and East Parade,
- provision of a temporary by-pass open drain to the south of the existing drain to allow the remaining Inlet excavation,
- removal and relocation of gas, sewer and power services that cross the existing Claisebrook Drain,
- construction of the edge treatments and bridges, and
- construction of connecting channels with the Swan River followed by the breaching of the foreshore between the Swan and the constructed Inlet.

Inlet Excavation

The construction of the Claisebrook Inlet and the connecting channels will be carried out by excavators loading into trucks. This method has been chosen over the use of scrapers because of the heterogeneity of ground conditions at the Inlet location and the Inlets area and shape. It is expected that approximately 85000 m$^3$ of material will be excavated above the water table and 55000 m$^3$ below the water table in the construction of the main body of the Inlet. Excavation of the channel at the western end of the Inlet and its adjacent promenade will involve removing 90000 m$^3$ of material. Areas of excavation and filling are shown in Figure 5.5.

Material that is in excess to the immediate requirements of the project will be used in landscaping, or stored on site for later use in other projects within the metropolitan area. One such project is the duplication of the Plain Street Bridge across the Bunbury Railway which is nearby.

It is probable that excavation will be assisted by dewatering, as the excavation base will be 2m to 3m below the existing water table. Groundwater from the dewatering will be disposed of by discharge into the Claisebrook Drain after settling in a series of ponds. Alternatively, if small volumes are involved, the groundwater will be pumped into a bunded compound designed to allow it to percolate back through the soil.

Connection to the Swan River will be achieved at the final stage of construction by excavating through the river bank.

River Deepening

Two areas of the bed of the Swan River adjacent to the connecting channels of the Inlet will be deepened to enhance the exchange of water between the Inlet and the river. These areas are shown in Figures 5.5 and 5.6. The deepened areas will have an area of
about 3600m² each, a maximum depth of 2m, and a slope with a grade of 1 in 3. The southern area has been designed to avoid an emergent bank that is east of the mouth of the adjacent channel entrance.

These areas will be excavated by building temporary causeways over the area to be deepened on which excavation equipment can operate. The causeways will be constructed of sand or limestone. Spoil will be loaded onto trucks and taken to a spoil site away from the foreshore. At the end of the operation the causeways will be removed. Deepening of the riverbed will occur after the construction and connection of the Inlet to the Swan River.

It is envisaged that the deepened areas will silt up gradually and it is estimated based on experience from similar projects that maintenance dredging will be required every 10 to 15 years.

5.1.5 Associated Engineering Works

Bridges

The design of the Inlet includes a number of bridges which will allow motorised and pedestrian access either around or through the development area. Two road bridges will cross the channel at the western end while four footbridges will allow pedestrian and bicycle access through and around the development centred on the main section of the Inlet.

The road bridges will consist of two separate structures each of which will be 8.5m wide and will carry two lanes of traffic.

Each footbridge will have a width of 2m and will be composed of steel reinforced concrete box girders. The footbridge nearest the sewage pump station will have the relocated Mt Lawley sewer suspended beneath it. The two bridges crossing the mouths of the channels opening to the Swan River will form part of the existing cycleway which runs along the river foreshore.

Services

A number of services occur in and around the area in which the proposed Claisebrook Inlet will be built. In many cases the existing services are important to large areas outside the redevelopment area. Some of these impose constraints on development as they would be very expensive to remove and replace.

Major sewer facilities in and around the proposed Claisebrook Inlet include:

- The Claisebrook main sewer which runs along Royal Street and crosses diagonally through Haig Park.
- The Mt Lawley main sewer located in Trafalgar Road which crosses the Claisebrook Drain about 3m above its water level.
The Claisebrook pumping station, located east of Trafalgar Road south of the main drain. The station contains a major storage tank.

Two pressure mains from the station, one running west parallel to the southern bank of the drain, and the other running alongside the Swan River crossing the Causeway to Victoria Park.

The Claisebrook pumping station plays a significant role in the Water Authority of Western Australia's (WAWA) sewage system. The station has a high pump capacity and has a direct catchment that includes significant portions of suburbs to the north. The station can also receive flows from Victoria Park temporarily to allow maintenance of sewers south of the river and can pump to Victoria Park to allow maintenance of the Perth Main Sewer.

The area contains no major water distribution lines. Most of the area is supplied by small diameter mains reflecting the current low concentration of land use.

Two systems receive stormwater drainage in the redevelopment area. These are the Water Authority main drainage system, and Local Authority drains which feed into the WAWA main system.

The Claisebrook Main Drain is under the control of WAWA and is the major stormwater conduit through the area. Above East Parade the drain is within a pipeline but from East Parade to the Swan River it comprises an open drain plus a low flow pipe. The low flow pipe was provided to ease the impact of more highly contaminated waters flowing through the open section of the drain in summer. The open drain has a current flow capacity of about 28m³/sec.

Gas and power facilities in East Perth provided much of the supplies of Perth and its environs in the past and consequently many large capacity services still exist in the redevelopment area. High and medium pressure gas pipes are located on Brown Street and Trafalgar Road. These connect up to gas stations on the former East Perth Gasworks Site. A series of underground power cables and overhead 66kV transmission lines are located in Trafalgar Road and Brown Streets and a pair of 66kV feeder cables run along Trafalgar Road and cross Haig Park diagonally.

A number of services will be relocated as a result of construction of the Inlet and redevelopment around it. The final layout of services is given in Figure 5.7 and this can be compared to the existing layout of services shown in Figure 5.8. The required works are as follows:

- All road drainage will be replaced and drains on new and existing roads will have outfalls at various points into the Inlet. The Claisebrook Drain box culvert will be extended to allow discharge into the Inlet.

- Three major sewers will be relocated and the existing sewage pump station will be renovated and odour treatment facilities installed.
LIMITING FEATURES OF THE AREA

FIGURE 5.2

ALAN TINGAY & ASSOCIATES
Riverline vegetation on unirrigated grass

Sand/mud beach

Hard stabilising element to grass/sand edge

INLET EDGE TYPE A
1:100

INLET EDGE TYPE B
1:50

INLET EDGE TYPE C
1:50

SOURCE: KINHILL ENGINEERS PTY LTD, 1991

INLET EDGE WALL TYPES

ALAN TINGAY & ASSOCIATES

INLET EDGE WALL TYPES. FIGURE 5.3
LEGEND

--- Low water mark

□□□□ Areas to be dredged

Riverbed contours in metres below low water mark

0 metres 50

ALAN TINGAY & ASSOCIATES

AREA OF SWAN RIVER TO BE DEEPENED

FIGURE 5.6
The existing water supply will be expanded and its capacity increased.

It is envisaged that overhead electrical services will be buried, selected high voltage services will be extended and laid beneath the Inlet via a duct.

**Jetty**

A jetty will be constructed on the southern side of the mouth of the southern connecting channel. The jetty will be T shaped and of similar dimensions as other jetties on the Swan River downstream of East Perth.

**5.1.6 Works Associated with the Former Gasworks Site**

The northern connecting channel of the Claisebrook Inlet runs alongside the former Gasworks site which is known to be contaminated with industrial pollutants (Section 4.6). Studies have found that groundwaters beneath the site are contaminated with a variety of chemical compounds. Dewatering for the construction of the Inlet and the creation of the Inlet itself have the potential to introduce contaminated groundwater from the site into the Inlet thereby affecting its water quality (Section 6.1). In order to prevent this, a barrier wall will be constructed along that portion of the northern channel that borders the Gasworks site.

The groundwater flow cutoff wall will be constructed of metal sheeting driven to a depth of approximately 7m. It will be incorporated into the edge treatment of this section of the channel. The wall has the potential to be incorporated into the proposed remedial strategy for the Gasworks site as currently proposed by SECWA (Section 4.6).

**5.2 Associated Urban Design and Landscaping**

The Inlet can be divided into three separate design zones, the foreshore, the main basin and the perched water system west of Plain Street.

**5.2.1 Foreshore and Islands**

The foreshore area of the Inlet will retain its existing parkland character of roughly slashed, unirrigated grass and native riverine trees, and will maintain visual continuity with the existing Swan River foreshore. Islands created by the construction of the Inlet will be in keeping with this theme.

The planting theme will comprise grass and the following Australian indigenous trees selected for their environmental suitability and compatibility with existing vegetation:

- *Eucalyptus rudis* (Flooded Gum)
- *Eucalyptus botryoides* (Bangalay)
- *Allocasuarina obesa* (Sheoak)
- *Melaleuca raphiophylla* (Paperbark)
The maintenance of public access to and along the river has been a priority in planning the foreshore areas. The public will have access to the islands and grassed and landscaped areas adjacent to the foreshore and the Inlets connecting channels. The existing foreshore dual use path will be re-routed through this zone and across bridges linking the islands. There will be a change of function around the ferry wharf where occasional influxes of pedestrians will occur such as at the current South Perth jetty. The dual use path will accommodate light service vehicles and police vehicles.

5.2.2 Main Basin

The main basin of the Inlet will measure approximately 120 metres by 70 metres and will have an average depth of 2 metres. A small knoll which exists in the area may be retained as an island to provide an element of contrast in the middle of the water and a link for the two bridges which span the Inlet. Without these bridges, the distance from housing on the north shore of the Inlet to the retail facilities on the southern shore would be excessive.

Development around the main basin and other parts of the Inlet will vary in character from informal parkland at the river end, through small-scale harbour treatment to formal urban spaces at the East Perth TAFE end of the site. This change in character will be achieved primarily through the arrangement and detailed design of spaces. The use of similar materials throughout will provide visual continuity and highlight the major east-west pedestrian spine/open space linkage running through this zone.

The retail facility located on the waters edge is intended primarily for recreation, shopping, dining out and entertainment. The provision of parking is a key consideration, and it is assumed that developers will provide a basement car park to supplement the small area of surface parking situated adjacent to the traffic roundabout.

Current landscape plans propose that vegetation around the major basin and on the island will comprise indigenous species in order that this most accessible and visible component of the project has a unique Western Australia flavour. For example, Peppermint Trees are being considered, as their dense round form and dark colour will provide a strong contrast with the lighter tones of roofs and walls. A dark, vertical counterpoint will be provided by Rottnest Island Pines. The combination of these elements will produce a Mediterranean atmosphere.

5.2.3 Perched Water System

West of Plain Street, the Inlet becomes a closed system of elevated ponds with water flowing back towards the river. This will be a unique attraction and will have a well designed pedestrian access. It will continue the water element of the Inlet through to the upper end of the project area, and will end at the TAFE College with a public art feature which will be designed to emphasise the culmination of this design element.

Landscaping in this area would consist of rows of Peppermint Trees or flowering gums and benched grassed areas in the apex of the triangular site. Hard edged pavements will cover the remainder of the pedestrian areas between the water and buildings.

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6. ENVIRONMENTAL ISSUES

6.1 Inlet Construction

6.1.1 Water Quality and Connection to the Swan

The water that initially fills the Inlet excavation will exchange with river water when connection is made to the Swan River. This represents a release of water to the Swan River and consequently its quality must be considered.

The base of the Inlet will be below the water table and it will fill with groundwater when dewatering ceases. Some water from the Claisebrook Drain may also find its way into the excavation, however, the intention is to maintain the flow of the Claisebrook Drain into the Swan River throughout most of the construction period.

Studies of water of the Claisebrook Drain and groundwaters beneath the site have found them to be of good general quality (Section 4.3 and 4.5). However, initially the water in the Inlet will contain an abundance of suspended sediments as a result of the construction activities. The management techniques that will be employed to minimise the level of suspended sediments are described in Section 7.1.

6.1.2 Claisebrook Drain Sediments

Investigations by SECWA and the EPRA have established that the sediments of the Claisebrook Drain are contaminated with a range of chemical compounds that originate from numerous sources throughout the catchment of the drain.

Sediments below the drain weir and in locations within the Swan River are known to have been contaminated by pollutants that originated from the adjacent gasworks. SECWA proposes to excavate or dredge these sediments from the drain along with contaminated sediments in the Swan River. A proposal for this excavation is included in the PER on the remedial treatment of the Gasworks site prepared by SECWA. However, some of these sediments will be excavated for the construction of the Inlet. It is proposed that SECWA will retain responsibility for these sediments. If for some reason this is not the case, EPRA will be responsible for the excavation and disposal of these sediments.

Elevated but low level heavy metal contamination has been identified within the sediments that line the drain in areas which will be excavated as part of the Inlet construction. The levels of heavy metals are mostly within the range of concentrations found in Australian soils (Table 4.2) and thus are not considered to be high enough to warrant special treatment. Sampling and analysis has determined that the contamination is confined to the uppermost superficial sediments in the drain and consequently a relatively small volume of contaminated sediments is involved. In addition, as it would be difficult to excavate only this thin layer without the inclusion of an abundance of clean sediments, the resulting mixture of material will have low concentrations of heavy metals which will approximate background levels. Therefore, it is proposed that the material be treated as normal spoil.

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6.1.3 Fill Material

The results of initial geotechnical investigations indicated the possibility that contaminated waste may be present on the Inlet site. However, further site investigations found that this is unlikely.

A layer of "black soft fill" was described in geotechnical investigations and special attention was paid to identifying this material. Trenches were dug to investigate the potential for buried material and samples of selected suspect materials were taken at depth and on the surface for analysis. The soft black fill was identified as burnt coal dispersed amongst quartz sand and organic rich clay materials. The investigations found an abundance of inert fill but no evidence to suggest that wastes containing significant quantities of environmental pollutants had been dumped on the site. These results were confirmed by bore logs from holes drilled to study groundwater on the site (Section 4.3).

Despite the above there is a minor potential for small quantities of contaminated waste materials to be present on the site as these would be difficult to detect in a wide spaced sampling program. Strategies for the identification and disposal of wastes of unknown character which may be located during excavation are generally described in Section 7.2. An Environmental Management Program describing in more detail the methods of material excavation and disposal will be provided to the EPA prior to construction.

6.1.4 Dewatering

Dewatering will be required to some degree in the construction of the Inlet and the installation of edge treatments around its periphery. This action has the potential to lower the groundwater table and influence the flow of contaminated groundwater on the Gasworks site.

*Lowering of Groundwater Table*

The affect of dewatering on the groundwater table has been modelled using data collected during a geological drilling and testing program carried out over the location of the Inlet. For simplicity it was assumed that the entire Inlet would be dewatered at one time to its completion depth of -2mAH.

Generally the groundwater table will be depressed by as much as 3.5m in and around the Inlet excavation, however, the effect will be less substantial with distance from the excavation. It is predicted that initially 876kl/d will need to be pumped to reduce the water table to -2mAH. This will approach 299kl/d later in the excavation period. Dewatering will only be for a period of about two months and any impact will be minor and temporary.

*Gasworks Groundwater*

Contaminated groundwater beneath the Gasworks site have the potential to be drawn into areas where construction of the Inlet is taking place due to dewatering. This would
create problems with the disposal of groundwater and potential exposure of workers to contaminants. A groundwater flow cutoff wall designed to prevent the flow of contaminated groundwaters into the Inlet during construction therefore will be installed prior to dewatering. As a result it is anticipated that no disposal of contaminated groundwater will be required.

**Disposal of Groundwater**

Groundwater will be pumped into unlined bunded ponds in order to allow settling out of particulate matter prior to discharge into the Claisebrook Drain. Alternatively these ponds will be sited to allow the percolation of groundwater through the base of the pond and back into the ground.

The final detailed design and location of these ponds has not been determined but a full description will be provided in an Environmental Management Program. This will also describe the disposal of soil and water from the excavation.

### 6.1.5 Dust

The excavation of the Inlet has the potential to generate nuisance dust. However a number of characteristics of the proposal will serve to reduce this risk to below what would normally be expected of an operation of this scale.

A significant proportion of the excavation will be performed at ground depths below the existing water table. This excavation will either be accompanied by dewatering or will be directly excavated. As a result much of the excavated material will be handled when wet and the resulting excavation will also remain wet, if not submerged, beneath water. There will therefore be little or no potential to generate dust.

An abundance of water on the site either as a result of dewatering or from inflow into excavations will be available to dampen down dry excavations. Additional management techniques designed to lessen the potential to generate nuisance dust are described in Section 7.3.

### 6.1.6 Noise

Excavation of the Inlet is expected to generate noise over a 15 week period. The sources of this noise are expected to be heavy earthmoving equipment, dewatering pumps and the trucking of spoil materials away from the site. The noise has potential to disturb nearby residents and workers; however, the potential for disturbance is lessened by a number of characteristics of the area.

Most of the area immediately adjacent to the excavation site is used for light industrial and office use. These activities combined with the heavy traffic along Plain Street serve to produce high background levels of noise relative for example to a residential area. The remaining adjacent land is either parkland (Haig Park) or vacant land under the control of the EPRA. The nearest residential area is to the south-west of the...
proposed Inlet in and around Macey Street. This area is more than 200m away from the closest point of the excavation.

Management procedures designed to minimise noise will also be implemented. These are described in Section 7.4.

6.1.7 Traffic

The most significant traffic impact during the construction of the Inlet will be over a 10 to 15 week period when 20 to 40 trucks an hour are expected to enter and leave the site throughout the day to remove excavated material. At this stage it is assumed that most of the material will be transported to the location of the proposed Plain Street duplication bridge over the Bunbury Railway, however, this may be subject to change.

Initially most of the trucks will enter and leave the site along Brown Street but after the median is constructed along East Parade, trucks will enter using Brown Street and leave along Trafalgar Road and Kensington Street. There will be some minor delays for trucks turning right onto East Parade from Kensington Street and Brown Street, particularly during peak periods. The affect on traffic on East Parade will be negligible and no affect on residents is envisaged as this portion of East Parade has no residential properties.

During the construction period a smaller number of traffic movements will be generated by other activities such as the transportation of equipment and materials associated with the Inlet excavation and edge treatment construction. At this stage the on-site workforce is likely to be 30-35 persons with some increase occurring during the relocation of services. Traffic movements will be spread out over the day and are unlikely to have a significant impact on the existing road system.

6.2 Deepening of the Swan River

Two areas adjacent to the two mouths of the Claisebrook Inlet need to be deepened to allow the exchange of water between the Inlet and the Swan River. This deepening has the potential to cause long and short term changes to the Swan River, but only within the confines of the small area to be excavated and its immediate surrounds.

The area adjacent to the northern mouth is relatively shallow as a result of the accretion of sediments that have been carried down the Claisebrook Drain into the Swan River. It is expected that the substrata in this area is mobile and experiences the seasonal deposition and erosion of sediments. Studies have confirmed that sediments in this area contain elevated concentrations of various pollutants.

The area to be deepened adjacent to the mouth of the southern channel has been designed to avoid a shallow bank that is emergent at low tides directly to the east. This bank is used by water birds as a roosting spot.
There are no seagrasses or significant strands of other aquatic plants in either of the areas to be deepened.

Potential Short Term Impacts

Potential short term impacts that could arise from the dredging primarily relate to the suspension of fine particulate matter into the water column. This could affect filter feeding organisms such as mussels and reduce the available light for aquatic plants such as seagrasses. However, the area of mussel habitat nearby is relatively small so any impact will be minor and transitory and seagrasses are not present in this stretch of the Swan River.

The suspension of sediments may also promote the release of pollutants found in the river sediments at this location. Relatively high levels of hydrocarbon contamination exist in and around the Claisebrook Drain mouth and this "hot spot" of contamination, amongst others, will need to be removed from the river as part of the clean-up programme for the former Gasworks site. This is fully discussed in the PER on the remedial treatment of the former gasworks site by SECWA. Given the existing need for removal of the contaminated sediments it is considered that the excavation of this same material to promote Inlet flushing poses little or no additional impact to the aquatic biota of the area.

Potential Long Term Impacts

Long term impacts brought about by the permanent change of the area will be caused by the proposal. This especially relates to the removal of habitats and food sources for aquatic biota. However, this impact will be limited in area and will be offset by the production of new habitats and the recolonisation of the disturbed area by in-fauna such as molluscs.

6.3 Inlet Water Quality

6.3.1 Introduction

It is important that adequate water circulation in the Inlet and water exchange with the Swan River be maintained in order to minimise the potential for build up of pollutants, stagnation and algal blooms. These effects would result in the Inlet becoming unsightly and possibly a health hazard. In order to determine the degree of water circulation and exchange, a specific study was commissioned by the EPRA. The study is presented in full in Appendix 5.

In the following sections the factors which will influence water quality within the Inlet are described. Specifically these relate to water inputs into the Inlet and mechanisms which will induce water circulation and exchange.
6.3.2 Inputs

Water flowing into the Claisebrook Inlet will come from 3 sources, the Claisebrook Drain, groundwater inflow and the Swan River. Water from groundwater inflow and the Claisebrook Drain will be fresh while input from the Swan River will vary in salinity depending on the season and prevailing weather conditions in combination with tides.

The estimated quantities of water in-flows from groundwater and the Claisebrook Drain are as follows:

- Groundwater inflow 140m$^3$/day,
- Claisebrook Drain Summer base flow 6048m$^3$/day,
- Claisebrook Drain Winter base flow 10368m$^3$/day, and
- Claisebrook Drain flow during rain 345600m$^3$/day.

The quality of groundwaters and Claisebrook Drain flows are discussed in Sections 4.3 and 4.5. Generally they are of good quality, however nutrients and faecal coliforms are elevated above the levels found in the Swan River.

6.3.3 Exchange Mechanisms

A number of mechanisms are expected to induce water circulation and water exchange between the Inlet and the Swan River. These processes will result in the mixing of the various water inputs and the dilution and dispersion of contaminants that have the potential to build up in the water. These mechanisms are as follows:

- tidal fluctuations,
- currents driven by salinity and temperature differences between the two bodies of water,
- wind induced surface currents, and
- flood flows from Claisebrook Drain.

Tidal Exchange

Although no tidal information is available for the East Perth stretch of the Swan River the tidal fluctuation equates to that experienced at the Barrack Street tidal station. On average the daily tidal range will be 0.3m to 0.4m each day. This will result in water moving out of and then into the Inlet and it is estimated that as much as 20% of water in the Inlet will be exchanged on a daily basis by this process.

Density Currents

Tidal action can produce stratified levels of salinity within the Swan River and Claisebrook Inlet (Section 4.7). The stratification will change throughout the day.
according to the ebb and flow of the tide and will cause different conditions to exist at the same time in the Inlet and the Swan River. As salt water and freshwater have different densities a difference in the proportion of each within the two water bodies will cause flows of water from one to the other that will continue until conditions are equalised.

The process, which is shown graphically in Figure 6.1, promotes water exchange and circulation as denser saltwater intrudes along the bottom of the Inlet so that it equilibrates with the level in the Swan River. In turn the intrusion of saltwater into the Inlet forces freshwater out into the river. The reverse occurs with an outgoing tide.

**Wind Induced Exchange**

The Inlet is aligned with the predominant east-north-east, west-south-west wind directions and this is expected to produce currents induced by the shear stress created by wind as it passes across water. Such currents are limited to the top third of the water column and typically have a speed of about 2-5% of the wind speed. A reverse current of equal mass flow will form to preserve the conservation of mass in a closed end water body such as the Claisebrook Inlet. This relationship is described in Figure 6.2.

**Floods from Claisebrook Drain**

The Claisebrook Drain has a catchment of over 12km², consequently average to heavy rainfall events result in substantial flows down the Drain. These flows will induce movement of water out of the Inlet and will cause differences in temperature and salinity between the Inlet and Swan River. These differences in turn will cause density flows that will assist in water exchange and circulation. The flood flows of water from Claisebrook Drain have been calculated as follows:

0 1 in 1 year flood flow 10m³/sec,
0 1 in 10 year flood flow 17m³/sec, and
0 1 in 100 year flood flow 27m³/sec.

**6.3.4 Exchange Rates**

The rates of water exchange between the proposed Claisebrook Inlet and the Swan River area presented in Table 6.1. These rates are calculated on the basis of the results of a field measurement programme and indicate that good exchange rates will be maintained.

Density currents and tidal exchange will occur concurrently as tidal influences result in changes in stratification in the water column which in turn induces density currents. Occasionally periods of high winds will breakdown the stratification, but circulation induced by the high winds will produce currents of similar magnitude to the density currents.
Inlet

Time $t = 0$

River and inlet have similar profiles

$t = 1$
Seawater wedge travels upstream with tide

$t = 2$
Head differences drive density currents into inlet

$t = 3$
Seawater wedge travels downstream with tide

SOURCE: KINHILL ENGINEERS PTY LTD, 1991
WIND INDUCED VELOCITY PROFILE

FIGURE 6.2

SOURCE: KINHILL ENGINEERS PTY LTD, 1991

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As a result it is concluded that exchange times will be sufficient to flush the Inlet and prevent the build up of pollutants and the stagnation of the water within it. More detail is given in the study on water circulation presented in Appendix 2.

### TABLE 6.1

<table>
<thead>
<tr>
<th>Event</th>
<th>Mechanism</th>
<th>% of Inlet Water Exchanged by Mechanism/day</th>
<th>Exchange Time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring Tide</td>
<td>Tidal exchange</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Density currents</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Neap Tide</td>
<td>Tidal exchange</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Density currents</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>High Winds</td>
<td>Tidal exchange</td>
<td>10-20</td>
<td>2-3</td>
</tr>
<tr>
<td></td>
<td>Density currents</td>
<td>negligible*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wind currents</td>
<td>40-50</td>
<td></td>
</tr>
</tbody>
</table>

*High winds can result in breakdown of stratified flow*

### 6.4 Groundwater

A groundwater study was commissioned to analyse the impact that construction would have on the groundwater table in the area. The potential for migration of saline water inland from the Swan River has also been considered.

The results of the study with respect to the lowering of the groundwater table are presented in a series of figures beginning with Figure 6.3. This figure shows the water table after the construction of the Inlet. Figure 6.4 shows the drop in water table experienced over the area. Generally there will be a change in the depth of the groundwater of between a 1.8m increase adjacent to the Inlet to about a 0.2m decrease 400m away especially toward the north and south.

The majority of area affected by a drop in groundwater table levels of greater than 0.4m is or will be under the control of the EPRA and therefore the lowering will not affect any private bores. There may be an effect on established trees in close proximity to the Inlet and accordingly these trees will be monitored so that stress can be detected quickly and remedial action carried out to maximise their chances of survival.

Drilling close to the Swan River foreshore determined that the interface between saline Swan River waters and fresh groundwater is very steep with a layer of fresh water about 35m thick in the superficial formation. Modelling has indicated that areas of foreshore will experience a drop in groundwater table of between 0.2m and 0.4m when the Inlet is constructed and it is predicted that this will be be insufficient to promote the intrusion of saline waters.
PREDICTED CHANGE IN GROUNDWATER LEVELS AFTER CONSTRUCTION

FIGURE 6.4

LEGEND
- Cadastral Boundary
- Drainage
- River
- Railway
- Trafalgar Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
- Water Level Change (m)

SOURCE: MACKIE MARTIN & ASSOCIATES, 1991
6.5 Traffic

East Parade and Plain Street will provide regional access to the Inlet. Local access to the northern side of the Inlet will then be provided by Brown Street, Kensington Street and Trafalgar Road and to the southern side of the Inlet by Wittenoom Street, Trafalgar Road and the proposed south Inlet road.

It is planned to commence widening East Parade and reconstructing Plain Street in July 1992/1993 financial year. These works will affect the local traffic circulation on either side of the Inlet. Initially, access to the northern side of the Inlet will be along Brown Street. This will change when a median is constructed on East Parade and left in and left out turning movements only will be permitted at Brown Street. Vehicles on East Parade travelling from the south and to the north will have to use Kensington Street and Trafalgar Road. On the southern side of the Inlet, vehicles will initially use Wittenoom Street and Trafalgar Road. More direct access from Plain Street will be provided later when the south Inlet road is constructed.

Trafalgar Road is currently used by many workers employed by the SEC and the light industrial premises located between Kensington Street and Brown Street for access to and from the Causeway. However, traffic using the road is less than 200 vehicles in the morning peak hour and less than 100 vehicles in the afternoon peak hour. It is planned to close Trafalgar Road early in the construction programme for the Inlet which will require traffic currently using Trafalgar Road to divert to East Parade. The intersections of East Parade with Kensington Street and Brown Street will easily be able to handle the additional traffic movements.

6.6 Existing Human Usage

The area to be developed for Claisebrook Inlet does not contain residents other than SECWA which owns part of the gasworks site. All other land is vacant and owned by Government. A variety of light industries lease land adjacent to the Inlet from the State Government and these are aware of EPRA's plans for the area.

Existing use of the area for the proposed Claisebrook Inlet is limited to passive recreation on the Swan River foreshore including use of the cycleway. Cycleway users may be inconvenienced by construction activities and thus EPRA will provide alternative routes, if required, around the development. However, construction will be planned to limit any inconvenience.

The net impact with regard to human use of the area will be a positive one, as the development of Claisebrook Inlet will greatly enhance the attractiveness of this portion of the foreshore for passive recreation.
6.7 Nutrient Use

Foreshore areas and some areas adjacent to the Claisebrook Inlet will be parkland with roughly slashed and unirrigated grass and native riverine trees. Fertilisers will need to be applied to establish the grass and thereafter to maintain it in good condition. The maintenance of these areas will be the responsibility of EPRA, however, it may commission other authorities to perform maintenance work.

Excessive use of fertilisers could result in the transport of nutrients into the Inlet and the Swan River which could promote algal blooms. To prevent this the Proponent will commit to ensuring that the amount of fertiliser applied to these areas is minimised. The Proponent will seek advice from Perth City Council and other relevant Government authorities to achieve this objective.
7. ENVIRONMENTAL MANAGEMENT

7.1 Connection to the Swan River

It is predicted that the waters which fill the newly constructed Inlet will be of good quality with regard to chemical pollutants. It may contain suspended sediments due to earthmoving activities and water flow if the excavation occurs without dewatering. If this is the case, release of the water immediately into the Swan River could result in a plume of suspended sediments. The potential impact of this would be similar to the short term impacts posed by the deepening of areas of the river bed adjacent to the Inlet mouths.

Should there be a need, the potential impact will be minimised by management procedures for connecting the Inlet to the Swan River. In particular the connection with the Swan River will be:

- Made about a week after excavations have been completed so that waters in the Inlet have had an opportunity to settle,
- Timed if at all possible to correspond with high tide so that waters from the Inlet will discharge into the Swan and be carried downstream with an outgoing tide, and
- Will most likely occur during the late winter months when suspended sediments are naturally high in the Swan River.

7.2 Potentially Contaminated Fill

The results of site investigations have confirmed that quantities of industrial waste with high concentrations of environmental pollutants are unlikely to be buried at the site of the proposed Claisebrook Inlet. However, because filling of the site has been uncontrolled there is the potential that such waste materials could be present in small quantities.

If unidentified waste of suspect nature is uncovered during excavations the following procedures will apply:

- The site supervisor will redirect excavation activities to another location and will contact the Project Environmental Manager or Environmental Consultants.
- The Manager or Consultants will inspect the material and if it is considered that it may be contaminated, the area will be cordoned off and a sample taken for analysis.
- If the sample analysis reveals the presence of contaminants a specific management strategy will be developed in consultation with the EPA and Health Department.

Alan Tingay & Associates
If it is absolutely necessary to remove the material prior to analysis, it will be treated as if it were contaminated and will be relocated with appropriate worker protection and occupational health precautions and will be stored in a secured area.

Ultimately if any material is found to have unacceptable levels of contamination it will be relocated to an approved landfill that accepts material of this type.

Further details will be provided in an Environmental Management Program.

7.3 Dust Control

The construction of the Inlet was determined as having a medium risk with regard to the generation of nuisance dust as defined by EPA Dust Control Guidelines (EPA, 1990a). This risk will be limited to a degree by the wet nature of the excavation, however, dust suppression measures as detailed in the EPA guidelines for medium risk category sites will be implemented as follows:

- Wind fencing will be stored on site during excavation as required.
- Water carts will be available to water the site.
- Close control of works by the contractor and supervising engineer to limit where possible the potential for dust generation preferably by controlling the extent of excavation.
- Stabilisation of areas if required, after the completion of the works.

7.4 Noise Control

The potential impact of noise generated by construction activities is considered to be minimal given the physical characteristics of the excavation site and the presence of light industry, parkland and vacant land adjacent to it. However, the construction operation will be managed to minimise noise. Contractors are obliged to meet the requirements of the Noise Abatement (Neighbourhood Annoyance) Regulations, 1979.

As dewatering pumps will probably need to be operated on a 24 hour basis they will have a greater potential to produce annoying noise than other components of the operation. All dewatering pumps therefore will be bunded by earth to limit noise dispersion.

The excavators and trucks involved in the excavation will be in good operating order with standard noise mufflers to ensure excessive noise is not generated. These machines will operate during day light hours only between 0700 and 1800 hours Monday through Saturday.
7.5 Inlet Water Quality

Monitoring of flows down the Claisebrook Drain has determined that the water has elevated levels of faecal coliforms in excess of the draft EPA water quality criteria that would apply to the Inlet. The relevant water quality criteria are determined by the proposed use of a waterbody. In the case of the Inlet, this is secondary contact recreation, that is activities that could include some direct contact with water. The guideline level for secondary contact recreation for faecal coliforms is 1000 organisms per 100ml with 4 out of 5 samples containing less than 4000 per 100ml (EPA, 1990b).

Modelling has shown that currents induced by tides, water density differences and winds will result in complete water exchange between the Inlet and the Swan River every 3 days. This will be sufficient to prevent stagnation of the water body and the build up of pollutants. It is considered that concentrations of faecal coliforms will be close to the guideline level during the majority of the year as a result of the flushing of the Inlet and because faecal coliform bacteria have a high mortality when exposed to saline water. However, it is possible that the guideline level may be exceeded occasionally. As a result, the following management techniques will be implemented to minimise faecal coliforms in the Inlet:

- The low flow pipe will be retained to divert water around the Inlet and into the Swan River during summer when water flows are low and faecal coliform levels relatively high (Figure 5.7).
- Liaison will be made with WAWA and the SRT to begin an active program designed to reduce the level of faecal pollution entering the Claisebrook Drain.
- Monitoring of faecal coliform levels on a monthly basis in the Inlet and in the Drain.

The ultimate aim of management will be to achieve levels of faecal coliforms at or below the draft EPA guideline level.

7.6 Disposal of Soil and Water

The concepts and methods of handling soil and groundwaters extracted from the Claisebrook Inlet excavation are described in this Public Environmental Review (PER). However, as the detailed design of the Inlet has yet to be completed many important details were unavailable for inclusion in this document. Therefore, the EPRA will produce an Environmental Management Program which will give details relating to the following:

- Disposal of groundwaters from dewatering,
- Handling of potentially contaminated materials from the excavation,
- Handling and disposal of material sourced from the deepening of the Swan,
General handling and placing of clean fill from the excavation.

It is envisaged that ultimate approval for the proposal will not be given until the methodology described in the Environmental Management Program are to the satisfaction of the EPA.

7.7 Long Term Management

The East Perth Redevelopment Authority will revolve the long term management of the Claisebrook Inlet and its surrounds and will be responsible for the implementation of the commitments detailed in this Public Environmental Review. Eventually, however, the State Government will decide that the objectives for creating the EPRA have been satisfied and the remaining responsibilities of the Authority then will be passed on to other relevant government authorities.
8. CONCLUSIONS

The proposed Claisebrook Inlet is a key element in the economic rejuvenation of East Perth and its construction will provide a focus for development of an area that has become unattractive as a result of its past use. The redevelopment of East Perth will have the effect of promoting the repopulation of the inner city with all its social and economic benefits. The proposal will also result in the more efficient use of presently under utilised land and services in the area.

The Claisebrook Inlet will effectively be an ornamental water feature designed to enhance the attractiveness of nearby land. It will improve the recreational features of the area and promote the fuller use of this section of the Swan River by the people of Perth.

Construction of the Inlet is expected to be of benefit to the Swan River by promoting the removal or control of potential sources of water pollution. The construction of the Inlet will promote the clean-up of adjacent polluted land, will generate a program to improve the water quality of Claisebrook Drain, and result in the removal of contaminated sediments from the Claisebrook Drain and the Swan River.

Studies on water circulation and exchange with the Swan River have shown that mechanisms exist for the replacement of water in the Inlet about every 3 days. As a result eutrophication, stagnation, and the build up of pollutants are not considered to be a potential problem. Potential short term impacts related to the construction of the Inlet have been identified. Proposals to minimise these potential impacts have been formulated and it is anticipated that the affects will not be significant, especially considering their temporary nature.

It is concluded that the potential benefits of this proposal to the people of Perth and the general urban environment outweigh the minor potential impacts identified in this PER. Given this and the commitments made by the Proponent to minimise these impacts, it is concluded that the proposed Claisebrook Inlet does not pose an unacceptable impact to the environment.
9. COMMITMENTS

Commitments represent the Proponents solutions to potential environmental problems posed by the proposal. Essentially they are promises by the Proponent regarding the methods by which certain aspects of the proposal will be carried out.

The EPRA commits to carrying out the following commitment with respect to the Claisebrook Inlet:

1. With regard to connecting the Inlet to the Swan River the EPRA will ensure that, if required:
   - the connection will be made after most suspended sediment in the Inlet has had an opportunity to settle,
   - the connection will be timed if at all possible to correspond with high tide and a period during which suspended sediments are naturally high in the Swan River.

   The above will be implemented to the satisfaction of the EPA and the SRT.

2. With regard to managing the quality of water in the Claisebrook Inlet the EPRA will:
   - monitor the level of faecal coliforms in the Claisebrook Inlet and the Claisebrook Drain on a monthly basis until such time as it has been shown that coliforms levels are no longer a potential problem,
   - liaise with WAWA and the SRT with the objective of promoting a management program designed to reduce the level of faecal pollution entering the Claisebrook Drain.

   The above will be performed to the satisfaction of the EPA.

3. To prepare an Environmental Management Program (EMP) which will provide full details of the excavation, handling and disposal of hazardous wastes should they be uncovered during excavation, and of contaminated sediments, clean fill, and groundwaters extracted during dewatering exercises. This EMP will be supplied to the EPA as soon as design details become available and prior to construction commencing. This will be done to the satisfaction of the EPA.

4. Provide the following in order to minimise the potential generation of nuisance dust during and after construction of the Inlet:
   - adequate wind fencing will be stored on site during excavation,
   - water carts will be available for use during excavation,
   - stabilisation of areas if required.
The above will be carried out to the satisfaction of the EPA.

5. Perform the following with regard to minimising noise generation during Inlet excavation;

   - ensure trucks and excavators are in good operating order with standard noise mufflers,
   - ensure that dewatering pumps that are operating are within earth bunds,
   - only operate machinery during 0700 hours and 1800 hours Monday through Saturday.

The above will be done to the satisfaction of the EPA.

6. Minimise the fertilisers applied to landscaped areas adjacent to the Swan River and the Claisebrook Inlet to levels that maintain the grass in good health. The proponent will seek the advice of the City of Perth to achieve this objective.

This will be done to the satisfaction of the EPA.
REFERENCES


Environmental Protection Authority, 1990b. Water Quality Criteria for Marine and Estuarine Waters of Western Australia (Draft).


GUIDELINES FOR THE PREPARATION OF A
PUBLIC ENVIRONMENTAL REVIEW (PER)
EAST PERTH PROJECT, CLAISEBROOK INLET
ASSESSMENT NUMBER 698

Overview

In Western Australia all environmental reviews are about protecting the environment. The fundamental requirement is for the proponent to describe what they propose to do, to discuss the potential environmental impacts of the proposal, and then to describe how those environmental impacts are going to be managed so that the environment is protected.

If the proponent can demonstrate that the environment will be protected then the proposal will be found environmentally acceptable; if the proponent cannot show that the environment would be protected then the Environmental Protection Authority (EPA) would recommend against the proposal.

Throughout the process it is the aim of the EPA to advise and assist the proponent to improve or modify the proposal in such a way that the environment is protected. Nonetheless, the environmental review in Western Australia is proponent driven, and it is up to the proponent to identify the potential environmental impacts and design and implement proposals which protect the environment.

For this proposal, protecting the environment means that the natural and social values associated with the Claisebrook Inlet and the Swan River foreshore are protected. Where they cannot be protected, proposals to mitigate the impacts are required.

Purpose of a PER

The primary function of the PER is to provide the basis for the Environmental Protection Authority to provide advice to Government on protecting the environment. An additional function is to communicate clearly with the public so that EPA can obtain informed public comment. As such, environmental impact assessment is quite deliberately a public process. The PER should set out the series of decisions taken to develop this proposal at this place and time and why.

Objectives of the review

The Public Environmental Review should have the following objectives:

• to place this project in the context of redevelopment of the inner city environment utilising the natural resources available (particular the location adjacent to the Swan River and the Claisebrook Inlet);
• to explain the issues and decisions which led to the choice of this project at this place at this time;
• to set out the environmental impacts that the project may have; and
• for each impact, to describe any environmental management steps the proponent believes would avoid, mitigate or ameliorate that impact.

The PER should focus on the major issues for the area and anticipate the questions that members of the public will raise. Data describing the environment should be directly related to the discussion of the potential impacts of the proposal. Both should then relate directly to the actions proposed to manage those impacts.
Key issues

The key issues for this project should be clearly identified and the content of succeeding sections determined by their relevance to these issues.

In this case the key issues will revolve around management of the Claisebrook Inlet and its interface with the Swan River, specifically:

- water quality control issues in the Claisebrook Inlet including:
  - long term maintenance of water quality within the development;
  - design characteristics to promote appropriate circulation; and
  - impact of the proposed dredging of the river.

- potential pollution and health issues associated with the adjacent SECWA gasworks site;

- containment and/or removal of contaminants in the Claisebrook Inlet and adjacent areas of the Swan River;

- management of the Claisebrook Inlet and Swan River foreshores, including:
  - future use and management of the proposed artificial island; and
  - nutrient and irrigation management on Public Open Space adjacent to the Inlet/River.

- impacts on landscape and recreational values;

Other key issues will include the impact of the development on existing and historical social use patterns in the area, including:

- cultural impact on Aboriginal people with traditional affiliation to the land;
- impact on any existing residents in the development area; and
- impacts on existing human use.

plus any other key issues raised during the preparation of the report.

Public participation and consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the PER (such as discussions with government agencies, local authorities or nearby residents). It should describe the activities undertaken, the dates, the groups and individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management for the proposal which should clearly indicate how community concerns have been addressed. Where these concerns are dealt with via other departments or procedures, outside the Environmental Protection Authority process, these can be noted and referenced here.

Detailed list of environmental commitments

The commitments being made by the proponent to protect the environment should be clearly defined and separately listed. Where an environmental problem has the potential to occur, there should be a commitment to rectify it. They should be numbered and take the form of:

a) who will do the work;  
b) what the work is;  
c) when the work will be carried out; and  
d) to whose satisfaction the work will be carried out.

All actionable and auditable commitments made in the body of the document should be numbered and summarised in this list.
APPENDIX 2

HYDROGEOLOGICAL MODELLING STUDY OF CLAISEBROOK AREA
EAST PERTH PROJECT
CLAISEBROOK INLET FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING
DECEMBER 1991
EXECUTIVE SUMMARY

Mackie Martin & Associates were commissioned by the Department of Planning and Urban Development to undertake hydrogeological investigations at Trafalgar Precinct, a central feature of the East Perth Development Project. The study, which was managed by Alan Tingay & Associates, forms a major part of a feasibility assessment for the proposed Claisebrook Inlet, which will extend inland from the Swan River in the vicinity of the existing Claisebrook Drain.

The key components addressed in the course of this study include:

- the assessment regional and local hydrogeology to determine aquifer characteristics;
- the evaluation of the impact of inlet construction on the local groundwater system, including dewatering during excavation; and,
- the impact of the proposed inlet on contaminant migration from the SECWA gasworks site.

To determine aquifer properties and calculate groundwater fluxes a field investigation programme was completed, including geophysical survey, drilling, hydraulic testing, chemical analysis and water level monitoring. The compilation and analysis of the geophysical and hydrogeological data has provided a conceptual model of groundwater occurrence and distribution.

A computer model was developed with the capability to determine groundwater movement and to assess contaminant migration and concentration. The regional hydraulic model was calibrated against field investigation data and known aquifer properties.

Based upon the parameters defined for the calibrated model a solute transport model was implemented and two scenarios were developed. These included implementation of the inlet with no control of groundwater movement on the gasworks site and contaminant control via sheet piling along the northern margin of the inlet. Concentration ranges and distribution, groundwater levels and water level changes were predicted for these scenarios, with a simulated point source on the gasworks site.

The construction of the Claisebrook Inlet results in a reduction in water levels both to the north and south of the inlet. Calculated fluxes to the inlet/drain indicate that the incorporation of the proposed inlet into the numerical model has little net impact upon groundwater discharge (to the drain/inlet). An increase of approximately 10% over the present seepage to the drain is estimated. The limited impact of the inlet is due to the groundwater control presently effected by the drain and the low permeability of the superficial formations.
The contaminant migration is dominated by the groundwater movement across the gasworks site towards the Swan River and the drain. Predictions for Scenario 1 suggest that inlet will enhance the movement of contaminated groundwater into the drain (inlet). This is due to proximity of the discharge boundary to the contaminant source. The construction of a sheet pile wall prevents the migration into the drain but leads to an increase in concentration on the gasworks site itself.

Dewatering of the entire inlet area for excavation works results in a temporary decline of water levels in the vicinity of the inlet. The impact on the local groundwater table is limited to the project area. The estimated time frame to reach steady state, assuming that water levels across the entire inlet area are lowered simultaneously, is of the order of two to three months. Required pumping rates steadily decline to the steady state inflow rate. After one week the required pumping rate is approximately twice the long term inflow rate.

It is evident from water level data that saline intrusion of river water into the aquifer will be very limited over the winter months. Monitoring bores within the Water Authority reserve indicate a minimum water level of the order of 0.8 mAHD (which is approximately 0.9 mASL), suggesting a fresh water thickness of 35 metres. The actual location of the saltwater interface will depend upon local aquifer properties, with the low permeabilities dampening any seasonal movement of the interface. Water level monitoring over the summer months will provide sufficient data to assess the likely impact seasonal saline intrusion variations. Minimum groundwater levels are generally observed in April/May. Development of the inlet is not expected to change the nature and extent of saline intrusion in the aquifer.
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Figure 18: Predicted Groundwater Levels for Scenario 3
Figure 19: Predicted Groundwater Levels for Scenario 4
Figure 20: Predicted Impact on Groundwater Levels for Scenario 3
Figure 21: Predicted Impact on Groundwater Levels for Scenario 4
1.0 INTRODUCTION

Mackie Martin & Associates were commissioned by the Department of Planning and Urban Development to undertake hydrogeological investigations at Trafalgar Precinct, a central feature of the East Perth Development Project. The study, which was managed by Alan Tingay & Associates, forms a major part of a feasibility assessment for the proposed Claisebrook Inlet, that will extend inland from the Swan River in the vicinity of the existing Claisebrook Drain (Figure 1).

The study area includes the East Perth Gasworks site, where significant levels of contamination have been identified from the waste products of gas production (Camp Scott Furphy, 1990). Data compiled during previous investigations for this site was reviewed. In addition, regional drilling, hydraulic testing and water table mapping was completed for this study. Subsequently, a groundwater model was developed based upon all available hydrogeological data, to assess the impact and constraints to the proposed inlet construction. Contaminant migration from the gas works site for existing and future conditions was also simulated.

2.0 SITE DESCRIPTION

The Trafalgar Precinct is located on the banks of the Swan River to the north-east of the city (Figure 1). The northern part of this area is dominated by light industries, vacant industrial land, a disused gasworks and a Water Authority pumping station.

A small area of residential properties is located north-east of the historic East Perth cemetery. In the south-west of the Precinct, Haig Park (established in 1936) offers recreational facilities.

The re-development of this area includes the rehabilitation of former industrial sites and the improvement of the natural environment. Recent studies have identified the East Perth Gasworks as a major source of contamination. The construction of an inlet south of the gasworks offers the opportunity to rehabilitate (or contain) areas of industrial fill which presently contribute to the pollution of Claisebrook Drain and Swan River.

3.0 FIELD-INVESTIGATIONS

Field investigations were undertaken to obtain data on subsurface geological and hydraulic conditions within the study area. These data were used to define the aquifer properties and a conceptual model of groundwater occurrence and distribution was developed.
The majority of field work was performed in August and September 1991. The first stage involved a brief geophysical programme using electromagnetic surveying techniques. Based upon the geophysical results 15 investigation/monitoring bores were drilled and test pumped. Groundwater sampling was conducted during test pumping and samples were submitted for water quality analysis to a NATA registered laboratory. All bores were levelled to datum and water levels were monitored on a monthly basis to determine seasonal changes of the water table.

3.1 Electromagnetic Survey (EM)

Electromagnetic methods apply an oscillating magnetic field into the ground which induces small electrical currents. These currents generate a secondary field which is measured by a receiver coil. The apparent ground conductivity recorded depends on several parameters, such as soil type, groundwater conductivity and the depth to water saturation (water content).

Electromagnetic surveying was carried out along ten traverses. Survey lines were selected along the Swan River bank, Claisebrook Drain, the south-east boundary of the gasworks site and an area of industrial fill and waste to the north of Claisebrook Drain (Figure 2).

A total of 143 readings were obtained using a Geonics EM 34 instrument. Measurements were taken every 10 metres with a 10 metre coil separation. This separation ensures adequate spatial resolution and vertical integration of ground conductivity response to a depth of approximately 7 metres.

Ground conductivity profiles, presented in Figures 3 and 4, show the range of apparent conductance values across the investigation site. While measured conductivity was low to medium along line 1 to 4, line 6, 7 and 8, high values were recorded along line 5 and 9 with maximum values west of the gasworks site.

Comparison between lines 9 and 10, which are similarly located with respect to the river, suggests that these high values are not only influenced by the shallow depth to water at the Swan River bank. The high ground conductivity is also related to fill material which covers the shoreline and part of the gasworks site, as shown in the geological cross-section (Figure 5). A strip of about 40 metres width and a thickness of up to 6 metres was filled with rubble, sand and wastes from the gasworks between 1950 and 1960.
3.2 Drilling

Twelve holes were drilled within the Claisebrook Precinct and three to the north and northwest of the development area, using an HQ air core reverse circulation drill rig. Bore locations were selected adjacent to the proposed Claisebrook Inlet to obtain detailed information on surface lithology and groundwater table. Bores were drilled to depths between 6 to 12 metres and were completed with 40 mm class 9 uPVC slotted casing.

Complete stratigraphic logs for drill holes are presented in Appendix A. A summary of geological features of the site is provided in section 3.6.

3.3 Hydraulic Testing

Aquifer testing provides a means of determining localised hydraulic properties of water yielding strata. By conducting a number of tests at different sites within an aquifer system, representative hydraulic properties and their variability can be determined.

Test pumping was undertaken on completion of the drilling programme and involved pumping a bore at a constant discharge rate and measuring the drawdown in water level at the pumping bore.

Drawdown-time data was analysed using computer based techniques to determine aquifer properties. Table 1 provides specific details of each test including pumping rate, drawdown and estimated aquifer hydraulic parameters.

<table>
<thead>
<tr>
<th>BORE</th>
<th>Radius (m)</th>
<th>Pumping Rate (kl/d)</th>
<th>Duration of Test (min)</th>
<th>Drawdown (m)</th>
<th>Transmissivity (kl/d/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP1</td>
<td>0.02</td>
<td>11.0</td>
<td>30.1</td>
<td>0.27</td>
<td>11.6</td>
</tr>
<tr>
<td>EP3</td>
<td>0.02</td>
<td>10.3</td>
<td>22.4</td>
<td>0.91</td>
<td>12.2</td>
</tr>
<tr>
<td>EP4</td>
<td>0.02</td>
<td>9.25</td>
<td>22.1</td>
<td>1.31</td>
<td>4.1</td>
</tr>
<tr>
<td>EP5</td>
<td>0.02</td>
<td>11.0</td>
<td>24.6</td>
<td>1.90</td>
<td>2.3</td>
</tr>
<tr>
<td>EP6</td>
<td>0.02</td>
<td>10.5</td>
<td>23.3</td>
<td>0.11</td>
<td>66.6</td>
</tr>
<tr>
<td>EP7</td>
<td>0.02</td>
<td>8.9</td>
<td>21.5</td>
<td>2.28</td>
<td>38.7</td>
</tr>
<tr>
<td>EP10</td>
<td>0.02</td>
<td>3.8</td>
<td>29.8</td>
<td>2.25</td>
<td>0.7</td>
</tr>
<tr>
<td>EP13</td>
<td>0.02</td>
<td>17.8</td>
<td>26.0</td>
<td>0.71</td>
<td>20.5</td>
</tr>
</tbody>
</table>
Test pumping results show a range of transmissivity in the superficial aquifer from 1 to 67 kl/d/m, strongly reflecting the local variations in stratigraphy. Bores EP4, EP5 and EP10, which indicate a low transmissivity, are characterised by clayey soil with a thin surface layer of sand. Higher transmissivities are recorded at sites where lenses of sandy clay and sand dominate.

3.4 Groundwater Analysis

Two groundwater samples were collected from each bore during test pumping for detailed chemical analysis. These samples were submitted to Genalysis Laboratory Services. The chemical constituents analysed included Na, Mg, Al, S, K, Ca, Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, Pb, pH, EC, TDS, HCO3, CO3, OH, Cl, F, NO3, Phenol and P. All results are presented in Appendix B.

A tri-linear plot (piper diagram) of chemical analysis results is presented as Figure 6. This figure illustrates the variability in groundwater quality across the study area, with no distinct trends evident. It is possible that grouping of samples with respect to calcium may reflect exposure to the Tamala Limestone Formation. In general, these results are typical of slow moving groundwaters contained within a locally heterogeneous aquifer.

The concentration of total dissolved solids ranged from 260 to 2450 mg/kg with peak levels at bore EP4, EP5 and EP10. At most locations concentrations of heavy metals were below or equal to the detection limit, however elevated levels of zinc were recorded at EP3 (Old Brickworks Site) and EP6 (Scrap Yard). Phenols were only detected at bore EP15 (0.4 mg/L), located at the north western corner of Haig Park.

3.5 Piezometric Survey

Water levels were measured in all the monitoring bores on a monthly basis from September 1991. The water levels define the regional water table within and to the north west of the Trafalgar Precinct.

As the groundwater recharge is mainly derived from rainfall, maximum water levels are usually recorded at the end of winter, during October (Table 2), with minimum levels in April/May. Water table depth below ground level at the monitoring bores varies from less than 1 metre to about 7 metres.

The direction of groundwater flow is towards the Swan River and Claisebrook Drain. In September 1991 the highest water level within the study area was recorded at bore EP8 (8.01 mAH), the lowest at EP10 (0.80 mAH). To assess seasonal variations of the groundwater table, the monitoring programme will be continued for the next eight months.
## Table 2

**Groundwater Level Data**

<table>
<thead>
<tr>
<th>Bore</th>
<th>Top of Casing (mAHD)</th>
<th>Water Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sep 91 (mAHD)</td>
<td>Oct 91 (mAHD)</td>
</tr>
<tr>
<td>EP1</td>
<td>2.18</td>
<td>1.25</td>
</tr>
<tr>
<td>EP2</td>
<td>7.44</td>
<td>3.04</td>
</tr>
<tr>
<td>EP3</td>
<td>4.65</td>
<td>2.11</td>
</tr>
<tr>
<td>EP4</td>
<td>4.24</td>
<td>1.84</td>
</tr>
<tr>
<td>EP5</td>
<td>2.42</td>
<td>1.30</td>
</tr>
<tr>
<td>EP6</td>
<td>10.26</td>
<td>7.05</td>
</tr>
<tr>
<td>EP7</td>
<td>9.09</td>
<td>5.43</td>
</tr>
<tr>
<td>EP8</td>
<td>11.59</td>
<td>8.01</td>
</tr>
<tr>
<td>EP9</td>
<td>4.90</td>
<td>1.33</td>
</tr>
<tr>
<td>EP10</td>
<td>1.54</td>
<td>0.80</td>
</tr>
<tr>
<td>EP11</td>
<td>1.61</td>
<td>0.81</td>
</tr>
<tr>
<td>EP12</td>
<td>6.65</td>
<td>1.08</td>
</tr>
<tr>
<td>EP13</td>
<td>8.42</td>
<td>7.26</td>
</tr>
<tr>
<td>EP14</td>
<td>8.22</td>
<td>1.71</td>
</tr>
<tr>
<td>EP15</td>
<td>7.11</td>
<td>1.85</td>
</tr>
</tbody>
</table>

It should be noted that some tidal variation was observed in monitoring bores adjacent to the river and drain. A tidal efficiency (the ratio of bore fluctuation to tidal signal) of approximately 22% was calculated for EP1. The amplitude of the tidal signal decreases rapidly with distance from the open water, reflecting the low aquifer permeability. Interpretation of summer (April/May) water level data in bores near to open water will require adjustment for tidal conditions.

### 3.6 Hydrogeologic Assessment

Geological logs of the fifteen monitoring bores indicate an unconfined aquifer consisting of a 1 to 2 metres upper layer of medium sand, underlain by interbedded sands of the Tamala Limestone Formation and clays. Near the gasworks site, the stratigraphic sequence consists of a mixture of alluvial deposits from the Swan River and clayey sands.

The Haig Park area is dominated by clayey layers, whereas sand dominated soils occur at bore locations EP3, EP5, EP6. Vacant industrial land between Claisebrook Drain and Brown Street is made up of fill (building rubble) resulting from former industrial use of the site.
The shallow aquifer across East Perth, which unconformably overlies the Kings Park Formation, has a thickness between 25 to 35 metres. Hydraulic testing of eight bores indicated a permeability generally ranging from 0.1 to 2.5 m/day, with a maximum of 15 m/day (dependent upon the dominance of either clay or sand layers).

Groundwater contained within the superficial formations originates from direct infiltration of rainfall. This forms part of a regional shallow aquifer system, with the water table which exists at the surface of the unconfined groundwater system defined mainly by topography. The water table fluctuates seasonally by about 1 to 1.5 metres. Peak groundwater levels are observed in September-October, with minimum levels in April-May. Groundwater flow occurs towards the Swan River and Claisebrook Drain with an average gradient of 0.002. Claisebrook drain has a significant impact upon groundwater levels and flow directions.

It is evident from water level data that saline intrusion of river water into the aquifer will be very limited over the winter months. Monitoring bores within the Water Authority reserve indicate a minimum water level of the order of 0.8 mAH (which is approximately 0.9 mASL), suggesting a fresh water thickness of 35 metres. The actual location of the saltwater interface will depend upon local aquifer properties, with the low permeabilities dampening any seasonal movement of the interface. Water level monitoring over the summer months will provide sufficient data to assess the likely impact seasonal saline intrusion variations. Minimum groundwater levels are generally observed in April/May.

4.0 NUMERICAL AQUIFER MODEL

It is difficult to assess the relative contribution and significance of the various components in a hydrogeologic system using classical analytic methods. These methods generally assume aquifer homogeneity in the form of 1-dimensional equations and are more applicable in the assessment of local aquifer response. With a computer based numerical model however, it is possible to more accurately simulate regional conditions and to explore the impact of climate, land use and water budget changes by introducing spatial and temporal variability. The impact of surface and subsoil drainage, including inlet configurations can also be evaluated.

The development of a numerical model at an early stage of impact assessment also facilitates sensitivity analyses which will define the dominant parameters and mechanisms. This will highlight areas where further data should be sought during the course of project development.
Regional hydraulic and water quality modelling has been undertaken using AQUIFEM-N (Townley, 1990). This package relies on finite element techniques to solve the groundwater flow equations. The aquifer is discretised into a number of small triangular elements with each mapping such parameters as aquifer geometry, hydraulic properties, recharge etc. Elements are connected into a grid designed to satisfy numerical constraints having regard for geology and hydraulic boundaries.

During this investigation both regional hydraulic simulation and regional solute transport modelling were completed. Calibrated hydraulic parameters were employed to assess the impact of existing contamination prior to and after inlet construction. In the following section both models established for this study are described, with appropriate boundary conditions defined and the resulting calibrated parameters presented and discussed.

4.1 Regional Hydraulic Model

This model was designed to determine the effects of transforming the Claisebrook main drain into an inlet of the Swan River. The model grid used in the simulation consists of a network of 1445 elements described by 767 nodes, as shown in Figure 7, covering the area between the Swan River and the 9.5 m water level contour north-west of East Perth. The finite element mesh is graded from coarse elements representing regional conditions to a fine mesh in the vicinity of Claisebrook Drain to provide accurate predictions in the vicinity of the proposed inlet.

Along the Swan River shoreline boundary nodes were assigned constant piezometric heads at 0.1 mAHD. An inland boundary was located to the north and north-west where nodes were aligned with the 9.5 mAHD maximum groundwater contour (Water Authority data, Figure 8).

Nodes along the existing Claisebrook Drain were adjusted to represent existing average water levels to permit calculation of fluxes into the drain under present and planned conditions. Review of groundwater data from the Water Authority and investigation bores completed during this study suggested that the drain acts as a groundwater control for almost one kilometre inland. The open drain extends approximately 500 metres inland beyond which the drain is piped. It is inferred that the piped section is acting as a conduit, either by direct leakage into the pipe or flow in more permeable backfill adjacent to the pipe. Groundwater levels were fixed over this section of the drain slightly above the drain invert level.
Initial calibration of the numerical model assumed that the recharge was uniform across the model area, whereas permeability was interpolated for each node based upon values obtained from hydraulic testing and regional aquifer property data. The final calibrated permeability varies between 0.05 to 1.0 m/day and the applied recharge was estimated to be 10% of annual average rainfall (870 mm). On a local scale the predicted water levels agree with monitored groundwater levels in the Claisebrook area and on a regional scale with maximum groundwater levels estimated by the Water Authority of Western Australia (Figure 8). Predicted water levels presented in Figure 9 illustrate a higher hydraulic gradient in the northern part of the study area compared to a flatter gradient south of the Claisebrook Drain. The predicted contours clearly reflect to which extent the local groundwater table is influenced by the drain.

4.2 Regional Solute Transport Model

The calibrated hydraulic model provided the basis for modelling the impact of contaminant migration, from a point source on the Gasworks site, on the drain and Swan River for existing and future conditions. In a study of the East Perth Gasworks site undertaken by Camp Scott Furphy Pty Ltd (1990) a former tar plant was identified as an area of high soil and groundwater contamination. The model was used to predict the contaminant movement via groundwater from this point source and to determine the range of concentrations across the area under steady state conditions. Dispersivities applied in the solute transport model were 100 metres (longitudinal) and 10 metres (transversal).

5.0 GROUNDWATER IMPACT ASSESSMENT

The simulation of solute transport was applied for existing conditions and two scenarios of different inlet constructions. Figure 10 presents the contaminant movement in direction and concentration with a point source located on the SEC site. It should be noted that the concentration contours are non-dimensional and reflect the predicted trend only. It is apparent that the contaminant movement is directly related to the groundwater flow towards the Swan River and Claisebrook Drain.

Scenario 1 incorporates the proposed inlet design (Figure 1). Water levels within the inlet were assumed to be similar to the Swan River levels (0.1 m AHD). Predicted Groundwater contours and a difference plot (Figures 11 and 12) indicate that the 1 metre contour moves further inland reducing local water levels by up to 1.8 metres. The inlet also has a drawing effect on the contaminants from the gasworks site, increasing concentrations towards the drain, compared to existing conditions (Figure 13).
A summary of predicted fluxes into the drain and inlet is presented in Table 3. It is noted from these calculated fluxes that the incorporation of the proposed inlet into the numerical model has little net impact upon groundwater discharged to the drain/inlet. An increase of approximately 10% over the present seepage to the drain is estimated. The limited impact of the inlet is due to the groundwater control presently effected by the drain and the low permeability of the superficial formations.

**TABLE 3**

Predicted Groundwater Fluxes (m³/day)

<table>
<thead>
<tr>
<th>Groundwater Fluxes</th>
<th>Existing Conditions</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drain Inflow</td>
<td>291</td>
<td>184</td>
<td>184</td>
</tr>
<tr>
<td>Inlet Inflow</td>
<td>-</td>
<td>137</td>
<td>130</td>
</tr>
<tr>
<td>Total Inflow</td>
<td>291</td>
<td>321</td>
<td>314</td>
</tr>
<tr>
<td>Flux from SEC site (to inlet/drain)</td>
<td>22</td>
<td>15</td>
<td>0</td>
</tr>
</tbody>
</table>

An option to prevent contaminant migration into the inlet is the construction of a sheet pile wall along the southern boundary of the SEC site. This was simulated in Scenario 2, which also includes the construction of a second passage connecting the inlet to the Swan River.

Figures 14 and 15 indicate that the overall impact of the sheet pile wall (barrier) on groundwater contours is only observed on the northern side of the inlet (when compared to Scenario 1). A vector diagram (Figure 17) illustrates the groundwater flow direction and velocity across the project area. The sheet pile wall results in a diversion of groundwater flow, with a dividing streamline to west of the gasworks site. Contaminant migration from the SEC site is reduced (due to lower throughflow) leading to a rise in contaminant concentrations across the site (Figure 16). The predicted distribution suggests greater impact will be observed on the Swan River.
6.0 INLET Dewatering

In addition to modelling the impact of the completed inlet on the local groundwater system, a simulation of dewatering of the entire inlet area to a level of -2.0 mAH D, to allow for excavation works, was undertaken. Based upon the inlet configuration applied in Scenario 2 (inlet with two passages to the Swan River) dewatering was modelled for a period of 34 days assuming that the water table was at its seasonal maximum. Scenario 3 simulates dewatering without a barrier between SEC site and inlet, whereas Scenario 4 includes the construction of a sheet pile wall before excavating.

Groundwater contours (Figures 18 and 19) indicate enhanced flow towards the inlet, with steep gradients induced at the western end of the inlet. Difference plots (Figure 20 and 21) indicate that the impact on the local groundwater table is confined to the vicinity of the drain. If maximum groundwater levels are assumed, the water table is lowered locally by up to 4.0 m.

Table 4 provides groundwater discharge rates (required pumping rates) into the inlet after 1, 7 and 34 days. While the aquifer is being dewatered, required pumping rates decline continuously with time reaching steady state after two to three months. The required rate after one week is approximately twice the steady state inflow rate.

<table>
<thead>
<tr>
<th>Day</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>973</td>
<td>853</td>
</tr>
<tr>
<td>7</td>
<td>660</td>
<td>573</td>
</tr>
<tr>
<td>34</td>
<td>403</td>
<td>351</td>
</tr>
</tbody>
</table>
7.0 CONCLUSIONS

This study was undertaken to investigate site characteristics of the Trafalgar Precinct development area with regard to the planned inlet from the Swan River towards Claisebrook Drain.

The key components addressed in the course of this study included:

- the assessment regional and local hydrogeology to determine aquifer characteristics;
- the evaluation of the impact of inlet construction on the local groundwater system;
- the impact of the proposed inlet on contaminant migration from the SECWA gasworks site; and,
- the impact of dewatering the inlet area while excavating.

To determine aquifer properties and calculate groundwater fluxes a field investigation programme was completed, including geophysical survey, drilling, hydraulic testing, chemical analysis and water level monitoring. The compilation and analysis of the geophysical and hydrogeological data has provided a conceptual model of groundwater occurrence and distribution.

A computer model was developed with the capability to determine groundwater movement and to assess contaminant migration and concentration. The regional hydraulic model was calibrated against field investigation data and known aquifer properties.

Based upon the parameters defined for the calibrated model a solute transport model was implemented and two scenarios were developed. These included implementation of the inlet with no control of groundwater movement on the gasworks site and contaminant control via sheet piling along the northern margin of the inlet. Concentration ranges and distribution, groundwater levels and water level changes were predicted for these scenarios, with a simulated point source on the gasworks site.

The construction of the Claisebrook Inlet results in a reduction in water levels both to the north and south of the inlet. Calculated fluxes to the inlet/drain indicate that the incorporation of the proposed inlet into the numerical model has little net impact upon groundwater discharge (to the drain/inlet). An increase of approximately 10% over the present seepage to the drain is estimated. The limited impact of the inlet is due to the groundwater control presently effected by the drain and the low permeability of the superficial formations.
The contaminant migration is dominated by the groundwater movement across the gasworks site towards the Swan River and the drain. Predictions for Scenario I suggest that inlet will enhance the movement of contaminated groundwater into the drain (inlet). This is due to proximity of the discharge boundary to the contaminant source. The construction of a sheet pile wall prevents the migration into the drain but leads to an increase in concentration on the gasworks site itself.

Dewatering of the entire inlet area for excavation works results in a temporary decline of water levels in the vicinity of the inlet. The impact on the local groundwater table is limited to the project area. The estimated time frame to reach steady state, assuming that water levels across the entire inlet area are lowered simultaneously, is of the order of two to three months. Required pumping rates steadily decline to the steady state inflow rate. After one week the required pumping rate is approximately twice the long term inflow rate.

It is evident from water level data that saline intrusion of river water into the aquifer will be very limited over the winter months. Monitoring bores within the Water Authority reserve indicate a minimum water level of the order of 0.8 mAHĐ (which is approximately 0.9 mASL), suggesting a fresh water thickness of 35 metres. The actual location of the saltwater interface will depend upon local aquifer properties, with the low permeabilities dampening any seasonal movement of the interface. Water level monitoring over the summer months will provide sufficient data to assess the likely impact seasonal saline intrusion variations. Minimum groundwater levels are generally observed in April/May. Development of the inlet is not expected to change the nature and extent of saline intrusion in the aquifer.

8.0 REFERENCES


Government of Western Australia, East Perth Project - Outline Development Plan, October 1990.
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

LEGEND:

- Cadastral Boundary
- Drainage
- River
- Railway
- Trafalgar Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
- Survey Line

NOTE:
Base Map Produced from WAWA 1:5000 Series using Map BSKX 06.10.

ORIGINAL SCALE 1:5000

ELECTROMAGNETIC SURVEY SITES

FIGURE 2
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

ELECTROMAGNETIC SURVEY
LINE 1 TO 5

FIGURE 3
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

FIGURE 4

ELECTROMAGNETIC SURVEY
LINE 6 TO 10
LEGEND

- Fill
- Silty Clay
- Clayey Sand
- Sand
- Sandy Clay
- Silty Sand

GEOLOGICAL CROSS-SECTION
LINE 10

FIGURE 5
EAST PERTH PROJECT
Groundwater Samples

HYDROCHEMICAL FACIES DIAGRAM

- EP6
- EP7
- EP8

□ WAWA site bores
× Haig Park bores
★ Homeswest bores

Mackie Martin & Associates
GROUNDWATER ENGINEERS

FIGURE 6
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

LEGEND:
- Ceasstral Boundary
- Drainage
- River
- Railway
- Postal Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
-Finite Element Mesh

NOTE:
Base Map Produced from WAWA 1:5000 Series
Using Map E034 O6.10.

FIGURE 7

FINITE ELEMENT MESH
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

LEGEND:
- Cadastral Boundary
- Contour
- River
- Railway
- Trafalgar Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
- Groundwater Contour (mAH0)

NOTE:
Base Map Produced from WAKA 1:5000 Series
using WAK B534 06.10.
(After WAKA Sheets 10000 BS 34/3.5-3.6)

ORIGINAL SCALE 1:10000

PREDICTED MAXIMUM GROUNDWATER LEVELS

FIGURE 8

Mackie Martin & Associates
GROUNDWATER ENGINEERS
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

NOTE:
Base Map Produced from WACA 1:5000 Series
using Map BG34 06 10.

LEGEND:
- Geodetic Boundary
- Drainage
- River
- Railway
- Western Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
- Water Level Contour (mAHOD)

ORIGINAL SCALE 1:10000

PREDICTED GROUNDWATER LEVELS
FOR EXISTING CONDITIONS

FIGURE 9
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

NOTE:
The map produced from WAWA 1:5000 Series
using Map BG34 06.10.

PREDICTED IMPACT OF
CONTAMINANT SOURCE ON SEC SITE
FOR EXISTING CONDITIONS

FIGURE 10

Mackie Martin & Associates
GROUNDWATER ENGINEERS
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

LEGEND:

- Cadastral Boundary
- Drainage
- River
- Railway
- Zone
- Proposed Claibrook Inlet
- Monitoring bore
- Concentration Contour (non-dimensional)

NOTE:
Base Map Produced from WAWA 1:5000 Series using Map 8634 OS.10.

ORIGINAL SCALE 1:5000

PREDICTED IMPACT OF CONTAMINANT SOURCE ON SEC SITE FOR SCENARIO 1

FIGURE 13
EAST PERTH PROJECT
CLAISEBROOK INLET
FEASIBILITY STUDY
GROUNDWATER INVESTIGATIONS
AND NUMERICAL MODELLING

LEGEND:
- Cadastral Boundary
- Drainage
- River
- Railway
- Trafalgar Precinct
- Proposed Claisebrook Inlet
- Monitoring Bore
- Water Level Contour (mANO)
- Sheet Pile Wall

NOTE:
Base Map Produced from MAWA 1:5000 Series
using Map 8034 06.10.

ORIGINAL SCALE: 1:10000

PREDICTED GROUNDWATER LEVELS
FOR SCENARIO 2

FIGURE 14
FIGURE 15

PREDICTED IMPACT ON GROUNDWATER LEVELS FOR SCENARIO 2

NOTE:
Base map produced from W&M 1:5000 Series using Map B634 06.10.

GLOUCESTER PARK
Predicted Impact of Contaminant Source on SEC Site for Scenario 2

FIGURE 16

Hackie Martin & Associates
GROUDWATER ENGINEERS
FIGURE 17

PREDICTED GROUNDWATER FLOW DIRECTIONS FOR SCENARIO 2

NOTE:
Base map produced from DMA 1:5000 Series using Map BM34 06.10.
APPENDIX A

STRATIGRAPHIC LOGS
BORE HOLE EP1

Location: East Perth - Water Authority Site
Date drilled: 27-8-1991
Slotted PVC interval: 0.0 - 12.0 m
Top of casing: 2.183 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>fine-medium red/brown sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>medium white sand underlain by</td>
</tr>
<tr>
<td></td>
<td>yellow brown clay</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>damp yellow clay</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>damp yellow clay grading to a</td>
</tr>
<tr>
<td></td>
<td>grey sandy clay</td>
</tr>
<tr>
<td>5.0 - 8.0</td>
<td>grey sandy clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>grey clay</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>grey-yellow clay</td>
</tr>
<tr>
<td>10.0 - 12.0</td>
<td>wet grey clay</td>
</tr>
</tbody>
</table>

BORE HOLE EP2

Location: East Perth - Old Brickworks Site
Date drilled: 27-8-1991
Slotted PVC interval: 0.0 - 12.0 m
Top of casing: 7.444 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>medium-coarse grey sand</td>
</tr>
<tr>
<td></td>
<td>with occasional gravel stones</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>wet medium-coarse grey sand</td>
</tr>
<tr>
<td></td>
<td>grading into a hard grey sandy</td>
</tr>
<tr>
<td></td>
<td>clay</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>hard grey sandy clay</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>light grey clay</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>light grey clay, medium-coarse</td>
</tr>
<tr>
<td></td>
<td>yellow sand</td>
</tr>
<tr>
<td>5.0 - 7.0</td>
<td>wet medium yellow sand (grading</td>
</tr>
<tr>
<td></td>
<td>finer with depth)</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>wet white clayey sand</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>wet grey clayey sand</td>
</tr>
<tr>
<td>9.0 - 12.0</td>
<td>wet coarse white sand</td>
</tr>
</tbody>
</table>
## BORE HOLE EP3

**Location:** East Perth - Old Brickworks Site  
**Date drilled:** 27-8-1991  
**Slotted PVC interval:** 0.0 - 12.0 m  
**Top of casing:** 4.651 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>brown soil, charcoal-like aggregate</td>
</tr>
<tr>
<td>1.0 - 4.0</td>
<td>medium grey sand (wet near 4 metre mark).</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>wet medium grey sand, yellow/grey clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>wet yellow/grey clay, very coarse quartz sand</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>wet medium white sand</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>very coarse white sand (not as much water as above)</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>wet medium yellow clayey sand</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>wet medium-coarse reddish clayey sand</td>
</tr>
<tr>
<td>10.0 - 11.0</td>
<td>wet medium-coarse yellow clayey sand</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>wet medium white clayey sand, very coarse quartz sand</td>
</tr>
</tbody>
</table>

## BORE HOLE EP4

**Location:** East Perth - Old Brickworks Site  
**Date drilled:** 27-8-1991  
**Slotted PVC interval:** 0.0 - 9.0 m  
**Top of casing:** 4.244 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>dark brown soil and gravel containing bits of charcoal and brick</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>red/brown sand, brown/grey clay</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>brown clay (slightly sandy)</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>brown/yellow clay</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>grey and yellow clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>wet yellow/grey clay</td>
</tr>
<tr>
<td>6.0 - 8.0</td>
<td>wet yellow sandy clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>wet yellow clayey sand</td>
</tr>
</tbody>
</table>
**BORE HOLE EP5**

Location: East Perth - Old Brickworks Site  
Date drilled: 28-8-1991  
Slotted PVC interval: 0.0 - 9.0 m  
Top of casing: 2.418 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>grey soil, medium grey sand, yellow clay</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>grey sandy clay and bits of concrete</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>yellow and grey medium sand, bivalve shells</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>medium grey sand</td>
</tr>
<tr>
<td>4.0 - 6.0</td>
<td>wet medium-coarse grey sand</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>wet fine grey sand</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>wet medium-coarse grey sand</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>yellow/grey clay (sandy at top)</td>
</tr>
</tbody>
</table>

**BORE HOLE EP6**

Location: East Perth - Corner of Brown and Lime Street  
Date drilled: 28-8-1991  
Slotted PVC interval: 0.0 - 12.0 m  
Top of casing: 10.260 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>medium dark grey/green sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>medium grey/white sand</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>medium grey/brown sand + cinders material</td>
</tr>
<tr>
<td>3.0 - 5.0</td>
<td>medium brown sand</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>medium white sand</td>
</tr>
<tr>
<td>6.0 - 9.0</td>
<td>wet medium grey sand</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>wet medium grey/white sand</td>
</tr>
<tr>
<td>10.0 - 12.0</td>
<td>wet medium white sand</td>
</tr>
</tbody>
</table>
### BORE HOLE EP7

**Location:** East Perth - Corner of Claisebrook and Kensington Street  
**Date drilled:** 28-8-1991  
**Slotted PVC interval:** 0.0 - 12.0 m  
**Top of casing:** 9.085 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>medium yellow sand, brown clay</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>brown clay, medium yellow sand</td>
</tr>
<tr>
<td>2.0 - 4.0</td>
<td>medium yellow sand with cemented clasts</td>
</tr>
<tr>
<td>4.0 - 6.0</td>
<td>grey/brown sandy clay</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>green/yellow clay</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>wet grey clay, fine white/grey clayey sand</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>wet fine white/grey clayey sand</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>wet grey clayey sand</td>
</tr>
<tr>
<td>10.0 - 12.0</td>
<td>wet fine yellow/brown clayey sand</td>
</tr>
</tbody>
</table>

### BORE HOLE EP8

**Location:** East Perth - Corner of Westrail training carpark  
**Date drilled:** 28-8-1991  
**Slotted PVC interval:** 0.0 - 12.0 m  
**Top of casing:** 11.592 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>medium yellow-grey sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>medium dark grey sand with very minor gravel</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>medium grey sand with minor gravel</td>
</tr>
<tr>
<td>3.0 - 5.0</td>
<td>medium grey sand (damp at base)</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>medium brown sand</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>very cohesive grey sandy clay</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>sandy clay (grey grading to a brown/yellow)</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>brown/yellow clay</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>yellow sandy clay, medium yellow sand</td>
</tr>
<tr>
<td>10.0 - 11.0</td>
<td>wet yellow sandy clay, grey clay</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>damp grey/yellow clay</td>
</tr>
</tbody>
</table>
### BORE HOLE EP9

**Location:** East Perth - Water Authority Site  
**Date drilled:** 28-8-1991  
**Slotted PVC interval:** 0.0 - 12.0 m  
**Top of casing:** 4.895 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>dark brown soil, fine-medium brown sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>fine-medium brown sand</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>fine-medium brown sand with tree roots and cement fragments</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>dark brown loam with 10 cm of solid cement</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>medium white sand, grey/yellow clay (slightly sandy and tree roots)</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>grey/yellow clay</td>
</tr>
<tr>
<td>6.0 - 8.0</td>
<td>grey/red clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>grey/yellow clay</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>wet yellow/grey clay</td>
</tr>
<tr>
<td>10.0 - 11.0</td>
<td>wet yellow sandy clay</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>wet grey/white fine-coarse clayey sand</td>
</tr>
</tbody>
</table>

### BORE HOLE EP10

**Location:** East Perth - Water Authority Site  
**Date drilled:** 29-8-1991  
**Slotted PVC interval:** 0.0 - 6.0 m  
**Top of casing:** 1.540 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>brown soil, brown clay, medium yellow sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>brown/grey sandy clay</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>brown clay</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>wet grey clay (slightly sand)</td>
</tr>
<tr>
<td>4.0 - 6.0</td>
<td>wet dark grey clay</td>
</tr>
</tbody>
</table>
BORE HOLE EP11

Location: East Perth - Water Authority Site
Date drilled: 29-8-1991
Slotted PVC interval: 0.0 - 6.0 m
Top of casing: 1.614 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>small amount of medium yellow sand, red/brown clay</td>
</tr>
<tr>
<td>1.0 - 3.0</td>
<td>grey clay with yellow streaks</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>grey sandy clay, medium yellow sand</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>medium yellow sand, wet grey clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>wet yellow sandy clay, wet medium-coarse white sand</td>
</tr>
</tbody>
</table>

BORE HOLE EP12

Location: East Perth - Northeast corner of Haig Park
Date drilled: 29-8-1991
Slotted PVC interval: 0.0 - 12.0 m
Top of casing: 6.651 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>dark brown soil, medium grey sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>medium dark grey wet sand, yellow sandy clay</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>red/brown/yellow clays</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>missing (due to air-core blockage)</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>wet grey sandy clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>brown-yellow clay</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>grey-yellow clay (parts are slightly sandy and indurated)</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>grey/yellow/red clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>grey sandy clay</td>
</tr>
<tr>
<td>9.0 - 11.0</td>
<td>wet yellow clay</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>wet yellow clayey sand, coarse alluvial quartz agglomerate (quartz pebbles up to 3 cm in size)</td>
</tr>
</tbody>
</table>
**BORE HOLE EP13**

Location: East Perth - Southeast corner of Haig Park  
Date drilled: 29-8-1991  
Slotted PVC interval: 0.0 - 12.0 m  
Top of casing: 8.417 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 1.0</td>
<td>medium yellow sand</td>
</tr>
<tr>
<td>1.0 - 2.0</td>
<td>medium white sand</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>medium yellow/white sand</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>white clayey sand (damp)</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>semi-indurated grey sandy clay, red/grey clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>pink/grey clay</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>orange/grey clay</td>
</tr>
<tr>
<td>7.0 - 9.0</td>
<td>brown/yellow clay</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>grey clay (slightly sandy)</td>
</tr>
<tr>
<td>10.0 - 11.0</td>
<td>grey sandy clay, brown clay (both slightly sandy)</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>grey sandy clay, yellow/brown sandy clay</td>
</tr>
<tr>
<td>12.0 - 15.0</td>
<td>grey brown clay (slightly sandy)</td>
</tr>
</tbody>
</table>

**BORE HOLE EP14**

Location: East Perth - Southwest corner of Haig Park  
Date drilled: 29-8-1991  
Slotted PVC interval: 0.0 - 12.0 m  
Top of casing: 8.223 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 2.0</td>
<td>medium pale yellow sand</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>medium pale yellow clayey sand</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>pale yellow sandy clay</td>
</tr>
<tr>
<td>4.0 - 5.0</td>
<td>semi-indurated red/grey clay</td>
</tr>
<tr>
<td>5.0 - 6.0</td>
<td>pink/grey clay</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>fine yellow sand, orange/brown sandy clay</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>brown/yellow-clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>orange/brown clay, grey clay</td>
</tr>
<tr>
<td>9.0 - 10.0</td>
<td>orange/brown clay</td>
</tr>
<tr>
<td>10.0 - 11.0</td>
<td>yellow/brown clay</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>fine-coarse white sand (some quartz grains &gt;2mm)</td>
</tr>
<tr>
<td>12.0 - 13.0</td>
<td>medium-coarse yellow sand</td>
</tr>
<tr>
<td>13.0 - 13.5</td>
<td>more indurated at the base</td>
</tr>
</tbody>
</table>

medium-coarse yellow sand, green/grey clay
BORE HOLE EP15

Location: East Perth - Northwest corner of Haig Park
Date drilled: 29-8-1991
Slotted PVC interval: 0.0 - 12.0 m
Top of casing: 7.110 m (AHD)

<table>
<thead>
<tr>
<th>Depth (mBGL)</th>
<th>Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 2.0</td>
<td>medium grey sand (wet at base)</td>
</tr>
<tr>
<td>2.0 - 3.0</td>
<td>medium grey clayey sand</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>grey sandy clay, yellow sandy clay</td>
</tr>
<tr>
<td>4.0 - 6.0</td>
<td>wet grey clay, yellow clay</td>
</tr>
<tr>
<td>6.0 - 7.0</td>
<td>wet grey/red/yellow clay</td>
</tr>
<tr>
<td>7.0 - 8.0</td>
<td>wet grey clay</td>
</tr>
<tr>
<td>8.0 - 9.0</td>
<td>wet grey clay, fine yellow sand</td>
</tr>
<tr>
<td>9.0 - 11.0</td>
<td>wet yellow/grey clay</td>
</tr>
<tr>
<td>11.0 - 12.0</td>
<td>wet yellow/grey clay (slightly sandy)</td>
</tr>
<tr>
<td>12.0 - 15.0</td>
<td>grey brown clay (slightly sandy)</td>
</tr>
<tr>
<td></td>
<td>more indurated at the base</td>
</tr>
</tbody>
</table>
APPENDIX B

GROUNDWATER ANALYSIS DATA
SAMPLE PREPARATION DETAILS

SAMPLE STATE(S) & SAMPLE PREPARATION(S)

NR

Abbreviations used for Preparation codes:

- CR: Course Pulverise
- FP: Fine Pulverise
- NS: Mix & Split
- QTZ: Quartz Clean Between

Abbreviations used for Sample States:

- CONC: Concentrates
- COST: Costeans
- D/CORE: Drill Core
- PERC: Percussion Chip
- RC: Reverse Circulation
- R/CHIP: Rock Chip
- SOLN: Solutions
- STSRSD: Stream Sediments
- U/CHIP: Vacuum Chip
- V/DRIL: Vacuum Drill

SAMPLE STORAGE OF SOLIDS:

BULK RESIDUES AND PULPS WILL BE STORED FOR 60 DAYS FREE OF CHARGE. AFTER THIS TIME ALL BULK RESIDUES AND PULPS WILL BE STORED AT A RATE OF $1.20/cubic metre/day UNTIL YOUR WRITTEN ADVICE REGARDING COLLECTION OR DISPOSAL IS RECEIVED. EXPENSES RELATED TO THE RETURN OR DISPOSAL OF SAMPLES WILL BE CHARGED TO YOU AT COST.

SAMPLE STORAGE OF SOLUTIONS:

SAMPLES RECEIVED AS LIQUIDS, WATERS OR SOLUTIONS WILL BE HELD FOR 6 WEEKS FREE OF CHARGE THEN DISPOSED OF, UNLESS WRITTEN ADVICE FOR RETURN OR COLLECTION IS RECEIVED.
Please Note.
The pH results for sample pairs CLAISEBROOK EP08A & 08B 040991 and CLAISEBROOK EP09A & 09B 040991 are reported as one value for each pair because the pH had changed substantially during the period taken for analysis. The pH quoted is that determined from one of the pair on receipt of the samples.

Abbreviations Used In Water Analysis Reports.

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<th>Meaning</th>
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<td>PH</td>
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<td>EC</td>
<td>Conductivity (meter) @ 25 degrees C.</td>
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<tr>
<td>TDSEva</td>
<td>TDS ex Evaporation @ 180 degrees C.</td>
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<td>Soluble Iron.</td>
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<td>Carbonate (as CaCO3)</td>
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<td>HC03</td>
<td>Bicarbonate (as CaCO3)</td>
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<td>C1</td>
<td>Chloride</td>
</tr>
<tr>
<td>NO3</td>
<td>Nitrate</td>
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<td>TotPhe</td>
<td>Total Phenols.</td>
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<td>P-Tot</td>
<td>Total phosphorus in solution.</td>
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STD: SOLN 0.54 0.50 0.50 0.48
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**STD: SOLN**
APPENDIX 3

FAECAL COLIFORM COUNTS FOR CLAISEBROOK DRAIN WATERS
<table>
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<tr>
<th>Laboratory</th>
<th>Sender No.</th>
<th>Chlorinated YES/NO</th>
<th>Sample and Location</th>
<th>TOTAL COLIFORMS</th>
<th>FAecal COLIFORMS</th>
<th>FAecal STREPTS</th>
<th>Salmonella AND OTHER RESULTS</th>
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<tr>
<td>015833-1</td>
<td>1</td>
<td>1</td>
<td>Claisebrook Drain 1</td>
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<tr>
<td>015834-2</td>
<td>2</td>
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<td>Claisebrook Drain 4</td>
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LABORATORY COMMENTS.
### Bacteriological Examination

**Environmental Laboratory**

**State Health Laboratory Services**

**Queen Elizabeth II Medical Centre**

**Nedlands, W.A. 6009**

**G.P.O. Box F312, Perth, W.A. 6001**

**Telephone: 380 1122 Ext. 2168**

---

**Sender's Authority and Address for Report**

**ALAN TINGAY & ASSOCIATES**

**35 Labouchere Road, SOUTH PERTH 6151**

**Routine Tests**

- [ ] COLIFORMS
- [ ] FAECAL STREPTS
- [ ] SALMONELLA

**Other Tests**

See over for instructions on sampling and despatch.

Date Collected: 28/11/91

Signed:

---

**Senders Comments**

---

**Sample Details**

<table>
<thead>
<tr>
<th>No.</th>
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<th>Sample and Location</th>
<th>Laboratory Report</th>
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<tr>
<td>081963</td>
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<td><strong>WASSE BROOK SEWAGE</strong></td>
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</tr>
<tr>
<td>081969</td>
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<td></td>
<td></td>
<td>19200</td>
</tr>
<tr>
<td>081970</td>
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<td>7400</td>
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<td>081971</td>
<td>4</td>
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<td>7300</td>
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**Laboratory Report**

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<th>Total COLIFORMS</th>
<th>Faecal COLIFORMS</th>
<th>Faecal STREPTS</th>
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<tr>
<td><strong>WASSE BROOK SEWAGE</strong></td>
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</table>

**Laboratory Comments:**

For same-day process, samples should arrive at the laboratory no later than 15.00 hrs.

Signed: **RC**

**Date Received:** 29 Nov 1991

**Date Reported:** 3/12 A1
### Bacteriological Examination of Natural Waters, Sewerage Drainage and Effluents

**Environmental Laboratory**  
State Health Laboratory Services  
Queen Elizabeth II Medical Centre  
 Nedlands, W.A. 6009  
G.P.O. Box F312, Perth, W.A. 6001  
Telephone: 380 1122  Ext. 2168

**Sender's Details**  
**Authority and Address for Report:**  
**Procedure:**
- **Routine:** COLIFORMS ☑  FAECAL STREPTS ☐  SALMONELLA ☐  
- **Other Tests:** See over for instructions on sampling and despatch

**Sample Details**

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<th>Sample No.</th>
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<td>180598</td>
<td>2</td>
<td>Yes</td>
<td>Location 2</td>
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<td>180599</td>
<td>3</td>
<td>Yes</td>
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<td>26.100 1900</td>
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<td>180600</td>
<td>4</td>
<td>Yes</td>
<td>Location 4</td>
<td>11.700 600</td>
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**Laboratory Comments:**

**Date Received:** 22 Oct 1991  
**Date Reported:** 28 Oct 1991
**BACTERIOLOGICAL EXAMINATION**
**OF**
**NATURAL WATERS, SEWERAGE**
**DRAINAGE AND EFFLUENTS**

**ENVIRONMENTAL LABORATORY**
State Health Laboratory Services
Queen Elizabeth II Medical Centre
 Nedlands, W.A. 6009
G.P.O. Box F312, Perth, W.A. 6001
Telephone: 380 1122 Ext. 2168

**SENDER'S AUTHORITY AND ADDRESS FOR REPORT**
ALAN TINGAY AND ASSOC.
ATTN. SCOTT BIRD
25 Labouchere Rd
SOUTH PERTH

**SENDER'S COMMENTS**

---

**SAMPLE DETAILS**

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<th>COLIFORMS</th>
<th>Fecal Strepts</th>
<th>Salmonella</th>
<th>OTHER TESTS</th>
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<td>Claise Brook Draw (Near SW Rd)</td>
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**LABORATORY REPORT**

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**LABORATORY COMMENTS:**
911573

**RE RECEIVED:** 12/6/91

**SIGNED:** K.C.

**DATE REPORTED:** 27/9/91
APPENDIX 4

SELECTED DRILL LOGS FROM
EAST PERTH GASWORKS SITE
Bitumen, Road Base
Brown, medium grained, quartz sand with traces of burnt coal.

Core Sample Slight odour at contact.
H1001
Yellow/grey, well sorted, quartz sand
Groundwater at 1.9m - 2.0m

Auger sample Slight odour
H1002
Grey, medium grained quartz sand.
No odour

Grey, medium grained quartz sand.
No odour

ALAN TINGAY
35 LABOUCHERLE
SOUTH PERTH 61
Depth (m) | H2 | Description
--- | --- | ---
0 | 0 | Topsoil, Cement Slab
0.1 | | Yellow, medium grained, quartz sand
1.6 | | Brown sandy clay with quartz sand.
1.9 | | Yellow, medium grained, quartz sand
2.8 | | No odour.
| 5.3 | Groundwater reached at 3.0m.
| | Brown sandy clay with coarse sand
| | Medium grained quartz sand in brown clay.

ALAN TINGAY & ASSOCIATES
35 LABOUCHERE ROAD,
SOUTH PERTH 6151
Depth (m) | H4
---|---
0 | Yellow, medium grained, quartz sand
0.1 | Brown, medium grained, quartz sand
No odour.
1.95 | Hard layer possibly rubble, lumps of granite, concrete
Groundwater reached at 2.3m
3.8 | No odour.
Clayey grey quartz sand
No auger returns thus hole ended
5.3 |
Depth (m)

0.0

0.1

0.2

H5001

Auger Sample

0.6

1.3

2

2.8

6.8

Description

Bitumen and roadbase at surface
Black coal, burnt and unburnt.

Dark brown, medium grained quartz sand and minor rubble.

Yellow, well sorted, quartz sand, and minor rubble.

Cream, medium grained, quartz sand

Groundwater reached at 2.0m

Yellow/brown medium grained quartz sand
No odour.

Grey, coarse grained, quartz sand.
Depth (m) | Description
---------|-----------------
0        | Auger Sample H6001
0.3      | Road and road base gravel.
0.4      | Black burnt coal layer.
0.6      | Gravel and dark grey quartz sand and brick rubble.
2        | Dark grey, coarse grained, quartz sand.
2.3      | Yellow/grey, medium grained, quartz sand.
3        | Yellow/brown, medium grained, quartz sand.
            | Sand smells "Acidic".
4.5      | Light grey/brown clayey coarse quartz sand.

Groundwater reached at 3.3m.

Light grey sandy quartz clay.
Description

Dark brown top soil.

Grey, medium grained, quartz sand.

Orange sandy clay with coarse quartz sand.

Odour

White sandy clay with coarse quartz sand. Groundwater reached at 2.5m.

Grey quartz sand, minor clay.

Cream grey/brown coarse quartz sand and clay.

Napthalene smell

Grey sandy clay.

ALAN TINGAY & ASSOCIATES
35 LABOUCHERE ROAD,
SOUTH PERTH 6151
0
Auger
Sample
H8001

0.5

1.3

2.3

Depth (m) H8

Description

Bitumen
Black sand stained with burnt and unburnt coal, minor amounts of brick with weak to moderate odour.

Brown sandy clay becoming sandier and greyer. Very weak odour.

Dark grey sand no stain, no odour.

Sandy grey clay, clay more abundant at depth.

Slight odour in wet sample

ALAN TINGAY & ASSOCIATES
35 LABOUCHERE ROAD
SOUTH PERTH 6151
Description

Bitumen

Stained black sand, burnt and unburnt coal.
Brown sandy clay becoming sandier

Orange/brown, well sorted, medium grained quartz sand

Orange sandy clay.
Ground water reached at 2.0 m

Orange sandy clay, slight odour.
APPENDIX 5

WATER CIRCULATION AND EXCHANGE STUDY
CLAISEBROOK INLET
EAST PERTH PROJECT
CLAISEBROOK INLET WATER QUALITY

Prepared by:

Kinhill, Riedel & Byrne
ACN 007 660 317
47 Burswood Road, Victoria Park, WA 6100
Tel (09) 362 5900; Fax (09) 362 5627

January 1992
PE1109
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<td>2 THE FLUSHING PROCESS</td>
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<tr>
<td>2.1 Tidal exchange</td>
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<td>2.2 Density currents</td>
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<td>2.3 Wind induced exchange</td>
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<td>3 FIELD PROGRAMME</td>
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<td>3.1 Measured data and analysis</td>
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<td>4 EXCHANGE RATES</td>
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<td>4.1 Calculation of flushing due to tidal exchange</td>
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### APPENDICES

A Spring Tide Field Trip Data

B Neap Tide Field Trip Data

C Drogue Velocity Data
1 INTRODUCTION

The East Perth Project (EPP) is a State Government initiative aimed at rejuvenating a large area of industrial land close to the Perth CBD, by transforming it into a new urban village. It is the largest urban renewal project ever undertaken in Western Australia.

As part of the project it is proposed to construct an inlet off the Swan River, around which both commercial and residential lots will be developed. The site locality is shown in Figure 1.1.

In August 1991, Kinhill Riedel & Byrne (Kinhill) were engaged to undertake an analysis of potential water exchange mechanisms and flushing rates within the proposed inlet.

Field trips were undertaken on 24/25 September and 25/26 October 1991 corresponding to neap and spring tide events respectively. The study included the field measurement of tides, tidal currents, salinity and temperatures within the Swan River adjacent to the proposed site.

The proposed development is shown in Figure 1.2.
2 THE FLUSHING PROCESS

The following mechanisms are likely to result in the exchange of water between the proposed inlet and the Swan River:

- Tidal exchange which occurs at least once a day.
- Density currents driven by salinity and temperature differences between the inlet and the Swan River.
- Wind induced surface currents mobilized by shear stress created by wind passing across the water.
- Density currents due to groundwater inflow.
- Flood flows from the Claisebrook drain.

2.1 TIDAL EXCHANGE

The Swan River is tidal as far up as Midland.

The tidal range of Barrack Street is almost the same as that at Fremantle.

<table>
<thead>
<tr>
<th>Tide Type</th>
<th>Value</th>
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<tr>
<td>Highest Astronomical Tide (HAT)</td>
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</tr>
<tr>
<td>Mean Higher High Water (MHHW)</td>
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</tr>
<tr>
<td>Mean Sea Level (MSL)</td>
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</tr>
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<td>Mean Lower Low Water (MLLW)</td>
<td>0.5</td>
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<tr>
<td>Lowest Astronomical Tide (LAT)</td>
<td>0.2</td>
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</table>

For all intents and purposes, the tidal range in the river opposite the proposed Claisebrook inlet is the same as Barrack Street.

On average, the tidal range each day is about 0.3 to 0.4 m.

The influence that the variation in water levels have on flushing depends to a large extent on the patterns of flow that are set up. For example, if stratified conditions have established due to a density differential then the tidal movements can provide head variations which will result in significantly greater exchange than under non stratified conditions.
2.2 DENSITY CURRENTS

The incoming and outflowing tidal action can produce stratified conditions as salt water is introduced from the ocean during flood tides and then fresh water from up river during ebb tides. Salt water has a different density to fresh water. This difference in density can drive currents until the conditions within the river and inlet are equalized. This significantly assists in water exchange and circulation.

Turner (1973) suggested that flow velocities may be estimated from density intrusions using the following formula:

\[ U = 0.5 \left( \frac{A\rho}{\rho} gd \right)^{0.5} \]

Where:

- \( \rho \) = density of layer
- \( g \) = acceleration due to gravity
- \( d \) = depth of waterbody.

The Swan River adjacent to the proposed development is tidal. During the flood tide a wedge of dense seawater travels upstream along the bottom of the river displacing the less dense fresh water. During the ebbing tide the wedge retreats downstream.

The effect of tidal exchange and density currents are shown in Figure 2.1. At time \( t = 0 \) the water in both the river and inlet will be of similar density and well mixed.

At \( t = 1 \) the tide is flowing up the river. A wedge of seawater is travelling along the bottom of the river and has reached the entrance of the inlet. The seawater wedge then enters the inlet by two means, by tidal exchange and by density currents due to the head present at the inlet entrance.

The seawater wedge travels to the end of the inlet. At \( t = 2 \), 50% of the inlet water has been exchanged by the river water. When the tide turns, the seawater wedge retreats downstream. The wedge flows out of the inlet and is replaced by fresh water from upstream. Therefore exchange takes place during the inflowing and outflowing tidal action.

2.3 WIND INDUCED EXCHANGE

Wind induced currents are known to be a very important source of mixing and water exchange in canal estates and harbours. There are many waterway developments for example in the south of France where the tidal range is virtually zero and yet water quality is maintained by wind circulation.
Time $t = 0$

River and inlet have similar profiles

$t = 1$

Seawater wedge travels upstream with tide

$t = 2$

Head differences drive density currents into inlet

$t = 3$

Seawater wedge travels downstream with tide

Figure 2.1

DENSITY CURRENTS
A number of researchers have examined the relationship between wind and surface currents (Wu, 1973; Bishop, 1979; Shemdin, 1972) and the general agreement is that the surface current is between 2–5% of the wind speed. Bishop suggests the most appropriate value is 3.5%. The magnitude of the current decreases rapidly with depth and in a closed end water body a reverse current of equal mass flow forms to preserve the conservation of mass. The forward flow is theoretically limited to the top one third of the water column. McKeehan (1975) presents the following formula to relate the current magnitude and direction to depth below the water surface:

\[ U(z) = U_s (1 - 4z/h + 3(z/h)^2) \]

Where:
- \( U(z) \) = water velocity at depth \( z \)
- \( U_s \) = water velocity at the surface
- \( z \) = distance below the surface
- \( h \) = total depth of water flow

The velocity profile correspondent to the above equation is shown in Figure 2.2.

![Figure 2.2](image)

**WIND INDUCED VELOCITY PROFILE**

The inlet is aligned with the predominant East–North-east, West–South-west wind corridor that is illustrated in the analysis of Perth wind records shown in Figure 4.1.

The winds blowing along the inlet will set up surface currents and a return flow along the bottom of the canal resulting in significant exchange with the river.
2.4 GROUNDWATER INFLOW

It is anticipated that fresh groundwater will flow into the inlet each day. The freshwater will mix with the more saline water in the inlet, which could result in a density difference between the inlet and Swan River. This head difference will produce currents which will aid in the mixing process.

The volume of groundwater inflow into the inlet has been estimated by mathematical modelling to be in the order of 140 m$^3$ per day. As the inlet has a volume of approximately 54,000 m$^3$ the contribution to mixing expected by groundwater inflow is therefore likely to be very small when compared to other processes.

2.5 FLOWS FROM CLAISEBROOK DRAIN

The Claisebrook Drain has as its catchment much of the Perth area and up as far as Morley Drive and Grand Promenade including residential and commercial zones. The average flows are as follows:

- summer base flow 0.07 cumec or 6,048 m$^3$/day
- winter base flow 0.12 cumec or 10,368 m$^3$/day
- general rainy flow 4 cumec or 345,600 m$^3$/day.

Flood flows:

- 1 in 1 year 10 cumec
- 1 in 10 year 17 cumec
- 1 in 100 year 27 cumec.

During periods of general rainy flow the Claisebrook Drain will discharge up to seven times the volume of the inlet within a 24 hour period. During low flows the differences in temperature and salinity between the inflow and Swan River will result in density currents and assist water exchange and circulation. This will result in significant exchange with the Swan River.

2.6 EXCHANGE RATES

The total exchange which might be expected at any one time is a combination of the above components.

The aim of the field programme was to identify and if possible quantify the contribution from each of the dominant mechanisms to the flushing of the proposed inlet.
A field program was undertaken during September and October 1991. Tides, currents, salinity and temperatures were measured in the Swan River adjacent to the proposed inlet. The data was collected over one complete neap tide cycle and one complete spring tide cycle (24/25 September 1991 and 25/26 October 1991 respectively).

Each of the parameters were measured at approximately one hour intervals. The location of the six sampling sites are shown on Figure 3.1.

Contributions to flushing from each exchange mechanism can vary throughout the year. For the flushing characteristics of the proposed inlet to be determined from the data obtained by the field trips, it was necessary to establish the impact of each mechanism on
exchange. The field program therefore needed to measure a number of parameters including currents, salinity, temperature and tides. Field notes were also kept of the estimated wind strength and direction.

Current measurements using drogues were used to measure current velocity at different depths. The drogues consisted of a 50 mm diameter standard fishing float attached by line to a 200 mm x 200 mm poly carbonate cross. The line was adjustable to various depths.

Salinity and temperature data were measured using a Yeo–Kal Hamon model 602 Mk II salinity–temperature bridge. The probe was lowered to give a vertical profile at each location.

3.1 MEASURED DATA AND ANALYSIS

3.1.1 SALINITY, TEMPERATURE AND DENSITY

Salinity and temperature measurements were taken at each site at approximately one hour intervals for both the spring and neap tide events.

The density of water is dependent on both its temperature and salinity. The density at different levels within the water column were determined using a method described by Fisher (1979).

Figure 3.2 shows the variation of salinity, temperature and density with time at Site 1 for the spring tide event.

From the figure, it can be seen that the salinity showed a definite trend over the period of measurement. From 08:00 a.m. to 10:00 a.m. on the 25 October, the probe recorded similar salinities for both the top and bottom of the waterbody indicating that the river water was well mixed. As the tide commenced to flood a more saline seawater wedge travelled upstream, along the bottom of the river. This tidal action caused stratification which is clearly seen between 10:00 a.m. on the 25 October and 08:00 a.m. on the 26 October. The stratification decreased as the tide ebbed and the seawater wedge retreated downstream. After 08:00 a.m. the probe recorded similar magnitudes for both the top and bottom of the waterbody, indicating that, once again, the river was well mixed.

From the temperature graph it can be seen that the upper probe indicated quite a range in temperature over the measurement period, while the bottom probe indicated more constant results. The upper portion of the waterbody was influenced by heating and cooling at the water surface. This resulted in a water temperature increase during the day and decrease at night as the air temperature varied. The lower portion of the waterbody was not affected to such an extent by the surface temperature changes, and therefore showed less variance in temperature.
Figure 3.2
SITE 1 — SPRING TIDE

DATE: 25 / 26 October
During the period of measurement, the density trends appear to be largely due to changes in salinity, not temperature. From Figure 3.2 it can be seen that the density increases and decreases with the change in salinity.

Plots showing the variation of salinity, temperature and density with time for all spring tide sampling sites are provided in Appendix A.

Figure 3.3 shows the variation of salinity, temperature, and density with time at Site 5 for the neap tide event.

For the neaps the changes in salinity and temperature are not as pronounced as for the spring tide event. It can be seen that stratification was established with the incoming tides during the periods of 06:00 p.m. to 11:00 p.m. on the 24 October, and 08:00 a.m. to the end of the measurement period on the 25 September. The differences in density between the top and bottom of the river are significantly lower than for the spring tides but are still sufficient to establish density currents which contribute greatly to flushing of the proposed inlet.

Plots for the other sampling sites for the neap tide event are provided in Appendix B.

3.1.2 WATER LEVELS

The tidal patterns are shown graphically in Figures 3.2 and 3.3 for the spring and neap tide events respectively. The tide measurements for the neap tide event were obtained from Mackie Martin & Associates. For the spring tide event a tide pole was established by Kinhill using a known datum.

3.1.3 WATER VELOCITIES

Drogues were used to measure currents at different levels within the water column. The results are shown in Appendix C. Figure 3.4 shows the current velocity at Sites 1 and 4 for the spring tide event. At one instance the shallow drogue travelled downstream at 0.1 m/sec while the deeper drogue travelled upstream at 0.13 m/sec, thus indicating two layer flow occurred in the river.

3.1.4 WIND VELOCITIES

For the neap tide event the weather conditions were fine. There was no wind during the night and light winds during the day with a maximum velocity between 5 and 10 knots.

For the spring tide event winds were once again light with a maximum velocity of less than 10 knots.
Figure 3.3
SITE 5 — NEAP TIDE
Figure 3.4

VELOCITY MEASUREMENTS — SPRING TIDE
4 EXCHANGE RATES

4.1 CALCULATION OF FLUSHING DUE TO TIDAL EXCHANGE

During the twenty-four hour measurement of the spring tide event a single tidal cycle was observed. The tidal range was measured to be approximately 0.5 m.

For the neap tide event two tidal cycles were observed during the twenty-four hour period. The tidal ranges were approximately 0.2 m and 0.15 m respectively.

The exchange co-efficient due to tidal currents may be calculated as follows:

\[ \text{Exchange co-efficient} = \frac{\text{tidal range}}{\text{average depth}} \times \frac{100}{1} \]

The calculated exchange for the 2 m deep inlet is shown in Table 4.1.

<table>
<thead>
<tr>
<th>Tide event</th>
<th>Tidal range</th>
<th>Exchange rate/tide cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring tide</td>
<td>0.5 m</td>
<td>25%</td>
</tr>
<tr>
<td>Neap tide</td>
<td>0.2 m</td>
<td>10%</td>
</tr>
<tr>
<td>Neap tide</td>
<td>0.15 m</td>
<td>7.5%</td>
</tr>
</tbody>
</table>

It is expected that between 17% and 25% of the water in the inlet will exchange with the Swan River each day.

4.2 CALCULATION OF FLUSHING DUE TO DENSITY CURRENTS

4.2.1 SPRING TIDE

The field measurements indicated that the river was stratified for the majority of the sampling period. This stratification was caused by a wedge of more dense seawater travelling upstream past the site on the flood tide.
Mixing of the proposed inlet will be greatly enhanced by density currents. These currents will be established due to a head difference between the seawater wedge and the water in the inlet, and exist for the duration of the head difference.

Using the method described in Section 2.2, and making an allowance for friction, the velocity of the density currents were calculated to be 0.05 m/sec. With this velocity the seawater wedge would enter the inlet and displace half the water over a period of approximately 5 hours. This will occur as long as the head difference is present for this period of time.

From the data presented in Appendix A it can be seen that the seawater wedge would be present at the entrance of the proposed inlet for a period of in excess of 5 hours, thus providing the head difference required for the flushing process.

Once the more dense seawater wedge has occupied the bottom half of the inlet waterbody, the head difference between the river and inlet would no longer exist. That is, the river and inlet water would have similar density stratification.

As the tide ebbs, the seawater wedge will retreat out of the inlet and downstream from the site. Fresh water from upstream will flow into the inlet to replace the seawater wedge. Hence the waterbody in the inlet should totally exchange with the Swan River over a period of one tide cycle, or one day, while spring tide conditions exist.

4.2.2 NEAP TIDE

The duration of the salt wedge at the entrance and the difference in density are less during neap tides than at springs. The head difference at the entrance of the proposed inlet would be sufficient to produce density currents of 0.01 m/sec.

It has been calculated that during the one day measurement period approximately 60% of the inlet water would exchange with the Swan River due to density currents. Section 4.1 indicates that 17% of the inlet water would be exchanged due to tidal exchange. Therefore, it is anticipated that while neap tide conditions exist, total exchange of the inlet with the Swan River will occur within a period of between 1 and 2 days.

4.3 TIDAL EXCHANGE AND DENSITY CURRENTS – DISCUSSION

Analysis of the field trip data indicated an exchange rate of 1 day for the spring tide event and 1 to 2 days for the neap tide event.

The field trips were undertaken in September/October. The relatively low salinities measured indicate that during the winter months the Swan River is very fresh. Previous investigations undertaken on the Swan River at Maylands (KRB May 1991) indicate that the river is much more saline at the end of summer. It can be expected that the incoming tidal seawater will always be more saline than that encountered in the river. As the density current velocity is dependent on the difference in density between the layers and
not on the magnitude of density, similar exchange rates can be expected during the summer months.

Except when broken up by strong winds, stratification, and therefore exchange, due to density currents can be expected in the proposed inlet throughout the year. The density differences will arise mainly because of the differing salinities between the inlet and the Swan River, largely produced by the daily tidal process in the Swan River. Differences in water temperature throughout the water column, although less important than salinity, will enhance stratification and therefore exchange.

It is therefore anticipated that total exchange will occur within 1 day during periods of spring tides throughout the year. Exchange should occur within 2 days for neap tides throughout the year.

4.4 WIND INDUCED EXCHANGE

Wind blowing from the west or south-west will cause a surface current to flow out of the proposed inlet and a bottom current bringing 'fresh' water into the inlet from the Swan River. With an easterly blowing the reverse will be the case. 'Fresh' water from the Swan River will be brought in at the surface and inlet water will flow into the river in the bottom two thirds of the canal (as shown in Figure 2.2).

An analysis has been undertaken of the 14 years of wind records available for nearby Perth Airport. The analysis is presented graphically in Figure 4.1. It is apparent that for all seasons in the year there is a very strong preponderance of wind from the southwest-westerly sector and east-northeasterly sector. For over 70% of the time the wind is blowing along the axis of the inlet helping to exchange the water with that in the Swan River. The records also indicate that the wind is quite strong, the vast majority of the time between 10 and 30 km/h. About 60% of the time winds are in the east-west corridor and greater than 10 km/h. Analysis of wind records at Cockburn Sound, Steedman (1979) indicated that a maximum calm period (wind speed < 5 km/h) of 16 hours could be expected to occur about once every year.

The proposed buildings on site and the hill at Plain Street can be expected to shield the site to some extent from the westerly and south-westerly winds and so the amount of flushing from this direction will be less than might be predicted from the Perth Airport winds. The duration of calms could also be expected to be larger inland compared to measurements at Cockburn Sound.

Based on the work done by Bishop and McKeehan and using an average wind speed of 10 km/h, the whole of the water within the inlet could be expected to be exchanged with river water within two to three days.
5 CONCLUSIONS

The field measurement programme and associated flushing study has indicated that good exchange rates will be maintained between the proposed inlet and Swan River at all times.

The anticipated exchange times for the various mechanisms are shown in Table 8.1. It should be noted that the density currents and tidal variations will occur concurrently during periods when stratification occurs.

The diurnal salinity and temperature variations in the Swan River associated with tidal flow will generate significant density flows at most times. Strong winds will occasionally result in a breakdown of stratified flow but will generate wind induced flows of similar magnitude.

It is apparent that water exchange between the proposed inlet and the Swan River will remain high throughout the year.

Table 8.1 Exchange rates

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<tr>
<th>Event</th>
<th>Mechanism</th>
<th>% of inlet water exchanged by mechanism/day</th>
<th>Exchange time (day)</th>
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</thead>
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<td>tidal exchange</td>
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<td>1</td>
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<tr>
<td></td>
<td>density currents</td>
<td>75</td>
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</tr>
<tr>
<td>Neap tide</td>
<td>tidal exchange</td>
<td>17</td>
<td>2</td>
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<tr>
<td></td>
<td>density currents</td>
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</tr>
<tr>
<td>High winds</td>
<td>tidal exchange</td>
<td>17→25</td>
<td>2→3</td>
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<tr>
<td></td>
<td>density currents</td>
<td>negligible*</td>
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</tr>
<tr>
<td></td>
<td>wind currents</td>
<td>40→50</td>
<td></td>
</tr>
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</table>

* High winds can result in breakdown of stratified flow.
6 REFERENCES


Appendix A
SPRING TIDE FIELD TRIP DATA
DATE: 25 / 26 October 1991

SPRING TIDE LEVELS
SITE 1 SPRING TIDE

DATE: 25 / 26 October 1991
DATE: 25 / 26 October 1991

SITE 2 SPRING TIDE
SALINITY

TEMPERATURE

DENSITY

- MID DEPTH
DATE: 25 / 26 October 1991

SITE 3 SPRING TIDE
SITE 4 SPRING TIDE

DATE: 25 / 26 October 1991
SITE 5 SPRING TIDE

DATE: 25 / 26 October 1991
SALINITY

TEMPERATURE

DENSITY

DATE: 25 / 26 October 1991

SITE 6 SPRING TIDE
DATE: 24 / 25 September 1991

NEAP TIDE LEVELS
SALINITY

TEMPERATURE

DENSITY

SITE 1 NEAP TIDE

DATE: 24 / 25 September 1991
SALINITY

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<th>18:00</th>
<th>22:00</th>
<th>02:00</th>
<th>06:00</th>
<th>10:00</th>
<th>14:00</th>
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<td>Salinity (ppm)</td>
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TEMPERATURE

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DENSITY

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- BOTTOM - TOP

DATE: 24 / 25 September 1991

SITE 2 NEAP TIDE
SITE 3 NEAP TIDE

DATE: 24 / 25 September 1991
SALINITY

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TEMPERATURE

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DENSITY

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<td>14:00</td>
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</table>

DATE: 24 / 25 September 1991

SITE 4 NEAP TIDE
SITE 5 NEAP TIDE

DATE: 24 / 25 September 1991
SALINITY

TEMPERATURE

DENSITY

SITE 6 NEAP TIDE

DATE: 24 / 25 September 1991
EAST PERTH PROJECT WATER QUALITY

Spring Tide Event 25/26 October 1991

Measured Current Velocity

+ upstream  
- downstream  

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EAST PERTH PROJECT WATER QUALITY

Spring Tide Event 25/26 October 1991

Measured Current Velocity

+ upstream  
- downstream  

T top  
B bottom

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EAST PERTH PROJECT WATER QUALITY

Neap Tide Event 24/25 September 1991

Measured Current Velocity

+ upstream  T  top
- downstream  B  bottom

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## EAST PERTH PROJECT WATER QUALITY

Neap Tide Event 24/25 September 1991

Measured Current Velocity

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