Problem	General characteristics	When and what to check
Landslide	Mass movement of soil or rock from slopes and valley walls around the storage	During routine inspection - look for material displacement
Movement or cracking in structural concrete work	Failure of mechanical components such as pipes, gates etc	During routine inspection or when mechanical problems such as a burst pipe or a jammed gate occur - look for any movement or cracking of the structural concrete work to determine the cause
Failure of appurtenant structures or operating equipment	Loss of ability to supply water or discharge floods safely	After detecting an operational anomaly - identify and investigate the cause
Abnormal instrument readings (if installed)	A sudden change in the values of instrument readings	On detection - check for equipment malfunction and investigate the cause
Algal blooms	Blue green opaque nature of near surface and shallow water	During routine inspections particularly in the summer months - look for rapid colour change of the storage to a blue green opaque nature
Chemical spills	Dead fish and other aquatic life in storage, or a strange odour or colouration	On detection - identify and investigate the cause

In the event of such problems occuring it may be appropriate for more detailed inspections by properly qualified dams engineers. If the problems are likely to cause failure of the dam and loss of storage, the Emergency Action plan should be activated.

9. Dam Failure Inundation Map

- Dam failure inundation maps should be developed at a scale sufficient to be used for identifying downstream-inhabited areas within the area subject to possible danger.
- Inundated areas should be clearly identified.
- It may be appropriate to supplement the inundation on the maps with water surface profiles showing the elevation before failure, the peak water surface elevation after failure, and the location of structures at critical locations.
- A narrative description of the areas affected by the dam break can be included to clarify unusual conditions.
- The best available topographic map should be used. The expected inundation following the assumed failure should be delineated on the map.

- The accuracy and limitation of the information supplied on the inundation maps and how best to use the maps should be described.
- Inundation maps should be updated periodically to reflect changes in downstream areas.
- Include any other pertinent information as a result of coordination with the appropriate emergency management authorities.

10. Any other charts, rating tables, considered by the dam owner as necessary

Other charts and rating tables may include charts developed in the hydrological analysis for the dam or during spillway design.

9.5 Emergency Event Report

Following an emergency, an Emergency Event Report should be completed which contains:

- a description of the event
- instrumentation readings (where appropriate)
- description of any observed damage
- photographs
- the EAP
- details of communication which took place during the emergency
- comment on the adequacy of the EAP
- any recommendations or suggested changes to the EAP.

Dam owners have the responsibility for implementing the recommendations contained in the Emergency Event Report. Comprehensive inspections and ultimately audits undertaken by the Regulator, will evaluate the dam owners response to Emergency Event Reports.

9.6 Counter Disaster Plan

The Department of Emergency Services controls counter disaster coordination and planning in Queensland. If an emergency occurs with a dam which will constitute a disaster, the State Emergency Service will be in charge of the community response including the evacuation of residents. Counter Disaster Plans should be linked to the EAPs prepared for each dam. Dam owners should co-operate with the Disaster District Agencies (DDCC and LGCDC) and the community when preparing Counter Disaster Plans.

For further information on Counter Disaster Plans, refer to Guide 7 of Emergency Management Planning for Floods Affected by Dams published by Emergency Management Australia.

9.7 Testing and Reviewing

To ensure EAPs are kept up to date and effective, they need to be maintained by:

- Testing

  EAPs should be tested periodically by conducting a drill simulating emergency conditions (exercises). Such tests can be either field or desk top exercises and are used to refresh and train those likely to be involved if an event occurs.

Operational staff at dams should participate in exercises annually. Larger scale exercises involving coordination between the Counter Disaster Agencies and other authorities should be conducted at least every five years.

- Updating the EAP

A periodic review of the overall plan should be conducted to assess its workability and efficiency (ie timeliness), and to plan for the improvement of weak areas. For example, telephone contact details should be reviewed and updated at least on an annual basis.

The EAP should be reviewed for adequacy at least every five years as part of the comprehensive 5 yearly inspection.

Once the EAP has been revised, the updated version (or the affected pages) should be distributed to all involved parties. The distribution of copies of the EAP and the notification flowchart (if issued separately) must be controlled and documented to ensure simultaneous updating of all copies. Updates should be made promptly. In addition, it is recommended that the entire EAP is reprinted and distributed to all parties at least every 5 years.

10 Decommissioning

10.1 Introduction

When a dam is no longer needed, the dam owner may:

- arrange for the transfer of ownership and associated responsibilities to another party
- decommission the dam.

10.2 Decommissioning

A decommissioned dam is a dam where parts of the structure are removed or otherwise modified to make it incapable of storing water, either temporarily or permanently.

The extent of modification required for the safe decommissioning of a dam should be assessed by an experienced dams engineer and may include:

- effective removal of part of the main wall
- permanent enlargement or opening of the outlet works
- lowering of the spillway crest
- removal of spillway, control gates or stopboards
- excavation of a diversion channel through an abutment.

10.3 Dam Safety Decommissioning Plan

When decommissioning a dam, owners should prepare a dam safety decommissioning plan, which outlines the proposed action to be taken to decommission the dam. The dam safety decommissioning plan should:

- include a time sequence of studies and works associated with the decommissioning
- address all dam safety issues associated with the decommissioning including:
  - show impacts of sudden loss of remaining embankments or other dam sections for a range of flood events in compliance with the Guidelines for Failure Impact Assessments of Water Dams
  - provision for safe release of stored water
  - assessment of altered hydraulic character of spillways and streams
  - provision to minimise impact on downstream residents
  - provision for consultation with downstream residents and landholders.

In addition to dam safety issues there are numerous environmental, economic and social issues to be considered when decommissioning a dam. The owner should determine the requirements of the Environment Protection Agency (EPA) when planning the decommissioning of any dam.

Appendix 1
Abbreviations and Definitions

Abbreviations

ANCOLD	Australian National Committee on Large Dams
AFC	Acceptable Flood Capacity
DDC	Disaster District Co-ordinator
DDDC	Disaster District Co-ordination Committee
DOC	Designer's Operating Criteria
DOMM	Detailed Operating and Maintenance Manual
EAP	Emergency Action Plan
FSL	Full Supply Level
IFF	Imminent Failure Flood
LGCDC	Local Government Counter Disaster Committee
NR&M	Department of Natural Resources and Mines
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RPEQ	Registered Professional Engineer (Queensland)
SOP	Standing Operating Procedures

Definitions

Abutment: That part of the valley side against which the dam is constructed.

Annual exceedance probability: The probability of a specified event being exceeded in any year.

Appurtenant Works: All ancillary structures of a dam including, but are not limited to, spillways, inlet and outlet works, tunnels, pipelines, penstocks, power stations and diversions.

Catchment: The land surface area, which drains into a dam or to a specific point.

Category 1 failure impact rating: A category of referable dam under *Water Act 2000*. The population at risk has been determined as between 2 and 100 persons inclusive.

Category 2 failure impact rating: A category of referable dam under *Water Act 2000*. The population at risk has been determined as greater than 100 persons.

Chief Executive: Chief executive of the Government Department (Qld) responsible for administering the dam safety provisions of the *Water Act 2000*. At the time of writing this was NR&M.

Collapse: The physical deformation of a structure to the point where it no longer fulfils its intended function.

Controlled Document: A document subject to managerial control over its contents, distribution and storage.

Dam:
(a) works that include a barrier, whether permanent or temporary, that does or could or would impound, divert or control water and
(b) the storage area created by the works. The term includes an embankment or other structure that controls the flow of water and is incidental to works mentioned in (a).

The term does not include the following -

- A rainwater tank
- A water tank constructed of steel or concrete or a combination of steel or concrete
- A water tank constructed of fibreglass, plastic or similar material

Dams Engineer: An engineer who is suitably qualified and experienced and who is recognised by the engineering profession as experienced in the engineering of dams.

Decommissioned Dam: A dam that has been taken out of service and which has been rendered safe in the long term.

Designers Operating Criteria (DOC): Comprehensive operating criteria, which stress the designers, intended use and operation of equipment and structures in the interest of safe, proper, and efficient use of the facilities.

Emergency: An emergency in terms of dam operation is any condition, which develops unexpectedly, endangers the integrity of the dam and requires immediate action.

Emergency Action Plan (EAP): A continually updated set of instructions and maps to deal with emergency situations or unusual occurrences at dam.

Failure (Dam):

- the physical collapse of all or part of the dam or
- the uncontrolled release of any of its contents.

Flood Control Dam: A dam which temporarily stores or controls flood runoff and includes dams used to form flood retarding basins.

Foundation: The undisturbed material on which the dam structure is placed.

Freeboard: The vertical distance between a stated water level and the lowest level of the non overflow section of the dam.

Full Supply Level (FSL): Means the level of the water surface when the water storage is at maximum operating level when not affected by flood.

Height of Dam: Means the measurement of the difference in level between the natural bed of the watercourse at the downstream toe of the dam or, if the dam is not across a watercourse, between the lowest elevation of the outside limit of the dam and the top of the dam.

Imminent Failure Flood (IFF): The flood event which when routed through the reservoir just threatens failure of the dam. The reservoir is assumed to be initially at maximum normal operating level.

Incident: An event which could deteriorate to a very serious situation or endanger the dam.

Inspection (Dam): A careful and critical examination of all physical aspects of a dam.

Inspector: A technical person suitably trained to undertake dam safety inspections

Maintenance: The routine work required to maintain existing works and systems (civil, hydraulic, mechanical and electrical and computer hardware/software) in a safe and functional condition.

Monitoring: The collection and review of data to assess the performance and behavioural trends of a dam and appurtenant structures.

Operator: The person, organisation, or legal entity which is responsible for the control, operation and maintenance of the dam and/or reservoir and the appurtenant works.

Outlet works: The combination of intake structure, screen, conduits, tunnels and valves that control discharge.

Owner: The owner of land on which the dam is constructed or proposed to be constructed.

Probable Maximum Flood (PMF): The flood resulting from PMP and, where applicable, snowmelt, coupled with the worst flood-producing catchment conditions that can be realistically expected in the prevailing meteorological conditions.

Probable Maximum Precipitation (PMP): The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage basin.

Referable Dam: A dam is a referable dam if:

- a failure impact assessment is required to be carried out for the dam and
- the assessment states the dam has a category 1 or 2 failure impact rating and the chief executive accepts the assessment.

Registered Professional Engineer (RPEQ): A registered professional engineer, a professional engineering company or a registered professional engineering unit as defined under the Professional Engineers Act 1988 (Qld).

Remedial Work: Any work required to rectify a deficiency to an adequate safety standard.

Reservoir: An artificial lake, pond or basin for storage, regulation and control of water, silt, debris or other liquid or liquid carried material.

Reservoir Capacity: The total or gross storage capacity of the reservoir up to full supply level excluding flood surcharge.

Risk: The probability of an adverse event. The likelihood of a dam failure occurring with adverse consequences ("chance of failure to perform" or "chance of harm" are alternative definitions).

Safety Review: The assessment of dam safety by methodical examination of all design and surveillance records and reports, and by the investigation and analysis of matters not addressed previously or subject to new design criteria.

Spillway: A weir, conduit, tunnel or other structure designed to permit discharges from the reservoir when pondage levels rise above the full supply level.

Spillway Crest: The uppermost portion of the spillway overflow section.

Surveillance: Ongoing monitoring and review of the condition of a dam and its appurtenant structures; and the review of operation, maintenance, monitoring procedures and results in order to determine whether a hazardous trend is developing or is likely to develop.

Tailwater Level: The level of water in the discharge channel immediately downstream of the dam.

Toe of Dam: The junction of the downstream (or upstream) face of dam with the ground surface (foundation); sometimes 'Heel' is used to define the upstream toe of a concrete gravity dam.

Top of Dam: The elevation of the uppermost surface of the dam proper, not taking into account any camber allowed for settlement, kerbs, parapets, guardrails or other structures that are not a part of the main water retaining structure. This elevation may be a roadway, walkway or the non-overflow section of the dam.

Appendix 2
Further reading

Legislation and Australian Guidelines

Water Act 2000 (Qld)

Water Resources Act 1989 (Qld)
(To be repealed on commencement of relevant sections of *Water Act 2000*)

Environmental Protection Act 1994 (Qld)

Integrated Planning Act 1997 (Qld)

Department of Primary Industries (Water Resources), Queensland, "Queensland Dam Safety Management Guidelines - Dam Safety Course Version", 1994. (Superseded by this document)

Australian National Committee on Large Dams, "Guidelines on the Environmental Management of Dams", 2001.

Australian National Committee on Large Dams (ANCOLD), "Guidelines on the Assessment of the Consequences of Dam Failure", 2000.

Australian National Committee on Large Dams, "Guidelines on Selection of Acceptable Flood Capacity for Dams", 2000.

Australian National Committee on Large Dams, "Guidelines on Tailings Dam Design, Construction and Operation", 1999.

Australian National Committee on Large Dams (ANCOLD), "Dam Safety Management Guidelines", 1994.

Australian National Committee on Large Dams (ANCOLD), "Guidelines on Risk Assessment", 1994.

Australian National Committee on Large Dams, "Guidelines on Strengthening and Raising Concrete Gravity Dams", 1992.

Australian National Committee on Large Dams, "Guidelines on Design Criteria for Concrete Gravity Dams", 1991.

Australian National Committee on Large Dams, "Guidelines on Concrete Faced Rockfill Dams", 1991.

Australian National Committee on Large Dams, "Roller Compacted Concrete for Gravity Dams", Guidelines Supplement, Bulletin No 75, 1991.

Australian National Committee on Large Dams, "Guidelines on Design of Dams for Earthquakes", 1988.

Department of Natural Resources & Mines, "The Guidelines for Failure Impact Assessments for Water Dams", 2002.

The Australian Standard for Quality Systems AS/NZS ISO 9001-3:1994.

Emergency Management Australia, "Emergency Management Planning for Floods Affected by Dams" Guide 7, 2002.

Useful Web Sites

Australian National Committee on Large Dams (ANCOLD)
http://www.ancold.org.au

U.S. Bureau of Reclamation, "Training Aids for Dam Safety", July 2001.
http://www.usbr.gov/dsis/tads.html

Queensland Government Legislation
http://www.legislation.qld.gov.au/legislation.htm

US Army Corps of Engineers
http://www.usace.army.mil/inet/usac-docs/eng-manuals/em.htm

Books, Journal Articles and International Guidelines

American Society of Civil Engineers "The Evaluation of Dam Safety", Proceedings of the Engineering Foundation Conference, ASCE, 1976.

American Society of Civil Engineers & U.S. Commission for Large Dams, "Foundations for Dams", Proceedings of the Engineering Foundation Conference, 1974.

Bowen, R., "Grouting in Engineering Practice", 1975.

Building Research Establishment, "An Engineering Guide to the Safety of Embankment Dams in the UK", Report 1990.

Canterford, R. P., "Australian Rainfall and Runoff", Institution of Engineers Australia, 1987.
(This document is presently being updated)

Department of Primary Industries (Water Resources), Queensland, "Queensland Dam Safety Course Notes", 1994.

Fell, R, MacGregor, P, Stapledon, D. "Geotechnical Engineering of Embankment Dams", 1992

Houlsby, A.C. (1977,1978). Foundation grouting for dams ANCOLD Bulletins 47,48 and 50

ISMES (Italy),"Activities for Dams (site characterisation to safety monitoring)", 1985.

ISMES (Italy), "Management of Information for Dam Safety", 1985.

Jansen, R. B., "Dams and Public Safety", U.S. Department of the Interior, Bureau of Reclamation, 1983.

Keller, W., "Geodetic Deformation Measurements on Large Dams", Kern Pamphlet, 1987

"Safety of Dams: Flood and Earthquake Criteria", National Academy Press, 1985.

"Safety of Small Dams", Proceedings of the Engineering Foundation Conference, ASCE, 1974.

Sherard, J. L. et al, "Earth and Earth Rock Dams", Wylie, 1963.

Thomas, H. H., "The Engineering of Large Dams", Vols. 1 & 2, 1976.

U.S. Federal Coordinating Council for Science Engineering and Technology, "Federal Guidelines for Dam Safety", FEMA No 93, June, 1979.

U.S. Bureau of Reclamation, "Downstream Hazard Classification Guidelines", Bureau of Reclamation, December 1988.

U.S. Bureau of Reclamation, "Design of Small Dams", U.S. Department of the Interior, Bureau of Reclamation, 1987.

U.S. Bureau of Reclamation, "Guide for preparation of Standing Operating Procedure's for Dams and Reservoirs", Bureau of Reclamation, 1986.

U.S. Bureau of Reclamation, 'Safety Evaluation of Existing Dams', U.S. Department of the Interior, Bureau of Reclamation, 1983.

U.S. Bureau of Reclamation, 'Concrete Manual', U.S. Department of the Interior, Bureau of Reclamation,1981.

U.S. Bureau of Reclamation, 'Earth Manual', U.S. Department of the Interior, Bureau of Reclamation 1980.

U.S. Bureau of Reclamation, 'Design of Arch Dams', U.S. Department of the Interior, Bureau of Reclamation, 1977.

U.S. Bureau of Reclamation, 'Design of Gravity Dams', U.S. Department of the Interior, Bureau of Reclamation, 1976.

U.S. Committee on Large Dams, "Dam Safety Practices and Concerns in the U.S.A.",

U. S. Federal Emergency Management Agency, "National Dam Safety Program - A Progress Report", FEMA, No 103, 1986.

U. S. Federal Emergency Management Agency, "Dam Safety: An Owners Guidance Manual", FEMA, No 145,1987.

U.S. National Research Council, "Safety of Existing Dams - Evaluation and Improvement", National Academy Press, 1983.

U.S. National Research Council, "Safety of Dams - Flood and Earthquake Criteria", National Academy Press, 1985.

The Australian National Committee on Large Dams produces a "Bulletin" as a periodical with 2 or 3 editions being published each year. These bulletins present papers on all aspects of Australian dam design, construction and ongoing operation and management of dam safety. Further details are available from the ANCOLD website (http:/www.ancold.org.au)

United States Bureau of Reclamation - Training Aids for Dam Safety (July 2001).

Dam safety inspection training modules[8]:

- Preparing to Conduct a Dam Safety Inspection.
- Documenting and Reporting Findings from a Dam Safety Inspection.
- Inspection of Embankment Dams.
- Inspection of Concrete and Masonry Dams.
- Inspection of the Foundation, Abutments, and Reservoir Rim.
- Inspection of Spillways and Outlet Works.
- Inspection and Testing of Gates, Valves, and Other Mechanical Systems.
- Instrumentation for Embankment and Concrete Dams.
- Identification of Material Deficiencies.
- Evaluation of Facility Emergency Preparedness.

Dam safety awareness, organization, and implementation modules: [9]

- Dam Safety Awareness
- How to Organize a Dam Safety Program.
- How to Organize an Operation and Maintenance Program.
- How to Develop and Implement an Emergency Action Plan.
- Identification of Visual Dam Safety Deficiencies.

Data review, investigation and analysis, and remedial action for dam safety modules: [10]

- The Dam Safety Process.
- Evaluation of Hydrologic Adequacy.
- Evaluation of Hydraulic Adequacy.
- Evaluation of Concrete Dam Stability.
- Evaluation of Embankment Dam Stability and Deformation.
- Evaluation of Seepage Conditions[11].

International Commission on Large Dams (ICOLD), Publish Bulletins and Transactions on a range of aspects of dam design, construction and ongoing operation and management of dam safety.

In Australia these are available through :-

- the ANCOLD Publications Officer. (In January 2002 the position was held by Mr Len McDonald [len@damsafety.nsw.gov.au].)
- or through the ANCOLD web site http:/www.ancold.org.au

A list of the ICOLD publications available at 1 January 2002 follows:-

No. 15 Frost Resistance of Concrete (1960)

No. 18 Guide and Recommendations on Aggregates for Concrete for Large Dams (1965)

No. 20 Surface-active Admixtures for Concrete for Large Dams (1968)

No. 22 Guide and Recommendations on Pozzolans and Slags for use in Concrete for Large Dams (1972)

8 These modules are for engineers with little or no inspection experience and technicians with some familiarity with dams.

9 These training modules are primarily for dam owners and operators.

10 These modules are for dam safety program managers, dam owners and operators, and experienced engineers.

11 Available from United States Bureau of Reclamation, Engineering and Research, D-3000, P.O. Box 25007, DFC, Denver, Colorado 80225-0007.

No. 24 Accelerating and Retarding Admixtures (1973)

No. 25 Extensibility of Concrete for Large Dams (1976)

No. 29 Report from the Committee on Risks to Third Parties from Large Dams (1977)

No.30a Finite Element Methods in Analysis and Design of Dams (2nd Edition, 1978)

No.32a Bituminous Concrete Facings for Earth and Rockfill Dams (1977-82)

No. 33 Compendium of Dam Symbols (1979)

No. 34 ICOLD Guide for the International System of Units (IS)

No.36a Cements for Concrete for Large Dams

No. 37 Dam Projects and Environmental Success (1981)

No. 38 Use of Thin Membranes on Fill Dams (1981)

No. 39 Upstream Facing Interface with Foundations and Abutments (1st Supplement to Bulletin 32a)

No.40a Fibre Reinforced Concrete (1988)

No. 42 Bituminous Cores for Earth and Rockfill Dams (1982)

No. 44a Bibliography - Mine and Industrial Tailings Dams and Dumps (1982, 1989)

No. 46 Seismicity and Dam Design (1983)

No. 47 Quality Control of Concrete (1983)

No. 48a River Control During Dam Construction (Reprinted 1986)

No. 49a Operation of Hydraulic Structures of Dams (Reprinted 1986)

No. 50 Dams and the Environment. Notes on Regional Influences (1985)

No. 51 Filling Materials for Watertight Cut-Off Walls (1985)

No. 52 Earthquake Analysis Procedure for Dams- State of the Art (1986)

No. 53 Static Analysis of Embankment Dams (1986)

No. 54 Soil-Cement for Embankment Dams (1986)

No. 55 Geotextiles as Filters and Transitions in Fill Dams (1986)

No. 56 Quality Control for Fill Dams (1986)

No. 57 Materials for Joints in Concrete Dams

No. 58 Spillways for Dams (1987)

No. 59 Dams Safety Guidelines (1987)

No. 60 Dam Monitoring - General Considerations (1988)

No. 61 Dam Design Criteria-Philosophy of Choice (1988)

No. 62 Inspection of Dams after Earthquakes - Guidelines (1988)

No. 63 New Construction Methods (1988)

No. 64 Registration of Dam Heightening (1988)

No. 65 Dams and Environment - Case Histories (1988)

No. 66 Dams and Environment - The Zuiderzee Damming (1989)

No. 67 Sedimentation Control of Reservoirs

No. 68 Monitoring of Dams and Their Foundations - State of the Art (1989)

No. 69 Moraine as Embankment and Foundation Material - State of the Art (1989)

No. 70 Rockfill Dams with Concrete Facing (1989)

No. 71 Exposure of Dam Faces to Aggressive Water (1989)

No. 72 Selecting Seismic Parameters (1989)

No. 73 Savings in Dam Construction (1989)

No. 74 Tailings Dam Safety (1989)

No. 75 Roller Compacted Concrete for Gravity Dams (1989)

No. 76 Conventional Methods in Dam Construction (1990)

No. 77 Dispersive Soils in Embankment Dams (1990)

No. 78 Watertight Geomembranes for Dams (Supersedes No. 38) (1991)

No. 79 Alkali - Aggregate Reaction in Concrete Dams (1991)

No. 80 Dam Construction Sites Accident Prevention - Review and Recommendations (1992)

No. 81 Spillways; Shockwaves and Air Entrainment (1992)

No. 82 Selection of Design Flood (1992)

No. 83 Cost Impact on Future Dam Design - Analysis and Proposals (1992)

No. 84 Bituminous Cores for Fill Dams - State of the Art (1992)

No. 85 Owners, Consultants and Contractors - How to improve relationships (1992)

No. 86 Dams and the Environment - Socio economic impacts (1992)

No. 87 Improvement of Existing Dam Monitoring - Recommendations and Case Histories

No. 88 Rock Foundations for Dams (1993)

No. 89 Reinforced Rockfill and Reinforced Fill for Dams - State of the Art (1993)

No. 90 Dams and Environment - Geophysical Impacts (1993)

No. 91 Embankment Dams - Upstream Slope Protection - Review and Recommendations (1993)

No. 92 Rock Materials for Rockfill Dams Review and Recommendations (1993)

No. 93 Aging of Dams and Appurtenant Works - Review and Recommendations (1994)

No. 94 Computer Software for Dams - Comments and Proposals (1994)

No. 95 Embankment Dams - Granular Filters and Drains - Review and Recommendations (1994)

No. 96 Dams and Environment - Water Quality and Climate (1994)

No. 97 Tailings Dams - Design of Drainage - Review and Recommendations (1994)

No. 98 Tailings Dams and Seismicity - Review and Recommendations (1995)

No. 99 Dam Failures - Statistical Analysis (1995)

No.100 Dams and Environment Ridracoli - A Model Achievement (1995)

No.101 Tailings Dams - Transport, Placement and Decantation (1995)

No.102 Vibrations of Hydraulic Equipment for Dams (1996)

No.103 Tailings Dams and Environment - Review and Recommendations (1996)

No.104 Monitoring of Tailings Dams - Review and Recommendations (1996)

No.105 Dams and Related Structures in Cold Climates - Design Guidelines and Case Studies (1996)

No.106 A Guide to Tailings Dams and Impoundments - Design, Construction, Use and Rehabilitation (1996)

No.107 Concrete Dams - Control and Treatment of Cracks (1997)

No.108 Cost of Flood Control in Dams - Review and Recommendations (1997)

No.109 Dams Less than 30m High - Cost Savings and Safety Improvements (1998)

No.110 Cost Impact of Rules, Criteria and Specifications - Review and Recommendations (1998)

No. 111 Dam-break Analysis - Review and Recommendations (1998)

No. 112 Neotectonics and Dams - Guidelines and Case Histories (1998)

No. 113 Seismic Observations of Dams - Guidelines and Case Studies (1999)

No. 114 Embankment Dams with Bituminous Concrete Facing - Review and Recommendations (1999)

No. 115 Dealing with Reservoir Sedimentation - Guidelines and Case Studies (1999)

No. 116 Dams and Fishes - Review and Recommendations (1999)

No. 117 The Gravity Dam: A Dam for the future - Review and Recommendations (2000)

No. 118 Automated Dam Monitoring Systems - Guidelines and Case Histories (2000)

No. 119 Rehabilitation of Dams and Appurtenant Works - State of the Art and Case Histories (2000)

No. 120 Design Features of Dams to Resist Seismic Ground Motion - Guidelines and Case Histories (2000)

No. 121 Tailings Dams: Risk of Dangerous Occurrences - Lessons Learnt from Practical Experience (2001)

No. 122 Computational Procedures for Dam Engineering - Reliability and Applicability (2001)

Proceedings of the X Congress, Montreal 1970, 6 Vols

Proceedings of the XII Congress, Mexico 1976, 5 Vols

Proceedings of the XIII Congress, New Delhi 1979, 5 Vols

Proceedings of the XIV Congress, Rio de Janeiro 1982, 5 Vols

Proceedings of XV Congress, Lausanne 1985, 5 Vols

Proceedings of the XVI Congress, San Francisco 1988, 5 Vols.

Proceedings of the XVII Congress, Vienna 1991, 5 Vols

Proceedings of the XVIII Congress, Durban 1994, 5 Vols

Proceedings of the XIX Congress, Florence 1997, 5 Vols

Proceedings of the XX Congress, Beijing 2000, 5 Vols

Appendix 3 - Checklist of Dam Technology Issues

Issues that should be considered when preparing a Design Report or a Safety Review Report

1. General

- Report on any specific investigations and analyses carried out.
- Report on design methods, standards and loads adopted and the design data gathered and developed (ie plans, reports of investigations).
- Report on the proposed and actual construction methods (including results of testing).
- Report on operational and maintenance intentions used in developing the design or necessitated by the constraints of the design.
- Describe the expected performance and condition of the structure.
- Describe the instrumentation and monitoring requirements for the dam.

2. Drawings

- Plan of the dam and appurtenant works drawn on a contour plan of the site.
- Arrangements, elevations and sections showing details of the structures, the proposed foundation levels and sub-surface geological features.

3. Summary of Principal Data

- Type of dam.
- Type of foundation cut-off (if any).
- Type of spillway.
- Height of dam (as defined in the *Water Act 2000*).
- Length of (as applicable) embankment(s) or non-overflow structure(s).
- Spillway crest(s).
  - Type, number and dimensions of spillway and any crest or sluice gates.
- Elevations of (as applicable):
  - original stream bed or lowest natural surface at toe
  - base of cut-off
  - spillway crest(s)
  - top of dam
  - full supply level
  - top of flood control storage (if any)
  - maximum flood level.
- Volumes of (as applicable):
  - excavation for foundations, cut-off and spillway
  - fill in each embankment zone and total
  - concrete in spillway, if separate
  - concrete in dam wall and appurtenance.
- Reservoir storage capacity:
  - to full supply level
  - in flood control storage
  - in surcharge storage.
- Reservoir surface area at full supply level.
- Catchment area.

- For the maximum design flood:
  - estimated recurrence interval
  - peak inflow rate
  - peak spillway discharge.
- For outlet works:
  - number and dimensions of outlet pipes and conduits
  - number, sizes and types of guard and regulating valves and gates
  - discharge capacity of each outlet with reservoir at full supply level.
- List of reports prepared by any person or organisation in the course of investigation and design.

4. Hydrological and Hydraulic Data and Analyses

- Failure impact assessment (including dam break analysis) and consequence assessment.
- Topographic map of the catchment or description of the terrain including elevations.
- Area of the catchment and of each sub-area controlled by other storages or lakes.
- Summary of stream flow, flood flow or rainfall records on which the hydrological analyses are based.
- Adequacy of spillway and means of assessment.
- Tables or curves of reservoir area and storage capacity versus water surface level.
- Summaries, as applicable, of hydrological analyses leading to the determination of flood frequencies, probable maximum flood, reservoir capacity, outlet capacity, spillway capacity and freeboard above maximum flood level.
- Recurrence interval of maximum flood adopted for the design of spillway and outlets, as applicable.
- Particulars of proposed reservoir operation including operation of outlets and spillway crest gates during floods.
- Tailwater rating curve(s) for spillways and outlets.
- Hydraulic data including formulae and co-efficients used in determining capacity of spillways and outlets.
- Discharge rating curves for spillways and outlets.
- Summary of assumptions and methods adopted for the design of energy dissipaters for spillways and outlets.
- Results of any physical or numerical hydraulic model studies.
- Fetch of reservoir and estimated wave height and run-up.

5. Foundation conditions and treatment

- Map and description of the general geology of the dam site and reservoir area showing major faults and identifying any other potentially hazardous features requiring special consideration.
- Report on any underground mine workings in the vicinity of the dam or reservoir and any provisions considered necessary to accommodate these workings.
- Records of foundation exploration holes, pits, excavations and other sub-surface investigations indicating:
  - nature and depth of material on which the dam, spillway, outlets and other appurtenant works are proposed to be founded
  - summaries of results of laboratory and in-situ tests for determining the engineering properties of the foundation materials indicating the number of tests, sampling locations and extreme as well as average values.
- Nature and extent of any proposed foundation treatments such as:
  - cut-off through pervious strata
  - provisions for drainage
  - curtain, blanket or consolidation grouting;
  - measures to consolidate, decrease permeability or otherwise modify the properties of the foundation or remedy defects.

6. Properties of construction materials

- For earthfill, filter materials, pervious materials, transition materials and rockfill:
  - approximate locations of the borrow areas and quarries and estimated volumes of reserves of each material
  - numbers of exploration holes, pits and excavations in each proposed borrow area and quarry
  - summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examinations and tests on rock materials, indicating the number of test samples and extreme as well as average values.
- For concrete aggregates, if not obtained from sources of materials previously described:
  - approximate locations of proposed sources and estimated volumes of reserves of aggregates
  - number of exploration holes, pits and excavations in each proposed source
  - summaries of results of laboratory tests for determining the engineering properties of each type of material, and of results of geological examination and tests on rock materials, indicating the number of test samples and extreme as well as average values.

7. Embankment Design and Stability Analyses

- Details of each design case considered.
- Summaries of the properties of the material in each zone of the embankment and the foundation adopted for the stability analyses including density and shear strength parameters both as placed and saturated as appropriate and the justification for the adopted properties.
- Basis for the estimates of the pore pressures in the impervious zones adopted for each design case examined.
- Particulars of the methods of stability analyses used, formulae used in the analyses or references in technical literature, and the upstream and downstream water levels used in each design case.
- Minimum values of the factor of safety obtained for each design case and the locations of the critical slip surface for each case drawn on a cross-section of the embankment or results of any other method of assessment of the stability of the embankment.
- References in technical literature to design rules if used to determine dimensions of a small embankment without analyses.

8. Stress and Stability Analysis of Concrete Structures & other structural components

- Details of each design case considered.
- Summaries of the properties of concrete and foundation materials adopted for the analyses.
- Assumptions as to loads, including combinations of loads due to water, dead weight, uplift, earthquake, silt or other solids and temperature change when appropriate.
- Limiting stresses.
- Methods of analysis.
- Results of any structural model studies.
- Results of analyses including safety factors and stresses in the structure and foundation or the results of any other method of assessment of the stability of the structure.

9. Instrumentation

- Layout and description of embedded instruments and other devices installed to observe the behaviour of the works including, as applicable, pore pressures and uplift, leakage, embankment settlements, foundation deformations, alignment, deflections, stresses, strains, temperatures, contraction joint openings, seismic and mechanical vibrations.
- Pore pressure and uplift values assumed for the design of the associated structures at instrument locations
- Recommended for frequency of observations/readings

10. Construction specifications

- Clauses dealing with:
  - foundation treatment and grouting
  - sources of construction materials
  - methods of treatment and placement of materials
  - acceptability criteria.
- Construction schedule and sequence of construction operations, if specified.
- Stream diversion plan with respect to safety during construction.

Appendix 4 - Checklist Of Details For Consideration When Undertaking A Surveillance Evaluation[16]

1. General Interpretation

All new data should be thoroughly examined in context with existing data.

Situation "Normal"

Generally the latest set of observations can be quickly scanned as numbers in a table or points on a plot and be seen to be as expected. In simple cases such as settlement or horizontal deflection of fill or gravity dams the reading should be within a millimetre or two of expectation, for a well-planned observation schedule.

For high thin arch dams, reservoir water level and seasonal temperature variations can justify statistical regression checks, and the observation should be within a few millimetres of a well-organised prediction from regression.

Leakage and piezometric data, when notionally cleared of local runoff effects, should generally follow any significant reservoir head changes. Seasonal opening and closing of joints or cracks in concrete dams can be reflected in gallery or toe drain flows, but after allowing for such influences, there should be negligible long term change.

Anomalies - Real or Not?

Sometimes an isolated instrument reading, or a survey observation, will indicate some severe distress or a strain, deformation or pore pressure which, if valid, would represent a real threat to the dam.

Every effort should be made to urgently assess such a situation, with repeat readings, repair of blown fuses, or extra instruments, targets or reference pillar checks.

If the dam has not failed and the adjacent parts are not indicated as behaving abnormally, that instrument reading or survey observation must be taken as anomalous, however carefully it purports to have been checked "correct".

Typical Assessment of "Overall Picture"

In foundations with piezometers upstream and downstream of grout and drainage curtains, and flow measurement of drains or drainage adits, it is possible to develop a good picture of the water table.

Ideally the piezometers will continue to indicate a roughly linear head drop along the seepage path. Rises and falls can be expected to follow corresponding reservoir level changes.

If tightening of foundation joints by creep causes a slow reduction in the long-term mean leakage flow, the head pattern described above should still apply.

16 Taken from ANCOLD Dam Safety Management Guidelines (1994)

If pressures build up downstream of the drainage curtain in dry weather, consideration of some extra drainage drilling is indicated.

Emergency Action "Triggering"

The surveillance engineer should be familiar with the designs, recent performance and possible failure mechanisms of all dams for which the engineer has surveillance responsibility.

Immediate personal access should be available to senior management in a perceived Dam Safety emergency. Senior management should not usurp the authority of the Dams Safety Engineer unless they are appropriately qualified and experienced.

Staff at the dam should be sufficiently trained to recognise an emergency and have the authority to trigger emergency action in the event of a disruption in communication.

Dam owners, particularly in relation to initiating, testing or upgrading Emergency Action Plans should maintain close regular liaison with those responsible for emergency services.

2. Factors For Consideration

The evaluation of a dam's performance usually requires a close inspection of the dam and its appurtenances, examination of water pressures and seepage records and the various movements relative to the abutments or of differential movement within the dam. These data are then compared with design assumptions, predictions and historical behaviour patterns to fully evaluate the existing situation.

Seepage

Seepage through, around or under a dam is expected. The quantity and nature of seepage, the seepage paths, and the velocity of the seepage waters are issues to be considered when analysing the dams' structural behaviour.

The quantity and nature of seepage is important for several reasons:

- Leaching:
  seepage may dissolve some of the chemical constituents of the concrete, rock or soil. Leaching may provide an enlarged seepage path resulting in increasing seepage. Dams founded on limestone are subject to this problem. Evaluation of the composition of the seepage water (eg turbidity, dissolved salt content) can provide a further insight into dam behaviour.
- Weakening:
  seepage water may completely saturate soils and rock, and cause excessive uplift (pore pressures) as well as softening and weakening of soil and rock.
- Loss of Storage:
  excessive leakage may, in extreme cases, compromise the storage capability of the reservoir.
- Indication of Behaviour:
  increases in seepage quantity with time may indicate the onset of internal erosion, and decreases may indicate infilling of seepage paths, with build up of internal pressures in dams and their foundations.

The location of a seepage path is of concern because:

- Piping:
  if seepage is confined to a few discrete paths and the velocity becomes sufficiently high to move soil particles, progressive erosion may occur resulting in a "piping" failure.
- Leaching:
  seepage waters may result in concentrated dissolution.
- Drainage:
  if discrete seepage paths are present and are not intercepted by drains, then drains should be installed. Seepage (or pore) pressures if above design values may compromise the stability of a dam.

Movements

Some movement of all or part of a dam can be expected eg seasonal movements, changes in water level. Movements may be in the vertical plane, the axial plane (along the dam's axis), and the upstream-downstream plane, or rotational. It is common for more than one direction and mode of movement to be present in a dam.

Vertical movements occur as a result of consolidation of the foundations or the embankment. Such settlement is typically greater along the crest of the dam than along the heel or toe and is also usually greater near the centre of the dam than near the abutments. Such settlement can result in cracking. Minor upward vertical movement (heave) can also occur at the toe of an embankment dam due to fill creep or excess uplift pressures.

Vertical movement of the centre of a fill dam with respect to the abutments is generally associated with horizontal movement toward the centre of the dam. This axial movement results in tension, which can involve cracking of the core or face membrane.

Upstream-downstream movements are usually in the downstream direction and are due to hydrostatic forces acting on the upstream face of the dam. These movements can be horizontal or rotational. Upstream movements are usually of a rotational-type and may occur during "rapid drawdown". These rotational movements may be a deep-seated or a relatively shallow configuration. The slides may extend into the foundation, intersect at the dam's heel or toe, or may be entirely contained within the dam. The general cause of such movements is deficient shearing resistance along the often saturated failure surface associated with high uplift pressures and reduced effective stresses.

3. Typical Periods for Evaluation

During the life of a dam, from initial planning, through construction, reservoir filling, and operation, an evaluation may be necessary as follows:

Preconstruction

Evaluation of pre-construction conditions using various instruments can be valuable. During the initial planning and design stages several important considerations affecting dam safety should be investigated. They include:

- Normal ground-water levels:
  the existing ground-water level in the abutments, dam area, reservoir rim, and downstream of the dam and its seasonal variation should be determined.
- Quality of the ground-water:
  ground-water mineral composition can be compared with later seepage water mineral composition

to aid in determining if dissolution is occurring.

- Seepage at abutments:
  seepage due to natural ground-water at abutments prior to construction will affect the design of the dam and later evaluation of the dam's performance.
- Landslide scars/faults:
  old landslide scars and faults in the vicinity of the dam indicate the potential for additional sliding during reservoir construction and operation.
- Permeability of existing materials:
  for the foundation, abutments, and reservoir floor, treatments such as grouting cut-off walls and upstream blankets can reduce the effect of excessively permeable materials.
- Foundation consolidation:
  knowing the characteristics of foundation materials allows anticipated settlement of the dam to be estimated.
- Fill and foundation shear strength:
  the shear strengths of the relevant materials are needed to determine the stability of the dam.
- Seismic:
  the seismic risk at the dam site is used to design the dam to resist loading up to the Maximum Credible Earthquake. Preparations should also be made to assess the existence of reservoir-induced seismicity.
- Hydrologic:
  catchment conditions, flood potential and the likelihood of changing conditions affecting future flood magnitude are important in determining spillway capacity.

During Construction

Installation and observation of instrumentation begins during construction. Visual observation is also vital during this period.

- Instrument installation:
  many instruments are installed during dam construction. These include piezometers, pressure cells, strain gauges, settlement and movement measuring devices and thermometers. It is absolutely essential that proper care be taken during their installation otherwise no information of value will be obtained from them. Incorrect installation techniques produce information detrimental to interpretation. Instruments must be tested as they are installed. Continuous supervision by specialists with authority to require repair or replacement is vital in the rough construction environment.
- Settlement:
  consolidation of foundation and embankment materials result in settlement of the surface of the dam as it is constructed. Settlement measuring instrumentation (such as hydrostatic manometers and cross arms), installed during construction, record such settlement.
- Observation of excavations:
  during construction excavations for foundation and core trenches, should remove undesirable materials. Visual observations by experienced personnel during this phase are extremely valuable and should be carefully recorded. Based on these observations, there may be need for instruments to be relocated or added or for design changes. This information can be important in diagnosing subsequent anomalous behaviour.
- Increasing Pore Pressures:
  rapid construction of embankments, at high moisture contents, may cause excessive pore pressures, which would result in instability if not allowed to dissipate. Records of such pore pressures can be of long-term significance.
- Slide movements:
  slide movements due to high pore pressure building up during construction may be noted either

visually or by instrumentation.

- Temperature:
  excessive temperatures from cement hydration in concrete dams may cause subsequent thermal cracking if not controlled.
- Permeability:
  filter permeability should be checked as placement can compact a filter more than specified.

During First Reservoir Filling

The first filling of a reservoir is normally a critical event for a dam. At that time, the first true analysis of the behaviour of a dam with reservoir loading can be made. Instrumentation readings and visual observations are conducted very frequently during this period.

- Seepage:
  as the water level in the reservoir rises, it is especially important to watch both the dam and abutments for increases in seepage quantities, changes in seepage clarity, new seepage locations and the functioning of drains.
- Pore pressure:
  at this time frequent readings should be taken to monitor pore pressure changes and patterns.
- Dam movements:
  the increasing load from the reservoir water will cause movements of the dam, particularly in the downstream direction. These require close monitoring, ideally including correlation with movement controlling factors.

During Normal Operations

Dam owners generally aim to have trouble free operation of a dam for many years. The water level in many reservoirs fluctuates each year resulting in seepage quantity and pore pressure fluctuations on a regular, somewhat predictable basis. It is therefore important to establish a regular instrumentation monitoring schedule and a regular visual inspection of the facility and to summarise the findings in regular surveillance reports on the dam. Any significant unusual changes noted should be an immediate cause for further investigation.

During Rapid Drawdown

Occasionally, the reservoir level is lowered rather quickly for some reason. The term "rapid" depends on the type of material in the dam and abutments. In some relatively permeable materials, "rapid" may mean hours or days, while in low permeability materials, a "rapid drawdown" might cover a period of weeks. During drawdown the external reservoir water pressure is removed but the internal pore pressures in the dam and abutments remain, to dissipate more slowly in impermeable materials. This creates a condition where slides may occur in the upstream face of an embankment, the abutments, or anywhere along the reservoir rim. Surface movements and pore pressures in the upstream shoulders require special monitoring at this time.

4. Interpretation Of Data

Data Presentation

The use of graphical presentation of instrumentation data should be undertaken for the evaluation of dams. Graphical presentation by computers is simple and rapid and reduces the chance of plotting errors and enables ancillary computations and data variation checks to be performed.

Data presentation, when properly done, is of very significant value, but incorrect data plotting may cause errors in interpretation. The characteristics of incorrect plotting include:

- Improper scale:
  proper and consistent scales must be used. Movements should not normally be shown larger than full-scale (1:1).
- Excessive data:
  in general, each plot should contain only two variables: (eg water level and time). There may, however, be a large amount of data points on a single instrument or even a number of instruments. The number of instruments shown on a single sheet of plotting is a matter of common sense. Plot lines should not repeatedly cross each other and distinctly different line symbols should be used for each plot.
- Coloured lines:
  distinguishing plots by colour should be avoided due to the use of black and white photocopying (eg when "quoting" plots in subsequent communications).

Detection of Errors

Data errors can usually be detected either in the field at the time of reading or in the office during processing or reviewing. Often, it has been found that if the instrument reader knows what the previous reading on an instrument was, they can re-check the current reading if it differs significantly. (The risk that the reader will report a reading close to the previous one without actually making an observation, or even where a different reading is actually obtained, has to be considered.)

Normal and Abnormal Conditions

Application of the terms "normal" and "abnormal" depends on the particular characteristics of a dam in question. The behaviour of pressures, strains, movements, and seepage, should be compared to the behaviour anticipated during the design of the dam and any preconstruction data gathered from the dam site. It is important for designers to state acceptable "ranges" in design reports and operating instructions. For dams with limited design data, historical behaviour patterns should be developed.

Correlation of Inspection/Monitoring Data

The recommendation for major remedial works on a dam should not depend on uncorroborated evidence. Ideally any visible anomaly should be confirmed by anomalies recorded on associated instruments.

It is important to compare measured aspects of a dam's behaviour over identical date ranges. Since observations cannot always be made concurrently, response factors, such as regression coefficients, should be used to determine the most probable values on the chosen comparison date, for movements, which could not be observed on the date.

Reservoir water level, ambient temperature, and age since construction should be included amongst the controlling variables in these studies. In comparing the designer's predictions and the prototype's performance, regression can be an important tool in separating the effects of temperature, water load and creep, so that each may be compared in turn.

In general, those responsible for interpreting monitoring results should endeavour to make all possible logical linkages throughout the range of dam data obtained from observations and inspections and be vigilant in the detection of errors and false alarms. Familiarity with the reliability of installations and observers is a great advantage in making a judgement as to whether an "alarm" is false or real as a result of a genuine excessive change in the value of the entity being monitored. In this regard close liaison between operators and surveillance personnel is critical.

Appendix 5
Checklist of Advice Concerning Dam Safety Inspections and the Preparation of Reports

This detailed advice applies to periodic and special inspections for physical integrity in the dam and to comprehensive inspections which assess the overall safety management of the dam. This checklist:

- defines the information about the structure that needs to be gathered during the inspection
- gives examples of the defects and problems that may be encountered
- requires the formulation of recommendations on remediation and repair strategies
- specifies the standard of report presentation that is acceptable to NR&M.

This advice is intended to define a minimum standard of report. It would be expected that engineers experienced in the management and performance of dams would provide a dam owner with comment and insight into the issues that are influencing the safety of a dam and advice on the management of the dam as an asset.

While most of the common causes of dam failure have been included in here, the list is not inclusive. Each dam is different and may present its own unique problems. Anyone who inspects dams should be aware of a wide range of potential problems and look for all potential modes of failure.

Where a dam contains novel or particularly complex features the inspection and report should reflect additional emphasis on these aspects.

Part A - Periodic Inspections

Periodic Inspections focus on the physical defects.

Personnel

For safety reasons it is advisable to have two or more personnel on each inspection. This applies particularly to isolated areas and to inspections where access to confined spaces is necessary.

Equipment

The following items may be useful

- checklist field book and pencils
- recording device (eg dictaphone)
- cameras (still and video)
- hand held levels
- probe
- safety gear: waders, harnesses, hard hats, safety boots, breathing apparatus, flame safety lamp and anything else to comply with safety regulations
- tape measures

- torch ("mine safe" for unventilated conduits, tunnels or adits)
- shovel
- geological hammer
- binoculars
- first aid kit
- stakes and flagging tape.

Recording Inspection Observations

Inspections require the accurate location, recording and photographing of questionable areas. The objective is to permit observation and comparison of the state of a dam through time. It is necessary to record:

- extent of such areas (ie length, volume, width and depth or height)
- a brief description of any anomalous condition eg:
  - quantity/quality of drain outflows, seepage and its source(s)
  - location, type and extent of deteriorated concrete
  - location, length, displacement and depth of cracks
  - extent of moist, wet or saturated areas
  - changes in conditions.

Areas For Inspection

Monitoring

A surveillance evaluation should be integrated into a periodic inspection. The surveillance evaluation report should:

- assess the available pressure, movement and seepage monitoring data by analysis of the impact (if any) of all monitoring results
- assess the seepage from the storage (A plan should be provided showing position, quantity, and quality of seepage.)
- report on the recent movement survey for the dam
- report on the foundation and embankment pressures being experienced by the dam (A plan showing the position and purpose of the individual piezometers should be provided).

An assessment should be made of the appropriateness of seepage, movement and pressure monitoring being carried out at the dam.

Operation

The report should include a review of the way in which the dam has been operating since the last periodic inspection and how it is intended to operate until the next periodic inspection is carried out. The report should comment on the impacts of the operation on dam safety including rainfall records, release records, record of flows in the spillway and maintenance and repairs carried out.

It is appropriate to report on the compliance with Standard Operating Procedures (SOP). It is also desirable to assess the SOP relative to best practice and the Queensland Dam Safety Management Guidelines 2002.

Requirements for specific elements of dams are outlined in Part E.

The following areas may also have to be considered in an inspection;

- a test operation of all equipment
- evaluation of all surveillance data
- major function checks and maintenance inspections. For example:
  - flip bucket watering
  - conduit dewatering
  - diver inspection of intake work
  - conduit video inspection
- the foundations, abutments, and reservoir rim should all be inspected regularly
- an inspection should be made far enough downstream to ensure that there are no problems that will affect the safety of the dam
- the reservoir surface and shoreline should also be regularly inspected to identify possible problems. whirlpools can indicate submerged outlets (Large landslides coming into the reservoir could cause waves overtopping the dam or water quality problems, suspect areas should be quantitatively monitored.)
- upstream development and other catchment characteristics, which might influence reservoir water or silt inflows, should be noted in major inspection reports to anticipate possible problems or modifications in the dam
- downstream development in flood plains should also be regularly assessed.

Part B - Special Inspections

A Special Inspection is recommended in the following cases regardless of the regular inspection schedule:

- whenever a concerning specific defect is observed in the dam
- during and immediately after the first reservoir filling or augmentation
- during and after a rapid draw down
- before a predicted major rainfall, or filling
- during (if possible) and after heavy flooding (or severe windstorm)
- following an earthquake, sabotage or overtopping; immediately and then regularly for several months to detect any delayed effects.

When carrying out a Special Inspection a dam owner should follow the steps listed for Periodic Inspections.

Part C - Comprehensive Inspections

Comprehensive Inspection focuses on the dam safety management program and documentation for the dam. It is an assessment of the appropriateness, the effectiveness and application (including the owner's response to recommendations) of the dam safety management program and documentation for the dam including:

- SOPs
- DOMMs
- EAP
- Data Book
- Design Report/Safety Review
- Surveillance and inspection program and records.

This assessment should take into account the development permit conditions for the dam.

Personnel

An experienced dams engineer who is a RPEQ should carry out Comprehensive Inspections. In assessing and reporting on these aspects of the dam the inspecting engineer needs to assess the current dam safety management program and documentation for the dam against that required firstly, in the development permit conditions and generally in the Queensland Dam Safety Management Guidelines 2002.

Operation

It is appropriate to report on the compliance with SOPs. It is also desirable to assess the SOP relative to best practice and the requirements of the Queensland Dam Safety Management Guidelines 2002

Inspection

Comprehensive Inspections should incorporate a review of the Periodic Inspection program and periodic inspection records for the dam as well as evaluating the dam owner's response to the conclusions and recommendations from inspection reports.

Emergency Preparedness

Comprehensive Inspections should incorporate an assessment of the emergency preparedness of the owners and operators of the dam. The owners EAPs and documentation should be assessed relative to the requirements of the Queensland Dam Safety Management Guidelines 2002.

Part D - Preparation of a Periodic, Special And Comprehensive Inspection Report

General

The aim of the periodic, special and comprehensive inspection reports is to document the findings of each inspection and to detail the required actions to be taken by the owner as a result of the inspection. These reports should be presented in a precise and readable form and be signed by the inspector.

Detailed data that is used to assess aspects of the dam should be attached as appendices and not included in the body of the reports. Captioned and dated photographs should be used extensively in the reports.

Information On The Dam

The report should include the following background information on the storage:

- ownership details including any change of owner
- details of the development permit conditions for the dam
- a brief description of the dam including:
  - location (latitude and longitude)
  - nearest town
  - principal dimensions and design water levels
  - construction type
  - current water levels
  - history, including inspection history.
- a thorough and critical review of:
  - Data Book

- SOPs
- EAPs
- operation and maintenance plans and log books for the dam
- Safety Review status for the dam.

Documenting The Inspection

The report should address the preparation for the inspection in the following areas:

- outline of the preparation for the inspection
- the preparation of checklists
- data gathering
- special provisions (eg drainage of stilling basins or aerial inspection)
- review of previous inspection, including identification of action items
- review of operation and design information.
- composition of the inspection team including:
  - details of the inspecting engineer or consultant including the RPEQ No. as appropriate (RPEQ No. compulsory for comprehensive inspections)
  - details of owner's representative
  - detils of operations staff involved in the inspection
- the photographic record of the inspection. All photographs should be dated and annotated to reflect the features recorded

Conclusions And Recommendations

Each inspection report should include an overall assessment of the state of the dam and recommend action to remedy defects or ensure continued appropriate management practices. These should include:

- comments on the implementation of recommendations from previous reports
- conclusions on the safety of the dam
- recommendations on additional evaluation, investigation or testing
- recommendations on rehabilitation, repair and operational modifications relating to issues that were noted during the inspection
- a summary sheet outlining the recommended action, the responsible person and the appropriate time frame
- the dam owner should sign the report and endorse the recommendations.

If observed defects are considered serious, advice from a suitably qualified and experienced engineer should be sought. Depending on the significance of the potential consequences, the advice should be documented in the report.

Circulation

Copies of the periodic inspection report should be circulated to the following:

- the dam owner
- the individual responsible for operation of the dam.

Copies of the comprehensive inspection report should also be circulated in accordance with the development permit conditions for the dam.

Sample Contents Page

- General
- Conclusions and Recommendations
- Information on the dam
- Inspection
- Monitoring
- Review of Data Book, SOPs, DOMMs & EAP *for comprehensive inspections
- Embankment (If Needed)
- Spillway
- Outlet Works (If Needed)
- Concrete (If Needed)
- Weir
- Captioned and Dated Photographs

Part E - Requirements for specific elements of dams for Periodic, Special And Comprehensive Inspections

This section outlines defects observed in each of the following elements of dams.

1. Earth embankments
2. Spillways and bywashes
3. Discharge control structures and outlet works
4. Concrete dams
5. Weirs

Owners should address the requirements for each element of their dam.

1. Requirements for earth embankments

There are several types of dam construction that are included in the earth embankment category. They include:

- homogeneous rolled earth fill dams
- homogeneous rolled earth fill dams with toe drains
- zoned rolled earth fill dams
- diaphragm rockfill dams
- central core rockfill dams.

These dams all include an impermeable zone of clay fill or concrete and a supporting rock or earthfill zone to provide strength. Filter zones provide internal drainage of the structure.

These dams can fail by:

- internal erosion of embankment material by seepage and transport of embankment material through sinkhole cracks, animal burrows, compaction flaws in embankment, compaction flaws in conduit surrounds, flaws in the abutments (known as a piping failure)
- bulk removal of material and loss of height and section through slumping, beaching, tree blow over, and gully and sheet erosion
- overtopping.

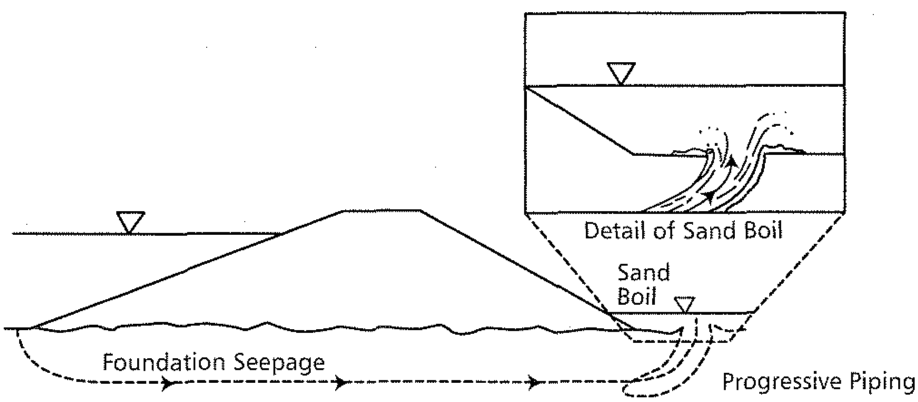
The report should document the inspection by including comments on the condition of the dam embankment with regard to

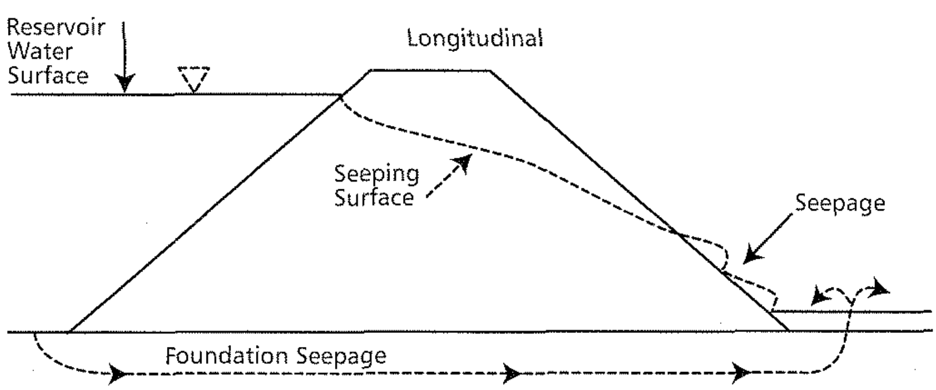
- erosion
- vegetative growth
- seepage
- slump formation
- beaching
- deterioration of rip rap
- cracking.

Following are some illustrations of deficiencies to look for when inspecting embankment dams.

Seepage

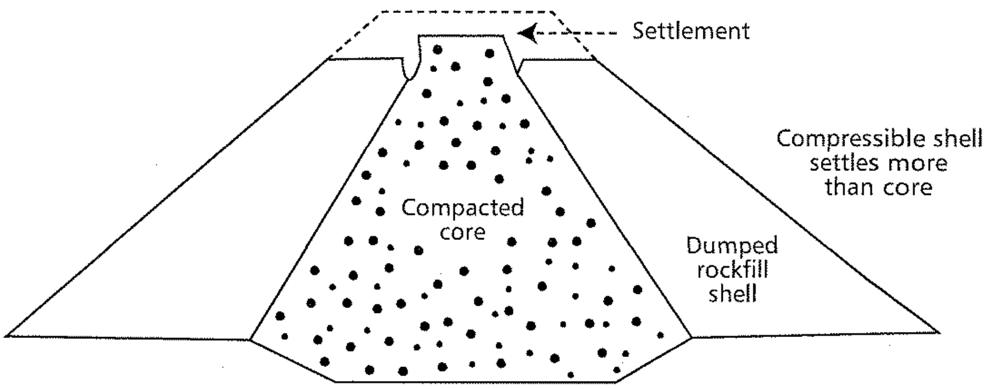
- A water flow or sand boil on the lower portion of the downstream slope or toe area, especially at the groins.
- Leakage around conveyance structures such as outlet works, spillway conduits, or penstocks.
- Blocked toe drains and relief wells.
- An increase in the amount of water being released from toe drains and relief wells. (Remember to take into account changes in the reservoir level, or the effects of rainfall on the downstream face and abutments).
- Wet areas or area where the vegetation appears greener or more lush on the embankment slope or toe area.
- Turbidity or cloudiness of the seepage.

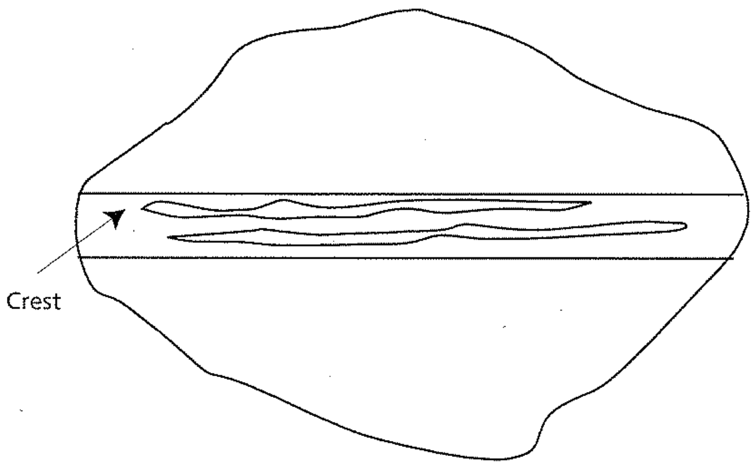




Cracking

- Desiccation Cracking: A random honeycomb pattern of cracks usually found on the crest and the downstream slope.
- Transverse Cracking: Cracks that are perpendicular to the length of the dam usually found on the crest.
- Longitudinal Cracking: Cracks that are parallel to the length of the dam. Longitudinal cracks may be associated with stability problems in the slopes.

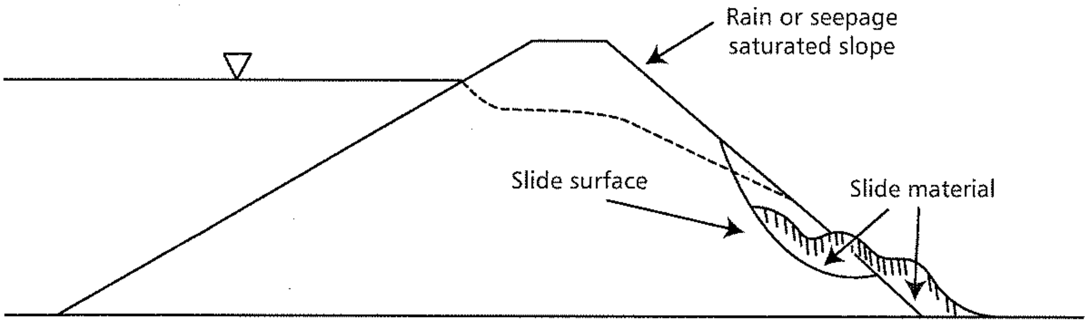


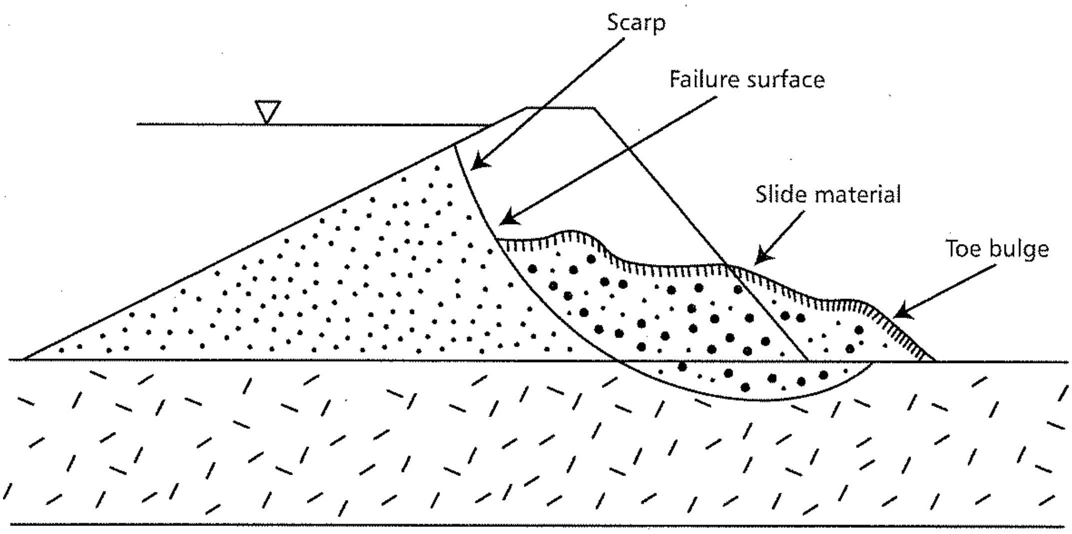


Plan view

Instability

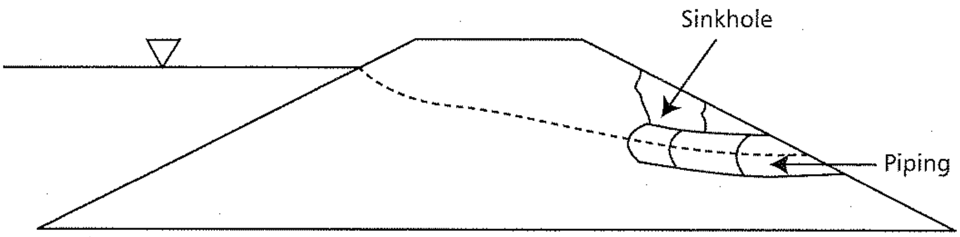
- Slides on the upstream and downstream slopes.
- Bulging, especially at the toe of the dam.
- Misalignments in the crest and embankment slopes found by sighting along fixed points.





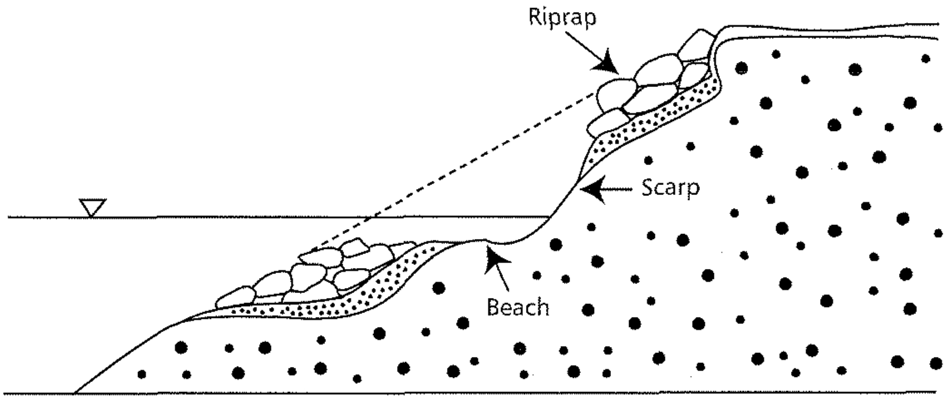
Depressions

- Sinkholes found by checking and probing each depression. Remember, sinkholes have steep, bucket-like sides while minor depressions have gently sloping, bowl-like sides. These are initiated by settlement or migration of materials in the embankment.



Maintenance Concerns

- Inadequate Slope Protection: Check for bald areas or areas where the protection is sparse or damaged.
- Surface Runoff Erosion: Check for gullies or other signs of erosion. Make sure to check the low points along the upstream and downstream shoulders and groins since surface runoff can collect in these areas.
- Inappropriate Vegetative Growth: Check for excessive and deep-rooted vegetative growth, especially trees.
- Debris: Check for debris on and around the dam, especially debris that could clog or choke outlet-works or spillway inlets.
- "Animal Burrows": Check for damage caused by burrowing animals.



2. Requirements for spillways and bywashes

Spillways are designed to withstand high flows that have the capacity to overtop and erode embankments and to undermine concrete and rockfill structures.

Spillways that are not able to adequately contain the extreme flows through the dam contribute to failure of the dam by overtopping.

Spillways can fail by erosion of the structure from downstream, and by erosion that results from failing to contain the flows within the spillway section and by erosion of support for any structural elements through weaknesses.

Spillway flow needs to be directed back to the stream safely. Poorly directed flows through the spillway can erode the toe of the dam embankment and initiate failure.

Spillways and bywashes should be inspected immediately after spill events to monitor any damage and to determine erosion patterns. Comments on damage sustained after spill events should be included in the surveillance report.

The surveillance report should include an assessment of, and recommendations on the dam spillway or bywash with regard to:

- erosion of the downstream slope
- slumps in sidewalls
- potential for blockages caused by fencing, debris build up, or vegetative growth
- profusion and integrity of grass cover to the downstream slope

- blockages in the underdrainage of concrete spillways.

A recommendation for any remedial works to ensure the spillway and bywash is capable of fulfilling its function.

3. Requirements for discharge control structures and outlet works

Dams with inadequate and failed outlet pipes experience loss of serviceability by emptying or by being unable to release as required. Leaking from the outlet conduit is a common source of internal erosion failure. Deterioration and failure of the outlet structure, collapse or deterioration of the outlet pipework or valves or failure of associated control systems could cause the loss of outlet capability.

Discharge conduit

The discharge conduit should be inspected internally if possible (proper regard for workplace health and safety requirements is essential). If access to the conduit is not possible, video inspection should be carried out. The following aspects of the conduit should be assessed and reported on:

- sources of leakage should be photographed, marked on a plan and the flow rate estimated
- misalignment should be measured, and marked on a plan
- deterioration of pipe and joint material should be photographed
- fouling of the intake structure
- extent of corrosion.

Valves

All valves should be exercised at each inspection and an assessment made on the condition, the ease of operation, maintenance history and ease of access. The report should contain comments on the appropriateness of labelling of valves.

The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for noise and vibration. Certain valve settings may result in greater turbulence. There is a need to also listen for noise like gravel in the system. This indicates cavitation is occurring, and these gate settings should be avoided.

Structures

All structure associated with the dam should be assessed for serviceability. Intake structures may need to be inspected by divers for fouling and deterioration. Valve pits and boxes inspected for concrete deterioration and settlement. Intake structure steelwork inspected for corrosion and misalignment and damage. Baulks and gates exercised and inspected for corrosion and damage. Outlet structures inspected for concrete deterioration corrosion and misalignment and damage.

Dams incorporating mechanical or fabridam gate structures should be reported on by an appropriately experienced mechanical engineer.

Electrical, mechanical and control systems

Mechanical equipment including spillway gates, sluice gates, valves, stoplogs, pumps, flash boards, relief wells, emergency power sources, siphons, and electrical equipment should be operated at least once a year and preferably more often. Testing should cover the full operating range under actual operating conditions. Each operating device should be permanently marked for easy identification, and all operating equipment should be kept accessible. All controls should be checked for proper security to prevent vandalism. All operating instructions should be checked for clarity and maintained in a secure, but readily accessible location.

All control systems associated with operation of the dam should be reported on by an appropriately experienced electrical engineer. The report should include assessment of the operation of all functions of the control system through the full range of responses and alarms. The report should incorporate an assessment of the condition and the maintenance and operation history of the system and of the existence and appropriateness of the operation plan for the controlled system. The report should make recommendations on the future maintenance requirements.

4. Requirements for concrete dams

Possible causes of concrete dam failure include:

- overturning or sliding due to erosion of the foundation or abutments during overtopping resulting from inadequate freeboard
- abutment or foundation failure due to overstressing
- structural failure of concrete unable to sustain imposed loads.

When inspecting the crest and the faces of concrete dams and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- seepage and leekage
- cracking concrete deterioration
- disintegration
- spalling
- efflorescence
- drummy concrete
- popouts
- pitting
- scaling
- surface defects
- displacement
- misalignment
- differential movement in cracks
- conditions of joints.

When inspecting the areas upstream and downstream of a concrete dam and weirs any of the following defects should be noted, documented and photographed and an assessment made of any changes in their severity since last inspection:

- cracking, bulges and slides
- sinkholes
- wet areas
- lush vegetation
- erosion of the abutment areas following spills.

5. Requirements for weirs

Weirs are designed to withstand overtopping by all river flows. As a consequence, weirs need to not only be stable and safe against the hydraulic forces applied and to retain water but must also be able to retain integrity in an erosive environment.

Whilst a regular time based inspection regime is appropriate, it is more important to inspect and document the deficiencies and remedial requirements after each river flow event.

Common causes of failure of weirs include:

- excessive and progressive downstream erosion, both from within the stream and through lateral erosion of the banks
- erosion of inadequately protected abutments
- hydraulic removal of fines and other support material from downstream protection (gabions and aprons) resulting in erosion of the apron protection
- deterioration of the cutoff and subsequent loss of containment
- additional aspects specific to concrete, rockfill or steel structures.

Inspection reports should comment on:

- details of any testing of flow control structure
- adequacy of flow control structure
- Mechanical / electrical equipment
- disruption to the downstream banks - as an indication of erosion
- water levels in the downstream pond - as an indication of seepage
- deepening of the downstream pond as a result of erosion
- erosion of abutment protection
- corrosion or other deterioration of the sheetpile or other cutoff material
- cracks and open construction joints in the downstream apron - as an indicator of hydraulic removal of fines.

Inspection reports for weirs should document the:

- magnitude of each river flow event since last report
- comment on the relative upstream and downstream water levels
- any repairs and maintenance resulting from each flow event
- comments on the operation of mechanical equipment (eg gates, bags) during flow events.

Notes

Notes

Queensland Government
Natural Resources and Mines

DEPARTMENT OF NATURAL RESOURCES AND MINES

QUEENSLAND DAM SAFETY MANAGEMENT GUIDELINES

This version approved February 2002

'DERM-11'

Department of Environment
and Resource Management

DS 5.1 Flood mitigation manual for a dam

WIR/2009/3991 – Version 1

Endorsed 28/10/2010
by Peter Allen, Director, Dam Safety (Water Supply), Office of the Water Supply Regulator

Queensland Government

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Table of Contents

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Version History

Version	Date	Comment
1	28/10/2010	Original Approval

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Purpose

To provide a framework for assessing a flood mitigation manual for a dam required by the chief executive under Chapter 4, Part 2 of the *Water Supply (Safety and Reliability) Act 2008* (the Act). This section of the Act provides the chief executive with the power to approve, by gazette notice, a flood mitigation manual for a dam.

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Rationale

Under s. 370 of the Act owners of dams prescribed by regulation under s. 370 must prepare a flood mitigation manual for their dams for approval by the chief executive.

The Explanatory Note to the Water Supply (Safety and Reliability) Bill (at page 122) states:

"A dam nominated in the regulation will be a dam which was constructed for the purpose of flood mitigation. A flood mitigation manual ensures that such dams make controlled releases of water for flood mitigation purposes in accordance with pre-agreed conditions."

At the time of writing, no regulation under s. 370 had been made. There are however existing manuals for three dams approved under the former Water Act 2000 that are taken to be manuals approved under s. 371 by force of the transitional provisions set out in s.613. The three dams are Wivenhoe, Somerset and North Pine. The most recent approval dates for each of these dams are:

- North Pine Dam, gazetted on 28 September 2007;
- Wivenhoe and Somerset Dams (approval for one manual for both dams), gazetted on 22 January 2010.

The chief executive may also require the dam owner to amend the flood mitigation manual by a notice (s. 372 of the Act). The dam owner must provide the chief executive with a copy of the flood mitigation manual for approval. The chief executive may also get advice from an advisory council before approving the manual. At the time of writing no advisory councils were in existence.

Before an approval for the flood mitigation manual for a dam expires, the owner of the dam must review and if needed update the manual (s. 373). The dam owner must then provide the chief executive with a copy of the updated flood mitigation manual for approval under s. 371 of the Act. This work procedure currently only has application to this review and further approval process for the three dams listed above.

An owner of a dam who observes the operational procedures in a flood mitigation manual, approved by the chief executive, does not incur civil liability for an act done, or omission made, honestly and without negligence in observing the procedures in the manual (s. 374).

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Procedure

This work practice is set out below.

A flow chart for this work practice can be found in Attachment A <attachments/ds5-1-fmm-flowchart-a.pdf> .

Note: any reference in this work practice to a flood mitigation manual may also be a reference to an amended flood mitigation manual received under ss. 372 or 373 of the Act.

Step 1 - Receiving a flood mitigation manual

Upon receiving the flood mitigation manual (or amended flood mitigation manual) the project officer:

- Stamps the covering letter (or a copy of the front page and contents page of the manual if there was no covering letter) with the Document received by DERM stamp
- Scans the document (or copy created above) and records details in Keeper on the flood mitigation manual file for the dam and fills in the relevant sections of the Document received stamp in accordance with local office processes and departmental standards
- Updates WICD–RDR
- Prepares an acknowledgement letter to the dam owner that the flood mitigation manual has been received and is being assessed. Refer to Attachment B <attachments/ds5-1-fmm-ack-let-b.pdf> for a template for an acknowledgement letter (A template for this letter is available in G:\WIR\Dam_Safety\Templates).
- Gives all documents and the file (if required) to the decision maker.

The decision maker:

- Checks and signs the letter confirming receipt of the manual. If changes are necessary to the draft letter confirming receipt of the manual, the decision maker should make the changes and return the letter to the Project Officer for updating prior to signing.
- Allocates an action officer to process the manual (the decision maker may also be the action officer)
- Gives the signed letter, the manual and the file to the project officer.

The project officer:

- Copies and sends the signed letter.
- Scans the signed letter and registers the letter in Keeper in accordance with local office processes and relevant departmental standards.
- Places the copy of the signed letter on the file relating to the flood mitigation dam.
- Updates WICD–RDR with appropriate information.
- Gives the manual and file to the action officer.

Proceed to Step 2

Step 2 - Action officer conducts an assessment of the flood mitigation manual

The action officer:

- Conducts a detailed assessment of the flood mitigation manual. Action officers are expected to conduct the detailed assessment having regard to the matters outlined in any relevant guidelines and the Flood Mitigation Manual (FMM) Assessment and Decision Form and the notes in that form (see Attachment C <attachments/ds5-1-fmm-a-d-form-c.pdf> . A template for this form is available in G:\WIR\Dam_Safety\Templates).

- Completes the FMM Assessment and Decision Form as the assessment occurs.

The purpose of the checklist in the FMM Assessment and Decision Form is to assist the action officer to determine whether the flood mitigation manual complies with the Act and any relevant guidelines and to enable the action officer to make a recommendation on whether the flood mitigation manual should be approved. However, action officers should note that the checklist in the FMM Assessment and Decision Form is not intended to be relied upon by action officers as an exact statement of the Act and any guidelines and it is essential that action officers regularly refer to the full text of those documents to determine the precise details of these requirements.

Discussions with dam owners and other stakeholders may be undertaken to refine the content of the manual and to ensure that the flood mitigation manual is adequate for its required purpose. See step 3.

In completing the FMM Assessment and Decision Form the action officer:

- Records on the FMM Assessment Checklist whether the manual complies with the Act and any guidelines
- Includes appropriate comments in the FMM Assessment Checklist about individual items (in the comments column for the appropriate item/s). Note: if the action officer believes additional information or clarification of information is required proceed to step 3 prior to completing this step.
- Completes the 'Action officer's recommendation to decision maker' part of the FMM Assessment and Decision Form, including all items that are relevant to the recommendation/s made.
- Gives the FMM Assessment and Decision Form, the manual and the file to the decision maker.

Action officers should be aware that the information and documents referred to in the FMM Assessment and Decision Form and kept and retained in Keeper and on departmental file/s may later need to be made available to the decision maker, or other people, for independent consideration or inspection.

Proceed to Step 4.

Step 3 - Request further information

In some situations the action officer may need to communicate with the owner of the dam, or other people, to clarify certain issues for the assessment of the flood mitigation manual. **Accurate and written records of any communications, including verbal communications, must be kept and retained in Keeper and on the relevant Departmental file.** These records should indicate who was contacted or consulted about particular issues, when this occurred and the advice that was given. It may also be appropriate for the action officer to make some reference to these communications in the FMM assessment and decision form itself (for example, in the comments column for the appropriate item/s in the flood mitigation checklist).

Action officers should be aware that the information and documents referred to in the FMM assessment and decision form and kept on departmental file/s may later need to be made available to the decision maker, or other people, for independent consideration or inspection.

A suggested format for a letter requiring further information can be found at Attachment D <attachments/ds5-1-fmm-req-info-d.pdf> . A template for this letter is available in G:\WIR\Dam_Safety\Templates.

The letter requiring further information must:

- Be prepared on the basis of the information contained in the FMM assessment and decision form (see step 2); and
- Be sent to the owner of the dam.

If the department does not receive any information from the dam owner in response to the request for further information, the action officer must discuss appropriate action to take with the decision maker.

Return to step 2 when requested information is received.

Step 4 - Decision maker makes decision about flood mitigation manual

The decision maker:

- Considers the flood mitigation manual and the recommendation made by the action officer.
- Decides what action should be taken in relation to the manual. Decision makers are expected to assess the appropriate action to take having regard to the matters outlined in the FMM Assessment and Decision Form and the notes to that form (Attachment C <attachments/ds5-1-fmm-a-d-form-c.pdf>).
- Completes the 'Decision maker's decision' part of the FMM Assessment and Decision Form.
- Gives the completed FMM Assessment and Decision Form, the manual and the file to the action officer.

Depending on the situation, available options for the decision maker may be to:

- Not approve the manual because it does not meet the expected requirements for approval. *Go to Step 5.*
- Approve the manual – *Go to Step 7.*
- Require more information from the dam owner – *Go to Step 3.*
- Require a more detailed assessment of the FMM by the action officer – *Go to Step 2.*

If the decision maker decides more information is required from the dam owner, they should indicate this on the Assessment Checklist and return all documentation to the action officer who will *return to step 2.*

Step 5 - Action officer prepares letter rejecting flood mitigation manual

Note: This step should only be taken if the action officer/decision maker has been unable to get appropriate changes made by the dam owner to the manual to make it suitable for approval. It is very unlikely that this would occur as it is in the best interests of the dam owner to have an approved flood mitigation manual as the dam owner is then indemnified against civil liability for an act done, or omission made, honestly and without negligence when observing the procedures in the manual.

Action officer receives the decision to not approve the manual from the decision maker and prepares a draft letter (including yellow file copy) advising of non-approval of the flood mitigation manual. See Attachment E <attachments/ds5-1-fmm-reject-let-e.pdf> for a template. A template for this letter is available in G:\WIR\Dam_Safety\Templates

Action officer gives the draft letter to the decision maker who either signs the letter or requests changes to be made.

Once the decision maker has signed the letter the action officer sends the letter to the dam owner.

If an amended flood mitigation manual is received from the dam owner *return to step 1.*

If a dam owner chooses not to prepare an amended manual they will no longer be indemnified against civil liability under the Act once the approval period has expired for the current approved manual, however, it is not an offence to not have a flood mitigation manual and no further action should be taken if they choose to not submit another manual. *Go to step 8.*

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Step 6 - Action officer prepares gazette notice

Action officer receives the decision to approve the manual from the decision maker and prepares a notice of draft gazette notice and memo for the Executive Council Team (Cabinet and Parliamentary Services, DERM).

The gazette notice should state the following:

- The notice number and year
- The name of the dam to which the flood mitigation manual applies
- The number of years for which the manual is approved. Where the manual is an amendment required by the chief executive the approval may be for the balance of the original five years or for a period of not more than 5 years as per the normal approval of a manual.

Note: see Attachment F <attachments/ds5-1-fmm-gaz-notice-f.pdf> for a draft template of the gazette notice. See Attachment G <attachments/ds5-1-fmm-gaz-memo-g.pdf> for the covering memo to the executive council team. A template for these documents is available in G:\WIR\Dam_Safety\Templates

Once the notice and memo has been prepared it must be signed off by the Director, Dam Safety (Water Supply) (or a higher position) and sent to the Senior Project Officer, Executive Council, Cabinet and Parliamentary Services with a covering briefing note. The electronic version of the gazette notice must also be sent by email. The executive council team will arrange for publication of the notice in the gazette and will advise the action officer by email of the publishing of the notice (a copy of the published notice is usually included in the email). *Go to step 7 when gazettal has taken place.*

Step 7 - Letter sent to dam owner advising of approval of manual

The action officer prepares draft letter (including yellow file copy) to dam owner advising of approval of the manual and enclosing a copy of the gazette notice. See Attachment H <attachments/ds5-1-fmm-app-let-h.pdf> for a template. A template for this letter is available in G:\WIR\Dam_Safety\Templates.

Action officer gives the draft letter and copy of the gazette notice to the decision maker for signing.

Once the letter has been signed by the decision maker the project officer sends the letter and gazette notice to the dam owner.

Go to step 8.

Step 8 - Action officer takes appropriate action with respect to RDR, the file and departmental records

The action officer:

- conducts a final check to ensure all relevant data has been entered into WICD–RDR.
- checks the completed FMM Assessment and Decision Form has been signed by the action officer and decision maker, and that this form and all other documents created or received during the course of this work practice have been placed on the appropriate departmental file/s.
- returns the departmental file to the project officer who will check that all relevant documents have been registered in Keeper. If not, the project officer will register the documents in Keeper in accordance with local office processes and relevant departmental standards.

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The assessment of a flood mitigation manual is complete.

Responsibilities

The dam owner must give the chief executive a copy of the flood mitigation manual for the dam for the chief executive's approval.

Section 371 of the *Water Supply (Safety and Reliability) Act 2008* gives the chief executive the power to approve the flood mitigation manual for a dam.

At the time of writing, the *Water Supply (Chief Executive) Delegation (No. 1) 2010* was in force. Under that instrument of delegation, the powers of the chief executive relating to flood mitigation manuals for dams under the Act were delegated to the following positions:

- Director, Dam Safety (Water Supply), Office of the Water Supply Regulator;
- Director, Water Industry Asset Management and Standards, Office of the Water Supply Regulator;
- General Manager, Office of the Water Supply Regulator.

Decision makers must ensure that they have, at the time of making their decision, a current delegation allowing them to make their decision. This is important as instruments of delegation can be revoked and replaced from time to time.

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Definitions

"the Act" – means the *Water Supply (Safety and Reliability) Act 2008*

"chief executive" – means the Director-General, Department of Environment and Resource Management

"dam" –

1. *Dam* means–
   - Works that include a barrier, whether permanent or temporary, that does or could impound water; and
   - The storage area created by the works.
2. The term includes an embankment or other structure that controls the flow of water and is incidental to works mentioned in paragraph (1) above.
3. The term does not include the following:
   - A rainwater tank;
   - A water tank constructed of steel or concrete or a combination of steel and concrete;
   - A water tank constructed of fibreglass, plastic or similar material.

"decision maker" – the person making the decision on whether to approve or request a change to a flood mitigation manual for a dam, under this work practice.

"flood mitigation manual" – means a manual prepared under s. 370, or amended under ss. 372-373, and approved under s. 371 or s. 372 of the Act.

"manual" – means a flood mitigation manual

"reasonable belief" – a reasonable belief does not have to be one that is completely without doubt, but it must also not rely on mere speculation, suspicion, guesses or assumptions that have been made without any foundation.

A reasonable belief is, generally, a belief based on information:

- reasonably believed to be reliable and accurate; and
- available to the decision maker.

"referable dam" – is a dam, or a proposed dam after its construction, for which –

- A failure impact assessment is required to be carried out under the Act; and
- The assessment states the dam has, or the proposed dam after its construction will have, a category 1 or 2 failure impact rating; and
- The chief executive has, under s. 349, accepted the assessment.

The term does not include –

- A hazardous waste dam;
- A weir, unless the weir has a variable flow control structure on the crest of the weir.

"registered professional engineer" – means a registered professional engineer, a registered professional engineering company or a registered professional engineering unit as defined under the *Professional Engineers Act 2002.*

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References

The following documents should be referenced in conjunction with this work practice:-

- *Water Supply (Safety and Reliability) Act 2008*
- *Water Supply (Chief Executive) Delegation (No. 1) 2010*
- Queensland dam safety management guidelines
- Acceptable flood capacity for dams guidelines
- Failure impact assessment guidelines

Officers involved in this work practice should also be familiar with, and comply with, requirements of the following departmental standards:

- Departmental policy RKP/2006/2907 – Recordkeeping overarching policy
- Departmental policy RKP/2006/2899 – Recordkeeping email policy
- Departmental standard IMP/2005/2253 – Procedures for using electronic mail
- Departmental standard ADM/2005/941 – Paper-based document management
- Departmental standard ADM/2002/965 – Decision making and requests for statements of reasons under the *Judicial Review Act 1991*
- Departmental standard ADM/2003/1402 – Information privacy.

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Legislation

Water Supply (Safety and Reliability) Act 2008

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Attachments

Attachment A - Flowchart <attachments/ds5-1-fmm-flowchart-a.pdf>

Attachment B - Acknowledgement letter <attachments/ds5-1-fmm-ack-let-b.pdf>

Attachment C - Assessment and decision form <attachments/ds5-1-fmm-a-d-form-c.pdf>

Attachment D - Request for information letter <attachments/ds5-1-fmm-req-info-d.pdf>

Attachment E - Reject flood mitigation manual letter <attachments/ds5-1-fmm-reject-let-e.pdf>

Attachment F - Gazette notice <attachments/ds5-1-fmm-gaz-notice-f.pdf>

Attachment G - Covering memo for gazette notice <attachments/ds5-1-fmm-gaz-memo-g.pdf>

Attachment H - Approval of flood mitigation manual letter <attachments/ds5-1-fmm-app-let-h.pdf>

'DERM-12'

Queensland Government

Department of
Environment and Resource Management

Ref CTS 04331/11

Mr Peter Borrows
Chief Executive Officer
Seqwater
PO Box 16146
CITY EAST QLD 4002

Dear ~~Mr Borrows~~ Peter

On 11 March 2011, you submitted the document titled: *January 2011 Flood Event: Report on the Operation of North Pine Dam.*

In that document a number of issues were raised relating to the dam's safety.

On p.124 it is stated: "...During the January 2011 Flood Event, a peak water level of 41.11m was reached. According to the dam design study this should occur during an event approaching an AEP of 1:10,000. The AEP of the event rainfall does not support a flood of this rarity ..." Further, on p.7 it is stated: "...Preliminary post-event analysis shows the Flood Event impacting North Pine on Tuesday 11 January 2011 had an AEP of approximately 1 in 200..."

Based on these two statements, the Report appears to raise issues which need to be evaluated in relation to the ability of North Pine dam to manage rare flood events.

On p.6 of the Report it is stated: "...The peak water level of 41.11m reached during the Event was only 0.5m below the level of the radial gates' switch gear. If the switch gear is inundated, normal control of the radial gates is lost and the back-up system is initiated. For safety reasons, this situation is avoided if at all possible..."

I concur with Seqwater's concern about this situation.

I understand that Seqwater has initiated action to investigate both of these issues, and develop possible solutions, including interim risk mitigation measures.

I request your urgent advice on the scope and timings of the investigations into these matters, (including risk mitigation measures), and any other actions being taken to resolve them.

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Queensland 4001 Australia
Telephone + 61 7 3330 6301
Facsimile + 61 7 3330 6306
Website www.derm.qld.gov.au
ABN 46 640 294 485

In particular, I would appreciate receiving your urgent advice as to any risk mitigation measures that Seqwater proposes to take, or considers other agencies should take, while the investigations referred to in the previous paragraph are in progress.

If you have any queries concerning this letter please telephone Mr Peter Allen, Director, Dam Safety of the department on telephone [redacted]

I have provided a copy of this correspondence to the Queensland Floods Commission of Inquiry for information.

Yours sincerely

[redacted]

John Bradley
Director-General

CC: Justice Catherine Holmes
Chair of the Queensland Floods Commission of Inquiry
PO Box 1738
BRISBANE QLD 4001

'DERM-13'

seqwater
WATER FOR LIFE

24 February 2011

Mr Peter Allen
Director, Dam Safety (Water Supply)
Department of Environment and Resource Management
Level 3, Mineral House
41 George Street
BRISBANE QLD 4000

Dear Peter,

Flood Event Reports – Request for Extension of Time

As you are aware, Seqwater is obliged under clause 2.9 of the Flood Mitigation Manuals for Somerset and Wivenhoe Dams and North Pine Dam ("**Manuals**") to prepare and submit a report to the Chief Executive within 6 weeks after each flood event. These reports are required to contain "details of the procedures used, the reasons therefore and other pertinent information". Seqwater is also obliged under clause 7.4 of the Manuals to submit a report, within the same time frame after each flood event, on the effectiveness of the operational procedures contained in the Manuals.

The nature and extent of the current wet season has resulted in numerous, closely spaced, individual flood events occurring in October 2010, December 2010 and January 2011. The most recent flood event occurred at North Pine Dam on Monday 21 February 2011. The frequency and duration of these events has required the Flood Operations Engineers to necessarily spend the majority of their time this season physically managing flood events.

The Manuals require submission of a report for each flood event. Unfortunately, one consequence of the nature and duration of the consecutive events that have occurred since October 2010 is that the Flood Operations Engineers have been unable to prepare and submit the reports required under the Manuals for the October and December 2010 flood events within the stipulated time.

You may also be aware that a 20 January 2011 letter from the Honourable Stephen Robertson MP, Minister for Natural Resources, Mines and Energy and Trade to Seqwater's Chairman emphasised that it was essential for the report under the Manual for Wivenhoe and Somerset Dams relating to the January 2011 flood event to be completed within the 6 week Manual timeframe. Given the above Ministerial request and the –

- rare and large nature of the January 2011 flood event; and
- announced Terms of Reference of the Commission of Inquiry;

Seqwater has to date been focussing primarily on preparation of the January 2011 flood event report for the Wivenhoe and Somerset Dams.

We note from our discussions with you that the required report submission date for the January 2011 flood event reports is 2 March 2011. We are pleased to advise that the report in respect of the Wivenhoe and Somerset Dams will be delivered to you by the 2 March 2011 submission date.

Seqwater was also requested in the Minister's letter of 20 January 2011 to give consideration (from a flood mitigation perspective) in respect of the Full Supply Level at Wivenhoe and Somerset dams 'as a matter of priority and urgency'. Seqwater has addressed this separate request and work in this regard has necessarily been actioned in tandem with preparation of the January 2011 flood event report in respect of the Wivenhoe and Somerset Dams.

Given the unprecedented level of activity for Seqwater staff, including dealing operationally with continued rainfall and dam openings, there has been little opportunity for the Flood Operations Engineers to finalise the following reports under the Manuals –

- report for the October 2010 flood event for the Wivenhoe, Somerset and North Pine Dams;
- report for the December 2010 flood event for the Wivenhoe, Somerset and North Pine Dams; and
- report for the January 2011 flood event report in respect of North Pine Dam only.

Accordingly, Seqwater confirms its verbal requests for formal extensions to be granted by the Chief Executive in respect of the above report. From our recent discussions with you and the Flood Operations Engineers, we understand this situation is not without historical precedent and we note that, in previous unusually wet seasons, reporting extensions have been granted for up to 6 months after individual flood events. We therefore do not consider it unreasonable to seek extensions for submission of post-event reports.

The extensions requested are –

1. Seqwater seeks a short extension to 11 March 2011 for submission of the January 2011 flood event at North Pine Dam. This report will become our highest priority for completion and submission as soon as the report for the Wivenhoe and Somerset Dams for January 2011 is completed.

2. Seqwater seeks an extension to 31 May 2011 for submission of the October 2010 and December 2010 flood event reports for the Wivenhoe, Somerset and North Pine Dams, and the February 2011 flood event report for North Pine Dam. In the context of the present wet season, these reports are of less urgency as there was no damage or extra flood mitigation implications arising from these events.

The requested extensions are sought to allow the Flood Operations Engineers sufficient time to review the events and prepare the reports without unreasonable time pressures given the tempo of events this season and the need to manage personnel availability and capacity in order to ensure continued preparedness in case another flood event occurs this season. The Flood Operations Engineers currently have no capacity to safely accelerate finalisation of the above reports ahead of these dates.

It should also be noted that the Flood Operations Engineers will continue to monitor the rainfall situation and systems on a rotational basis during this period in case of a possible further mobilisation. In the event that further flood events occur during this period an additional extension may be required, however we will write to you promptly should this occur.

We look forward to your response.

Yours sincerely,

[redacted]

Peter Borrows
Chief Executive Officer

'DERM-14'

Queensland Government

Ref CTS 03378/11

Department of
Environment and Resource Management

- 8 MAR 2011

Mr Peter Borrows
Chief Executive Officer
Seqwater
PO Box 16146
CITY EAST QLD 4002

Dear ~~Mr Borrows~~ Peter

Thank you for your letter dated 24 February 2011 concerning the extension of time for submitting flood event reports required under the Wivenhoe/Somerset and North Pine Flood Mitigation Manuals.

Due to the numerous flood events during the last few months, and the extensive workload they (and related matters) have caused your staff, I approve the extension of reports that are currently or will be shortly overdue to the dates as stated below:

- An extension to 11 March 2011 for the submission on the January 2011 flood event for North Pine Dam.
- An extension until 31 May 2011 for the submission on the following events:
  - October 2010 and December 2010 flood events for Wivenhoe, Somerset and North Pine Dams; and
  - February 2011 flood event for the North Pine Dam.

Should you have any further enquiries, please do not hesitate to contact Mr Peter Allen, Director, Dam Safety of the Department of Environment and Resource Management on telephone [redacted]

Yours sincerely

[redacted]

John Bradley
Director-General

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Website www.derm.qld.gov.au
ABN 46 640 294 485

'DERM-15'

Toowoomba Floods
Flood Retention Basins
Inspection Report

Design Philosophy

Toowoomba has a centrally draining storm water system which contains a substantial number of ponds some of which have functions ranging from ornamental to flood mitigation by retention ponds. East Creek and West Creek receive most of the storm drainage from the southern suburbs of Toowoomba. Both these creeks drain to the central business district (CBD) where they join to become Gowrie Creek which drains to the North and then to the West of Toowoomba. Suburban drainage systems are usually designed to manage storms more frequent than a particular AEP. According to the Insurance Council of Australia report on the Toowoomba Flood the piped drainage system is designed for 2 year ARI in the suburbs and up to 5 year ARI in the CBD..

Peak discharges from natural storms can be mitigated by the inclusion of retention basins along the drainage lines. By storing and releasing of runoff the flows in drains will be less but of a longer duration. This also reduces the risk of flooding areas outside of the drains themselves.

Background

On 10/1/2011 a storm cell passed slowly in a South Westerly direction over the Southern suburbs of Toowoomba, dumping up to 120 mm of rainfall in a short period of time (less than 40 minutes). The resultant flows in both East Creek and West Creek exceeded the capacity of culverts and storm drains in the CBD with resultant flooding of property, damage to cars and high risk to persons, including loss of life.

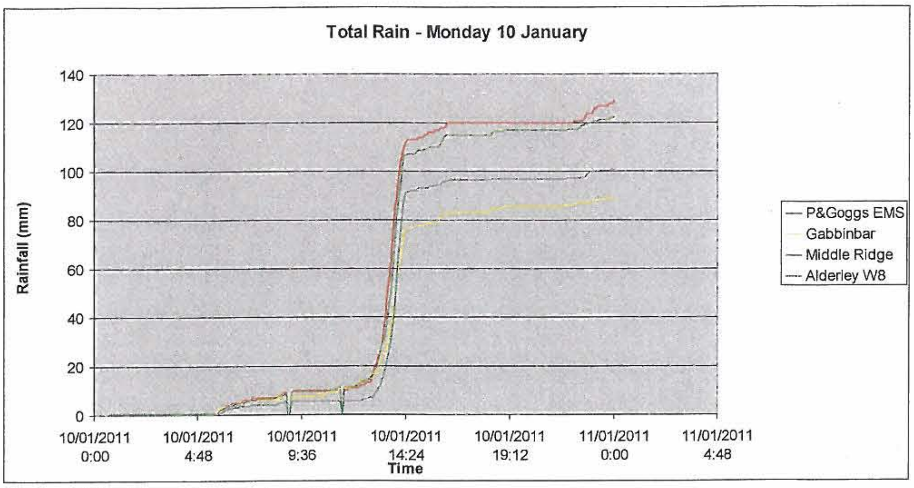


Figure 1 Pluviograph Record of Storm

The flooding was well documented and pictorial records acquired by the Department of Environment and Resource Management (the department) from various sources are contained in Appendix B.

The department was aware that the drainage lines in Toowoomba contained ponds and retention basins of various sizes. While these features can be considered to be dams, none of these features automatically triggered the criteria requiring them to be Failure Impact Assessed. Some preliminary failure impact assessment work was initiated by the department in 2005 which indicated potential population at risk (people in dwellings), however this work was not finalised.

The department is aware that the sudden release of a significant volume of water into an existing flood can cause flood waves to develop. This release could be caused by the collapse of containment embankments of the ponds or retention basins. The mechanisms causing such a collapse could be embankment instability, overtopping and erosion, internal erosion and piping or structural failure of control measures.

The hydraulic behaviour of the flood in the CBD (refer Appendix B) contained standing waves and other hydraulic features associated with high energy flows which are sometimes associated with dam break floods.

Figure 2 Gowrie Creek in Flood

While there had been no reports of damage to the ponds and retention basins along East Creek and West Creek, the department considered that the features needed to be inspected to see if any had failed or otherwise contributed to the behaviour for the flooding.

Inspection 18/1/2011

The inspection team consisted of:

Russ McConnell Manager Containment Systems;
Gary Hargraves Principal Engineer Containment Systems; and
Bryan Potter Senior Project Officer.

Access to Toowoomba was restricted by flooding in the Lockyer Valley prior to this date. However it is unlikely that the flood damage situation along the creeks would have changed since the 10/1/2011.

Due to severe delays on the highway to Toowoomba the inspection started at about 1:00 pm.

West Creek was inspected first and then East Creek, starting from the CBD end of both creeks and moving upstream. The inspection of East Creek was cut short because of failing light conditions and storm activity. Bryan Potter returned on the 20/1/2011 accompanied by Senior Engineer, Robert Fowden, to systematically examine each pond and retention pond for damage and condition. His description and photographic record is contained in Appendix A.

Observations

None of the containment embankments failed during the storm, thus ruling out the possibility that embankment collapse during the flood could have caused a "dam break flood" within the flood.

Many of the ponds and retention basins had overtopped during the storm with erosion initiating at several containment embankments, usually on the downstream batters (Figures 67, 88, 89 & 99). In some instances crushed rock paving material on the crest walkways had eroded preferentially (Figure 86).

The absence of severe erosion is attributable to the shortness of the period of overtopping and erosion resistant nature of the downstream batters which consisted of flat sloped well grassed batters.

The only control structure to partially fail was the inlet to the Long Street Retention Basin – WC16 (Figures 107 &108). This controlled flow in a formed drain from the pond upstream. It is unlikely that the volume released by the failure of the entrance control would be significant enough to have caused a surge downstream. The flow into the Alderley Retention Pond had overtopped the road over the inlet control.

The outlet to the Long Street Retention Basin – WC14 (Figure 106 & 109) is small and the overtopping of this embankment in particular would probably result in a large increase in flow for a small increase in pond depth. Most of the severe channel erosion occurred downstream of this retention basin. (Figures 118 to 121). The embankment did overtop.

One embankment (Figure 91, 95 &98) had the appearance of severe erosion but later inquiries found that the land form was the result of earthworks carried out by TCC workers the day after the flood.

The trash rack devices on several smaller outlets accumulated debris during the storm event. The restriction of such devices will increase the risk of overtopping the embankments.

Conclusions

On-site inspections by DERM officers revealed that no embankments associated with the ponds and retention basins collapsed during the storm, thus eliminating the possibility that the flood was aggravated by the collapse of a built structure.

The behaviour of the flood was probably the result of the interaction of the storm conditions and the drainage system.

Actions:

Whilst the flood event did not cause the collapse of any pond or retention basin along East Creek or West Creek, but given that there has been further development of ponds / retention basins on these creeks, the department's Dam Safety unit should re-examine whether a failure impact assessment should be completed for one or more of these structures including the impact of cascade failure.

A copy of this report should be forwarded to Toowoomba Regional Council

Report by

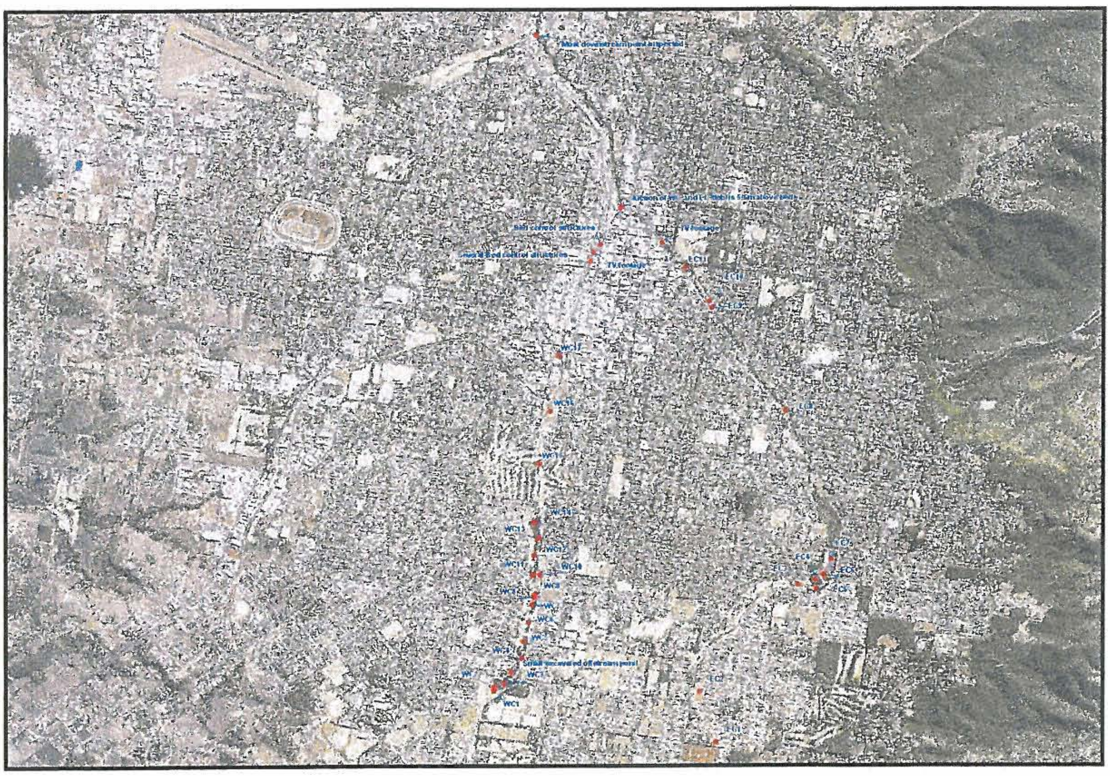
Russ McConnell
Manager Containment System, OWSR
Department of Environment and Resource Management.

APPENDIX A
Inspection Photographs and Map

Formatted Table

Dam identifier	Comments
East Creek 1 (EC1 Most Upstream)	Earth embankment 3.1m high with large capacity pipe (approx 1m) at GL, overtopping spillway 300mm below crest over pipe, no evidence of overtopping
EC2	Earth embankment approx 4m high, 3.7m from FSL to crest level, no evidence of overbank bywash, no overtopping, outlet is piped for 350m and emerges at Daffodil St
EC3	Largely an excavated structure that overtops at or near GL, drop inlet at same level, overtopped by at least 500mm possibly 1m,
EC4	Earth embankment approx 2.0m high, grassed spillway 300mm above drop inlet level with crest 600mm above drop inlet, overtopped crest by approx 200mm.
EC5	Earth embankment approx 2.5m high, on side gully of EC, grassed spillway E end (0.7m below crest) and W end(1.1m below crest), no drop inlet, almost overtopped crest on E end, some bywash erosion
EC6	Earth embankment approx 2.0m high, grassed spillway same level as drop inlet level with crest 400mm above, overtopped crest by approx 300mm.
EC7	Sheet pile weir 300mm above GL, overtopped by at least 1.2m of flow, overtopped side wall on E perimeter as well.
EC8	Weir type structure under Kitchener St crossing, road submerged, erosion to abutments, bridge in pondage area 1.8m above FSL was submerged.
EC9	1.2m high Earth and concrete sill basin, with several drop inlets piped to outlets 480m downstream, Herries St overtopped and is 2.6m above crest of earth embankment
EC10	3 Concrete basins at or below ground level, some erosion ds
EC11	Concrete Weir like structure 1.7m high, Flood level some 3m above bed, flows overtopped Margaret St
West Creek (WC1Most Upstream)	Rock and concrete protected weir type structure overtopped by significant depth of flow, no apparent damage
WC2	Rock and concrete protected weir type structure overtopped by significant depth of flow no apparent damage
WC3	Rock and concrete protected weir type structure overtopped by significant depth of flow, no apparent damage, flows overtopped Spring Street Road crossing immediately ds (pond/excavation ds Spring St LB is off main channel)
WC4	Concrete structure overtopped, some ds erosion, no apparent damage to structure
WC5	Earth embankment approx 4.3m high, grassed spillway 900mm below crest, drop inlet level 2.0m below crest, overtopped crest by approx 200 - 300mm, some erosion on toe of wall
WC6	Earth embankment approx 4.2m high, grassed spillway 600mm below crest, drop inlet level 2.5m below crest, overtopped crest by approx 100 - 200mm.
WC7	Rock and concrete protected weir type structure overtopped by significant depth of flow no apparent damage immediately ups of Stenner St
WC8	Weir or concrete sill forming bed control structure mostly below bed no higher than 300mm, no apparent damage
WC9	Weir type structure approx 1.2m high, no apparent damage.
WC10	Rock and concrete protected weir type structure, approx 2m overtopped by significant depth of flow no apparent damage

WC11	Rock and concrete protected weir type structure with drop inlet for passing low flows overtopped by significant depth of flow no apparent damage, is located to the W of main channel
WC12	Rock and concrete protected weir type structure approx 1.0m high with debris 1.6m above crest
WC13	Earth embankment and rock protected spillway, main channel flows past this storage, inflow predominantly from local RB catchment
WC14	Earth embankment approx 4.0m high, grassed spillway section 100mm below crest, drop inlet level 3.1m below crest, overtopped crest by approx 100 - 200mm, Council breached section of wall after flow event
WC15	Weir type / crossing structure approx 2.8m high, damage to ds batter and RB abutment, crest largely intact, however some undermining is apparent
WC16	Earth embankment approx 1.5m high with large excavated capacity, 4.9m from concrete control to Crest, possible high flow spillway LB 300mm below crest, crest overtopped by 200mm, no apparent damage
WC17	Excavated pond and surrounds off main channel, was inundated by flows out of lined channel to the East, no apparent damage



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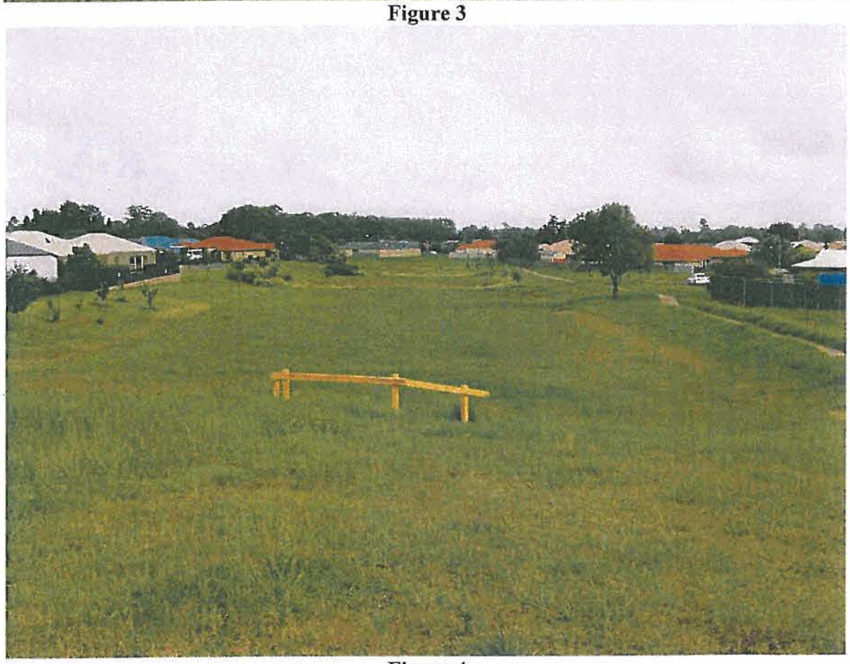

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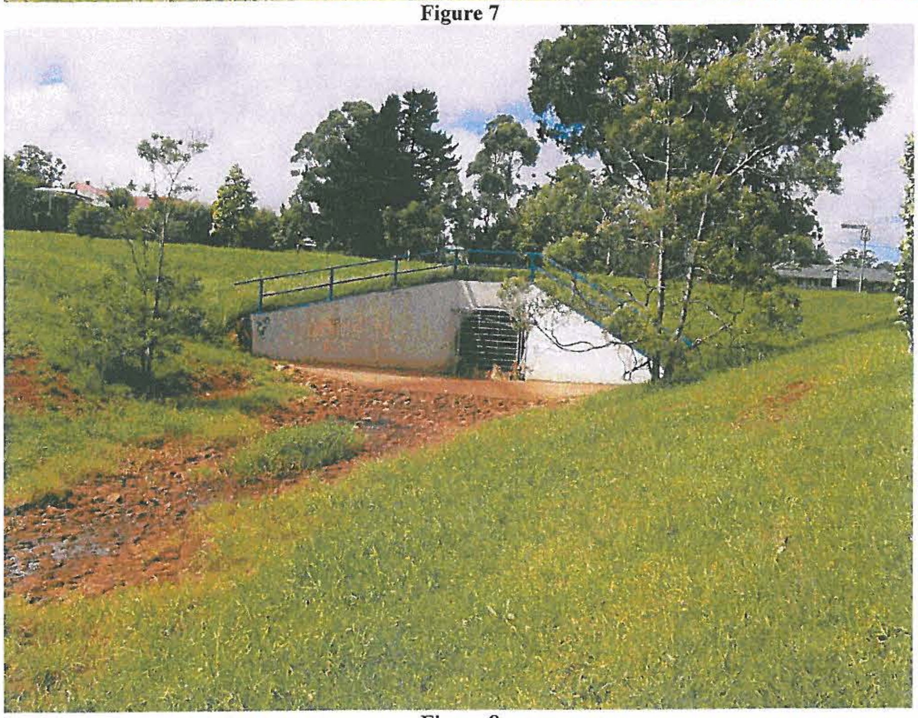

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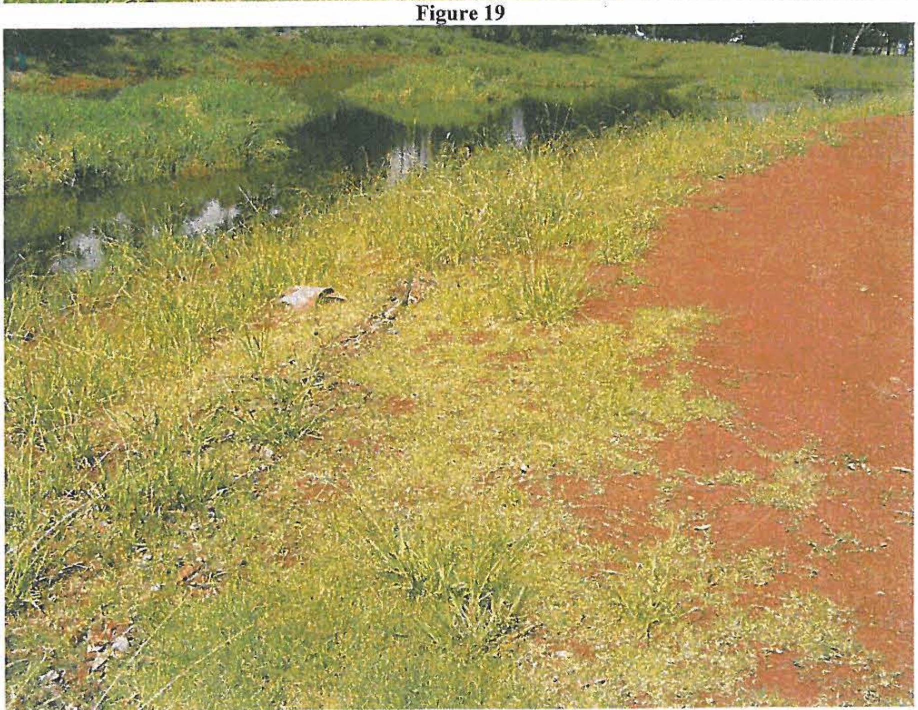

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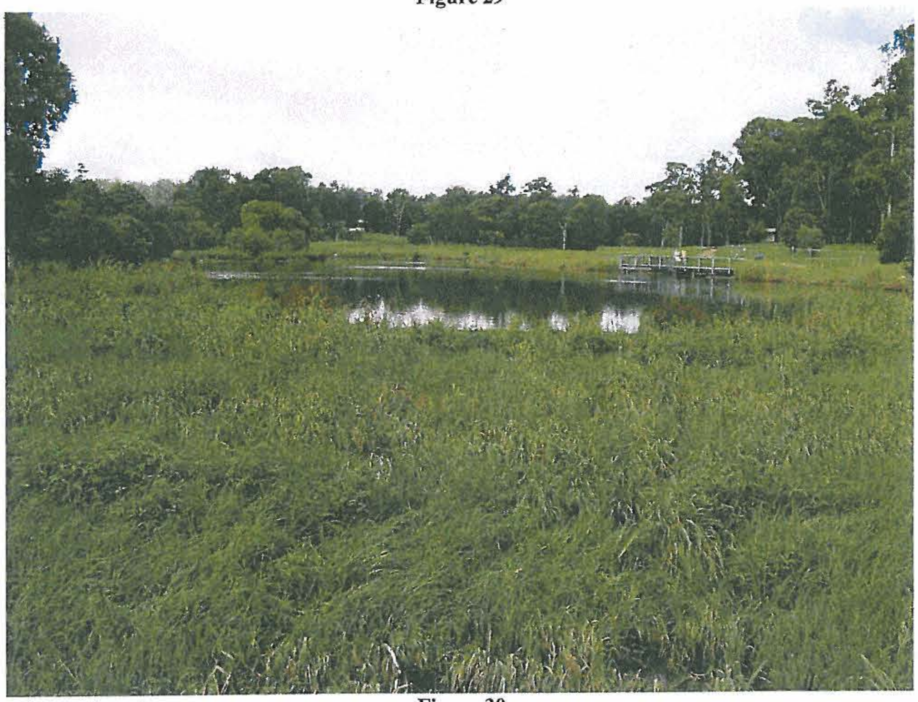

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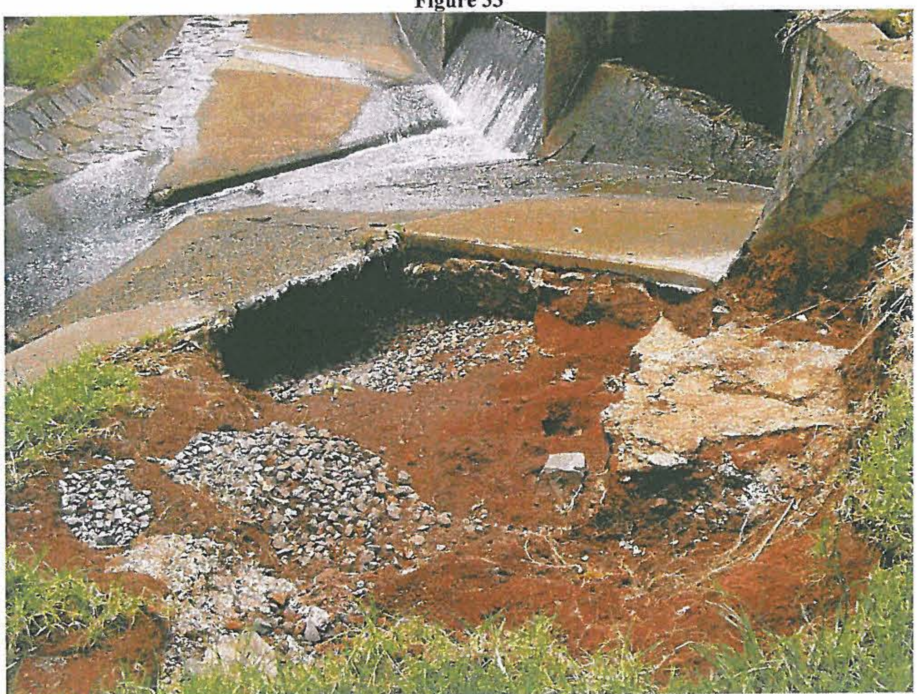

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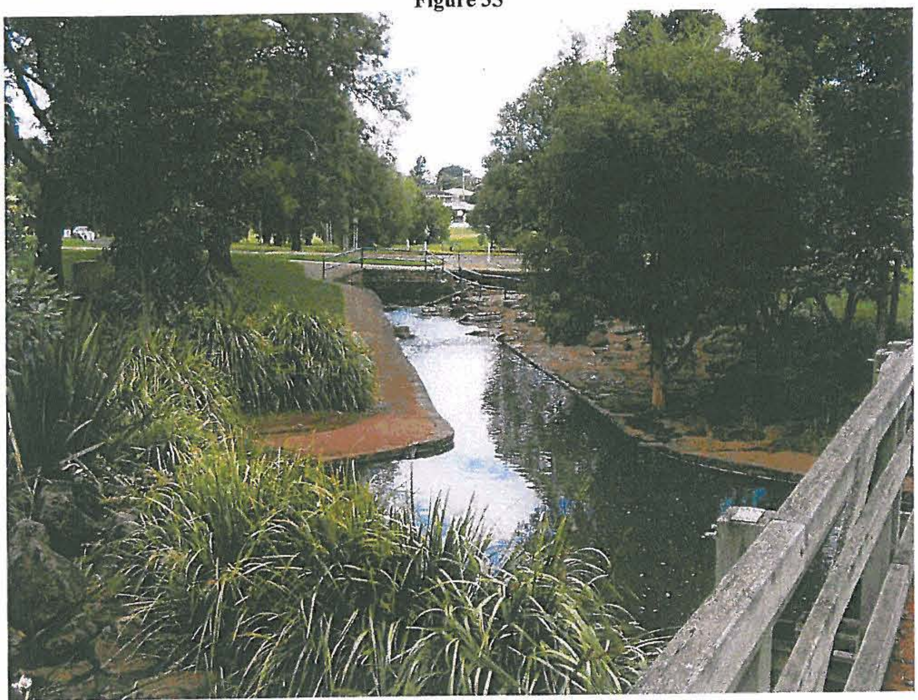
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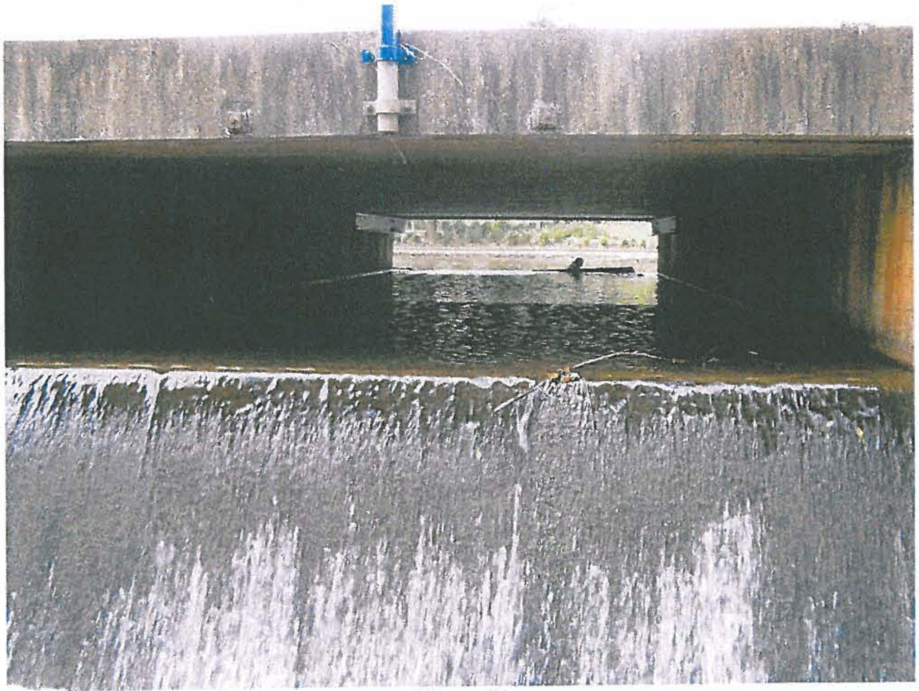

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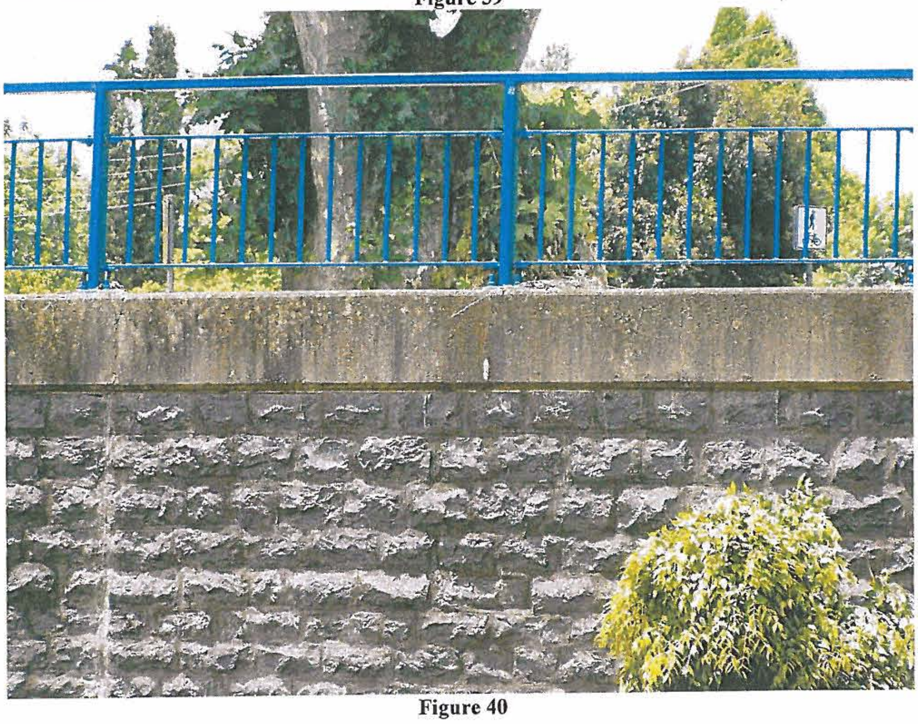

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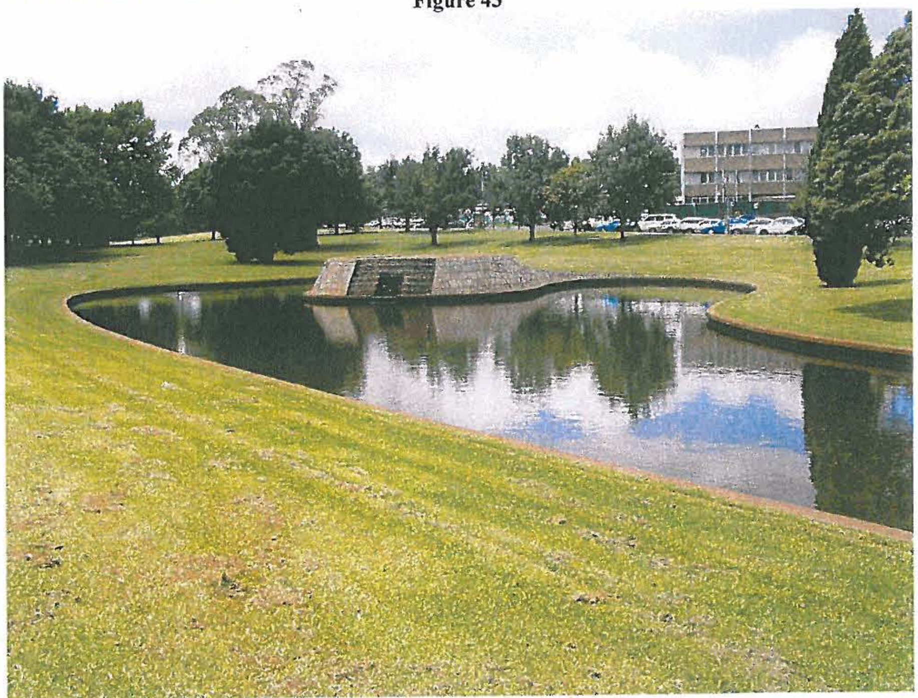

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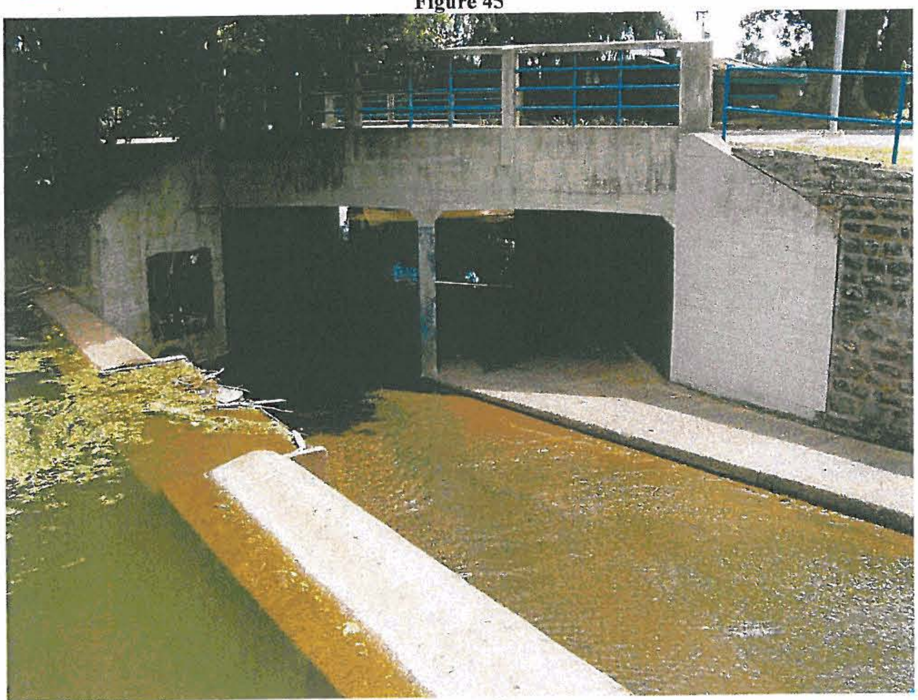

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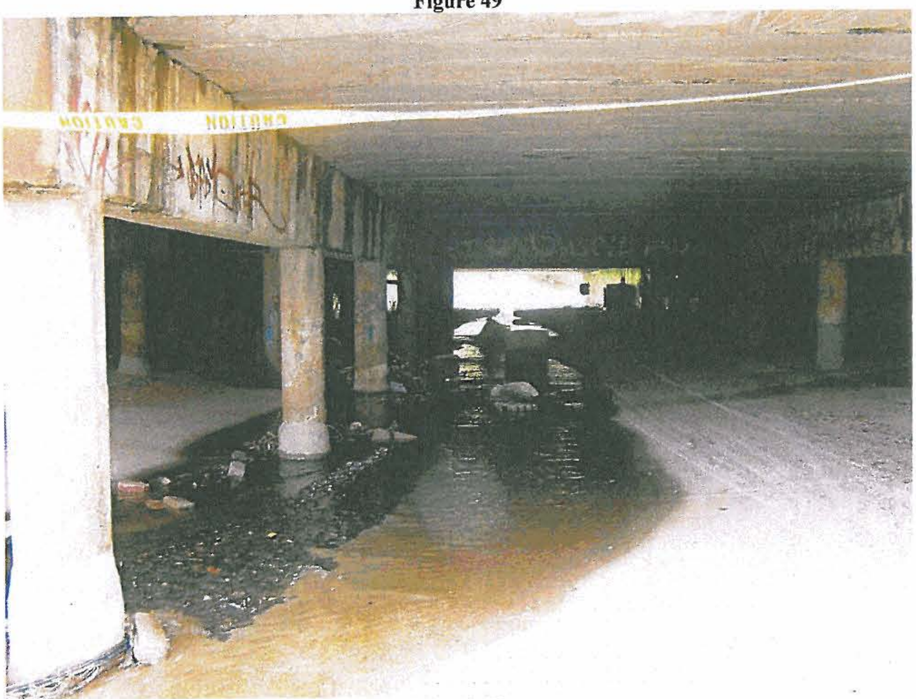

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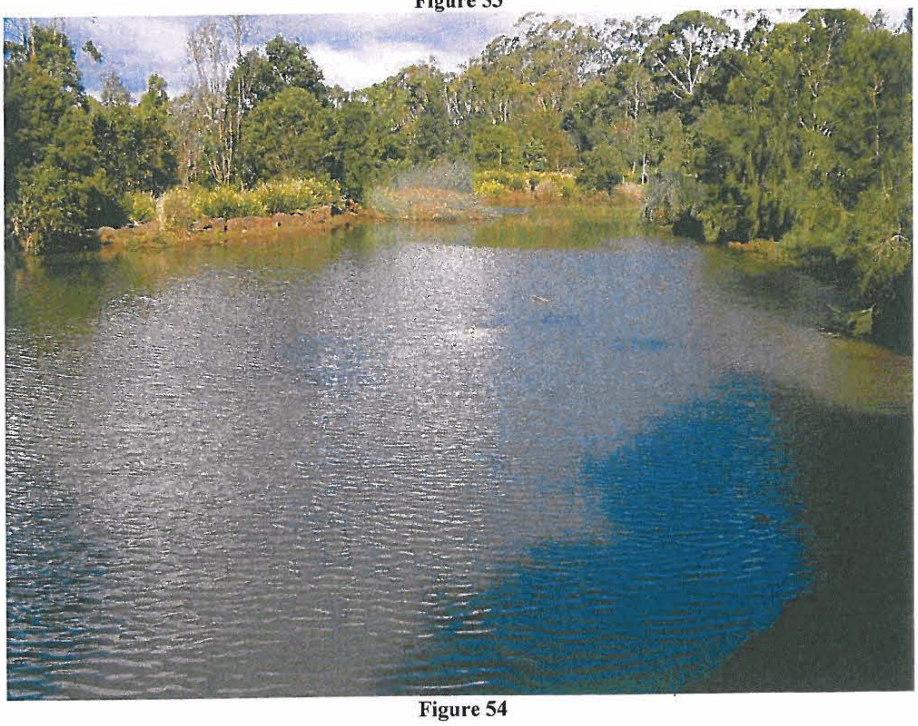

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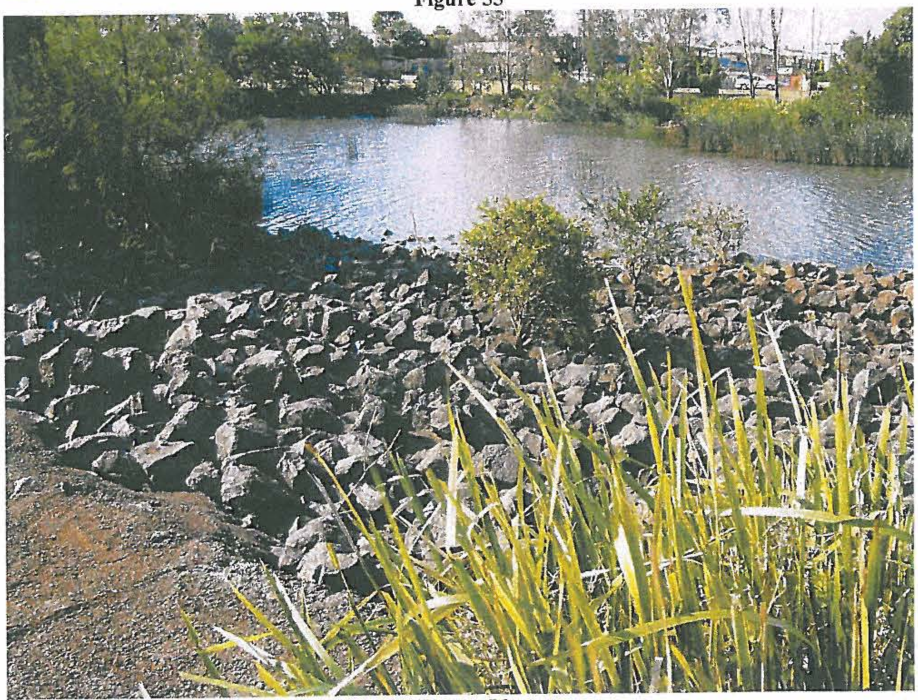

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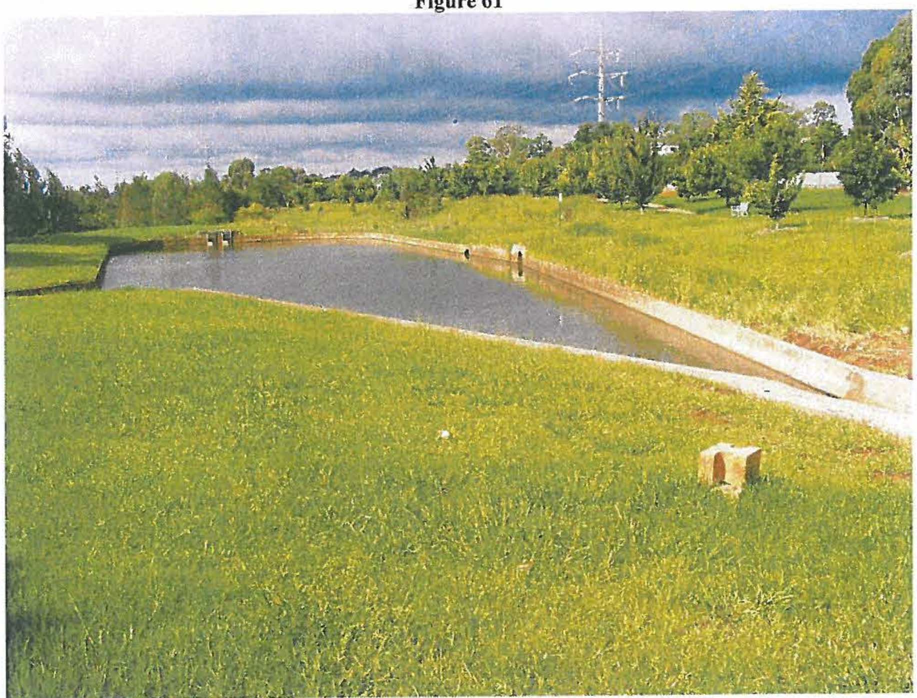

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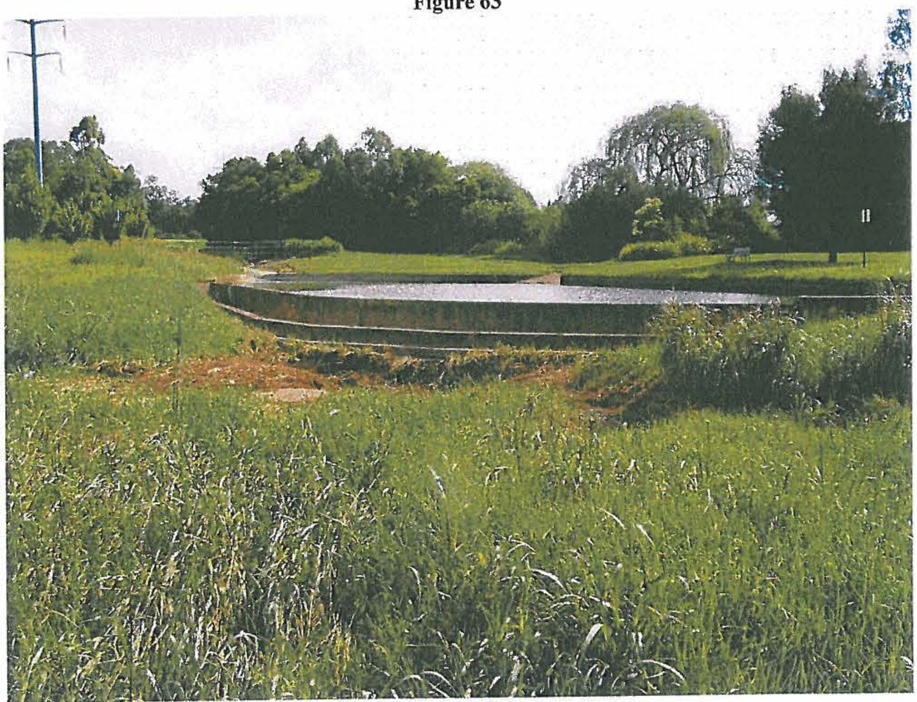

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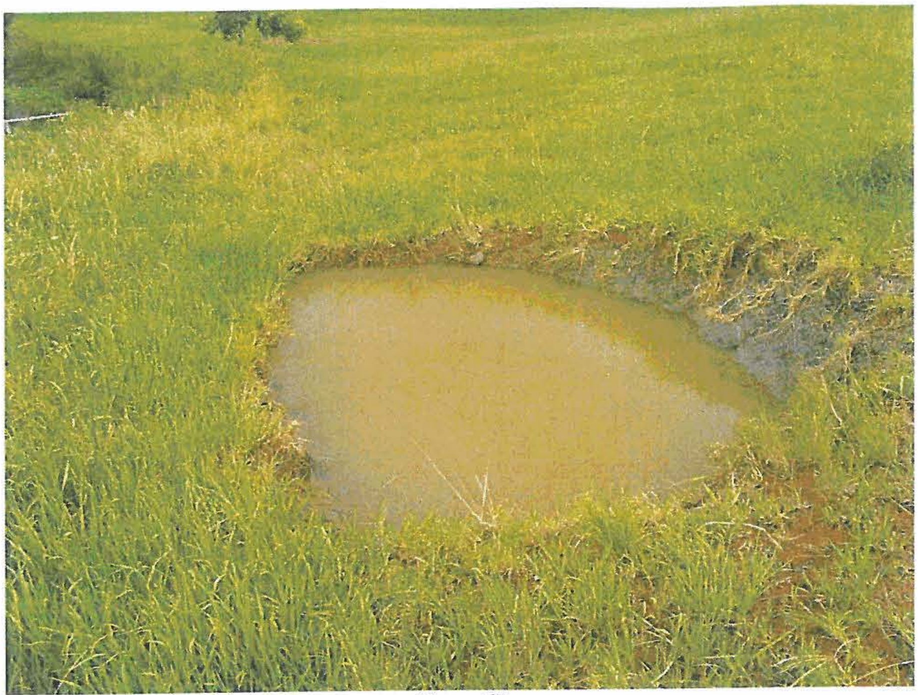

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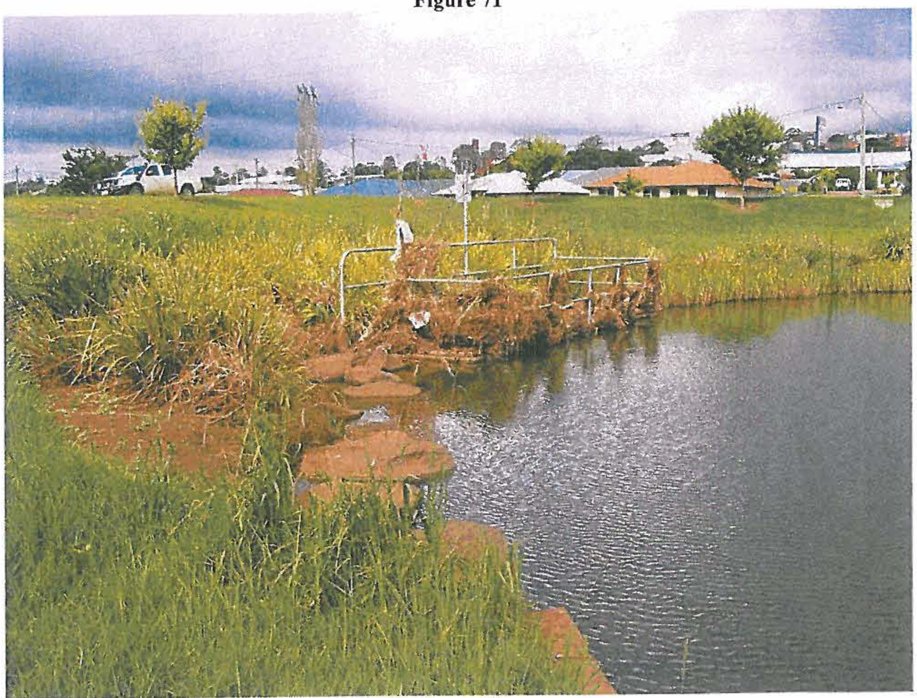

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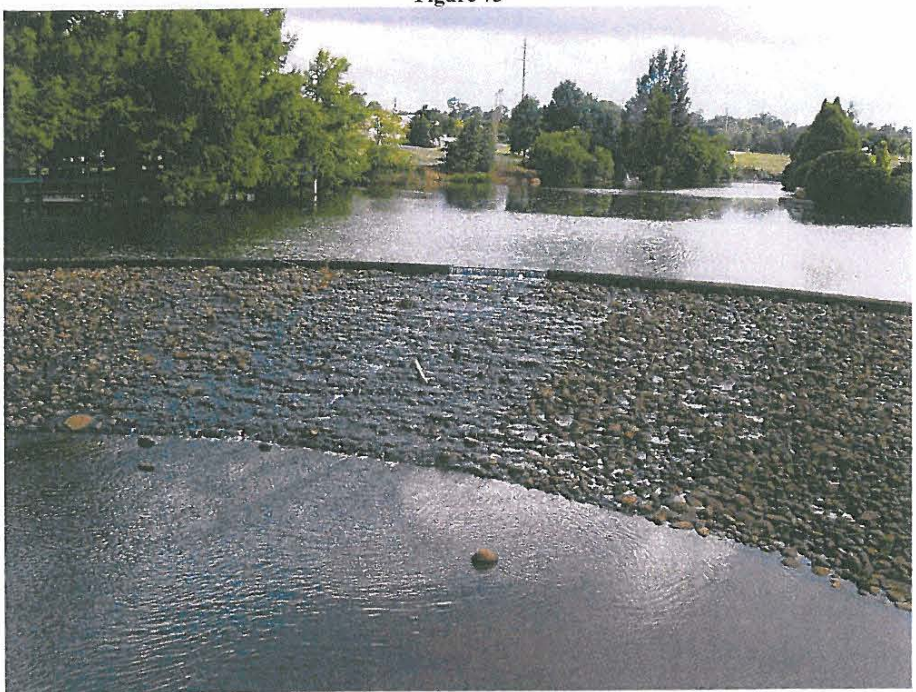

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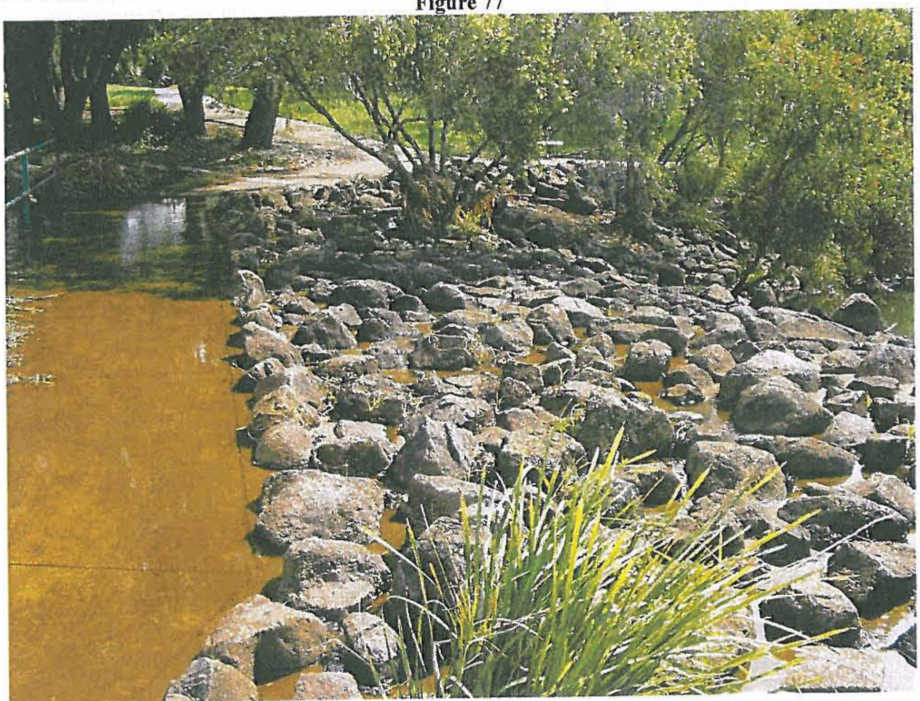

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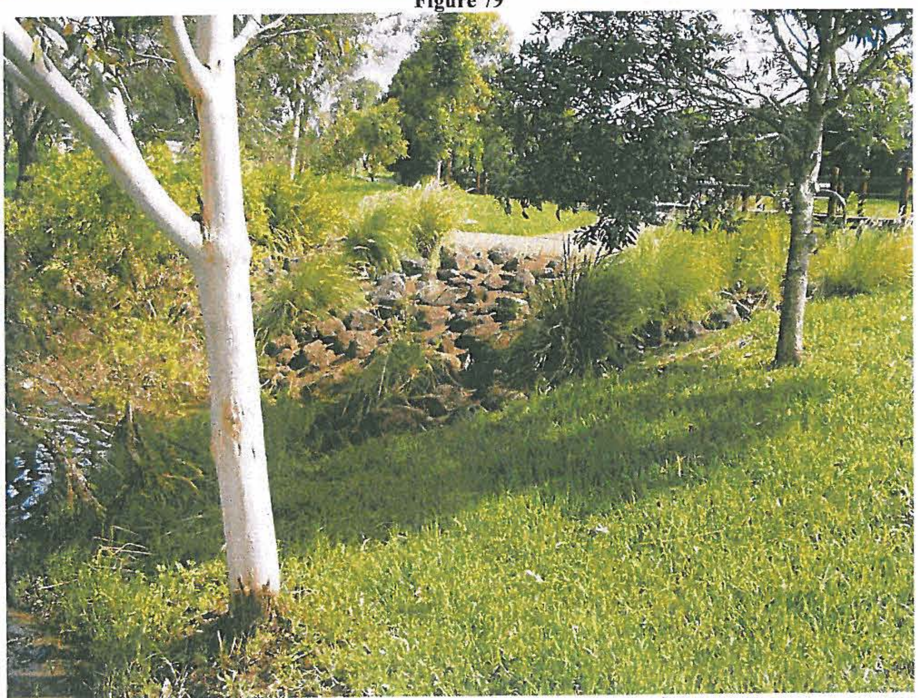

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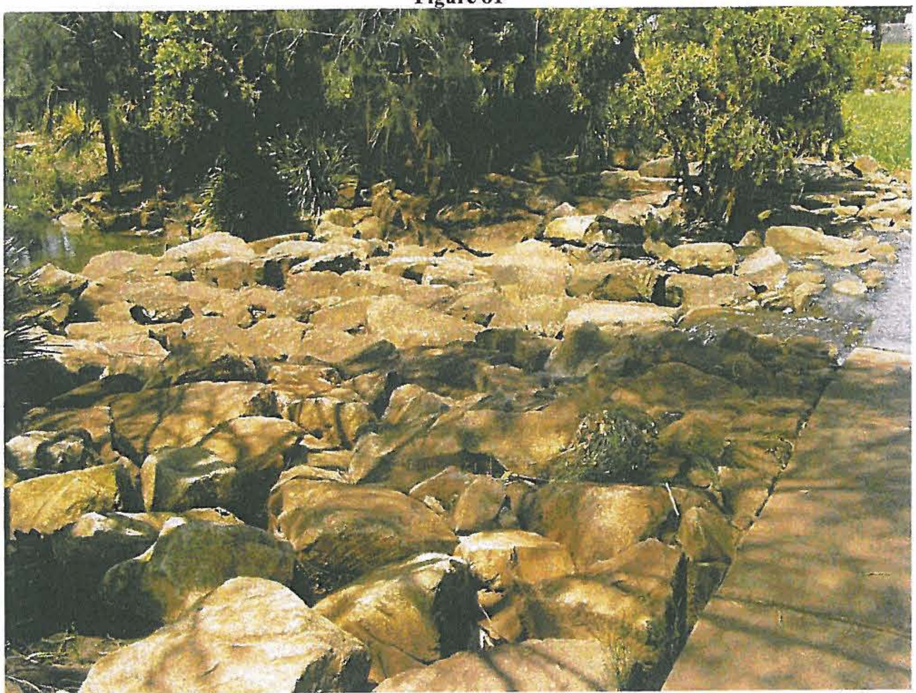

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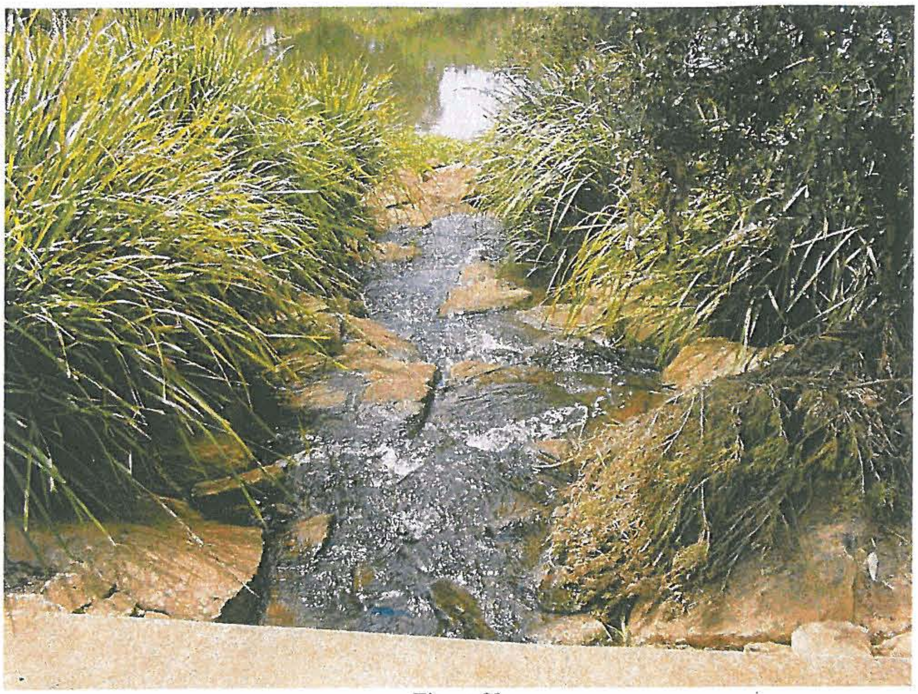

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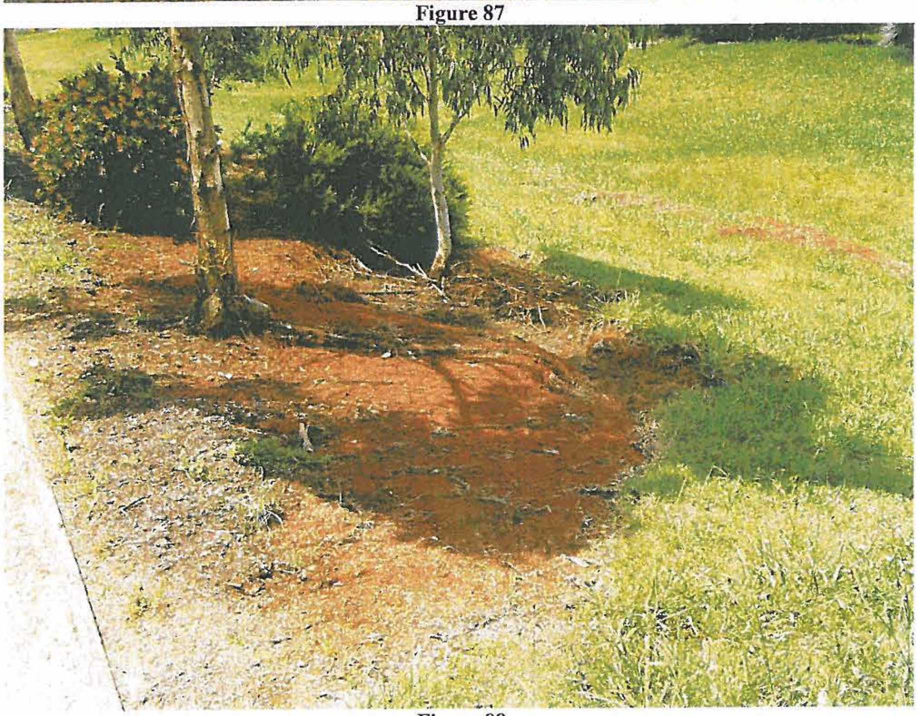
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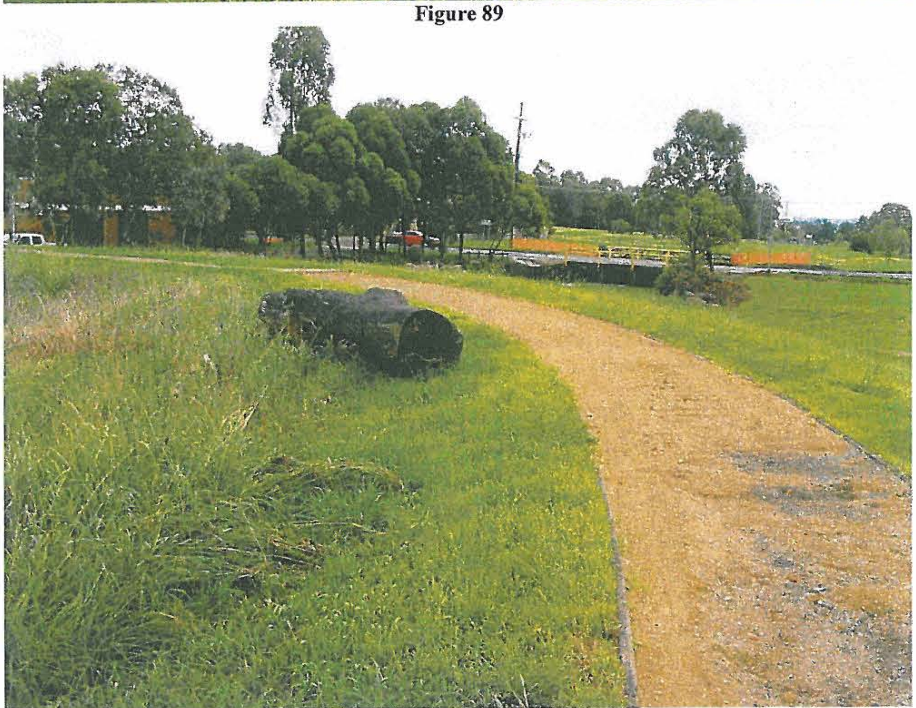

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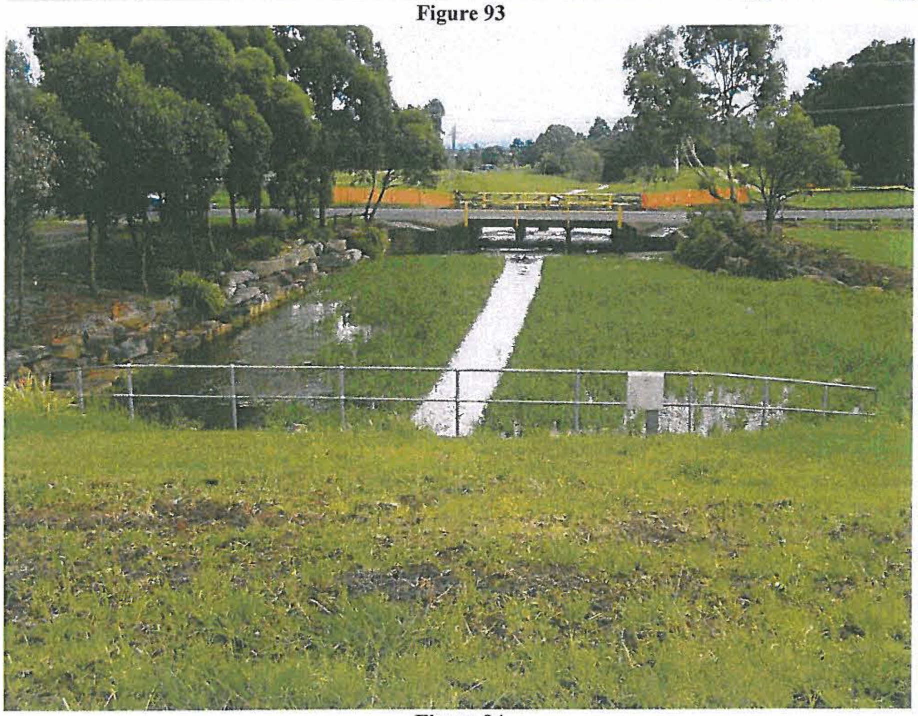

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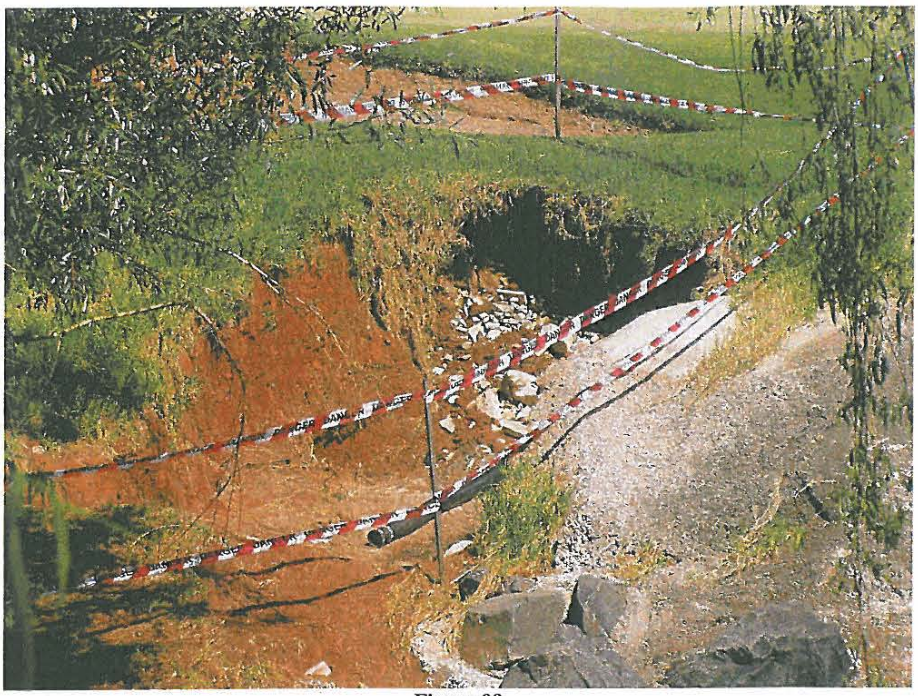

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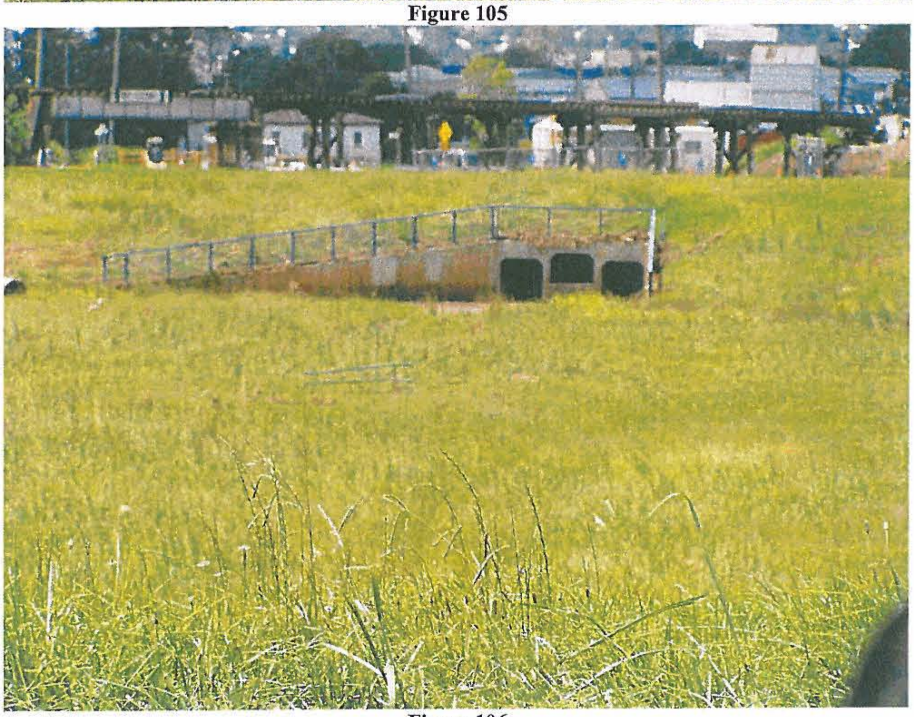

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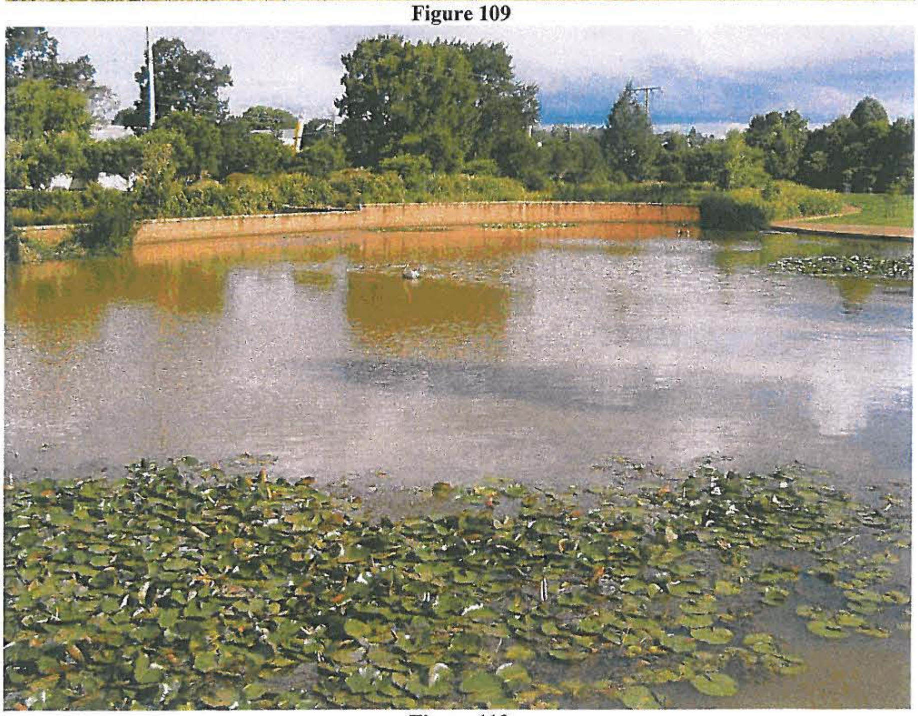

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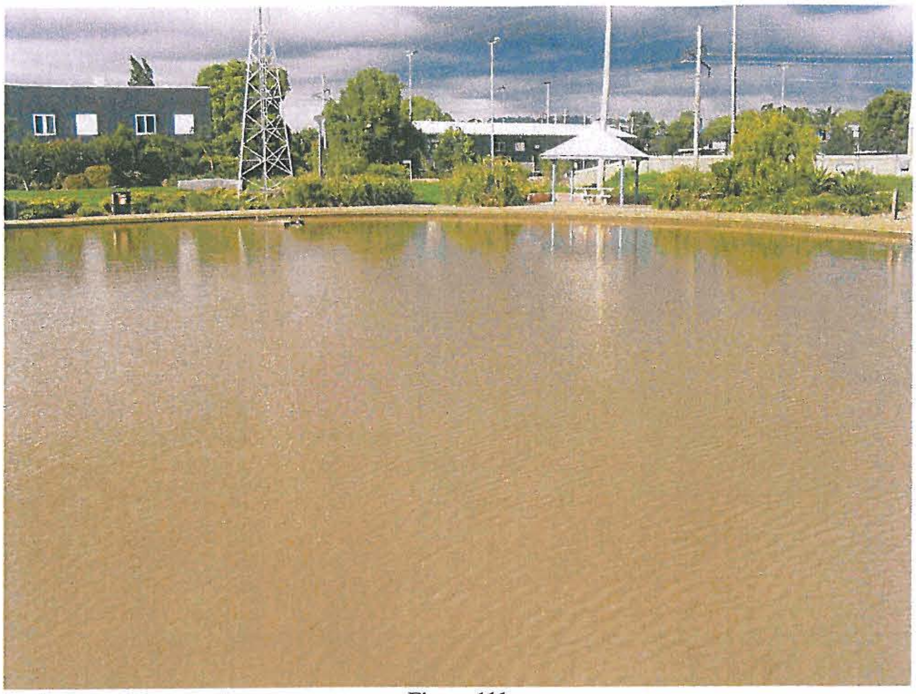

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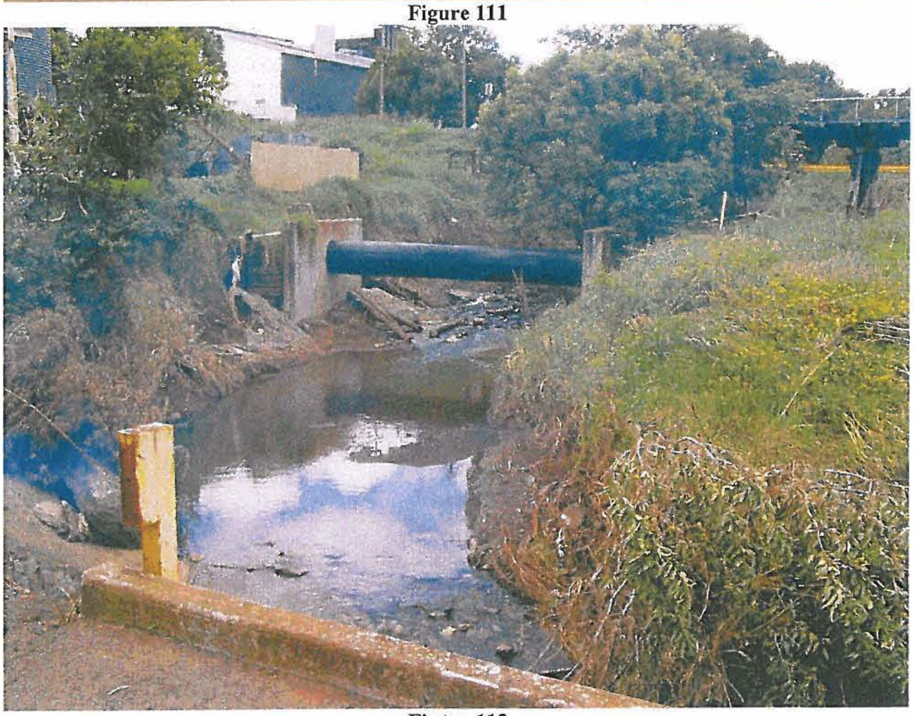

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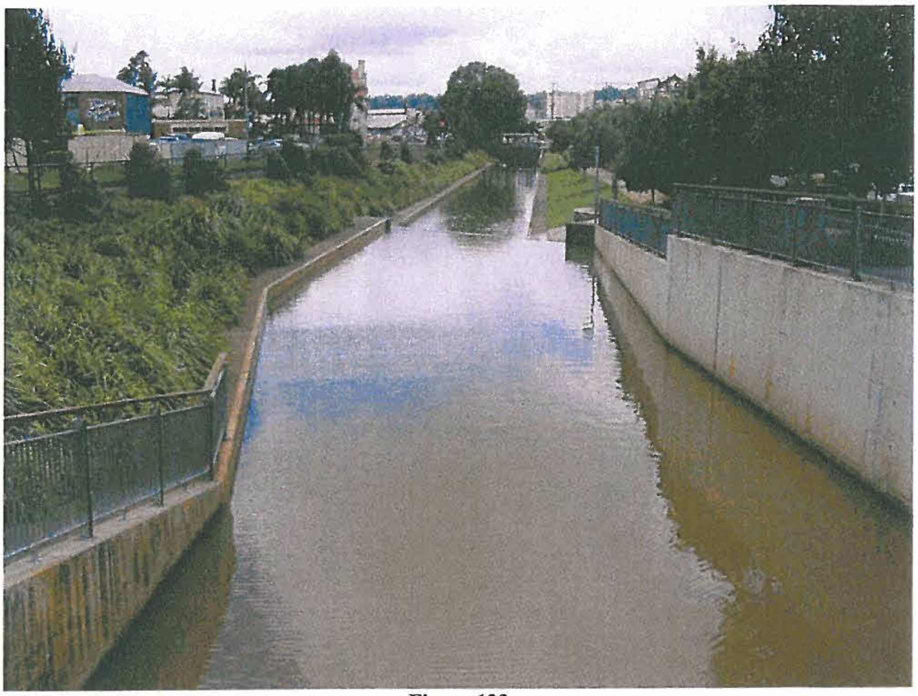

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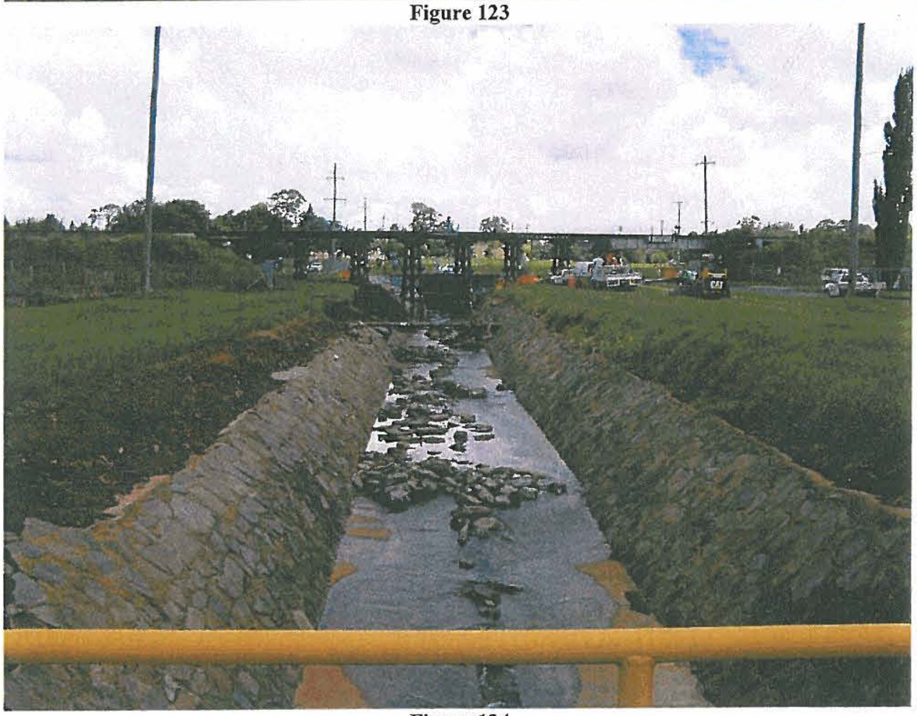

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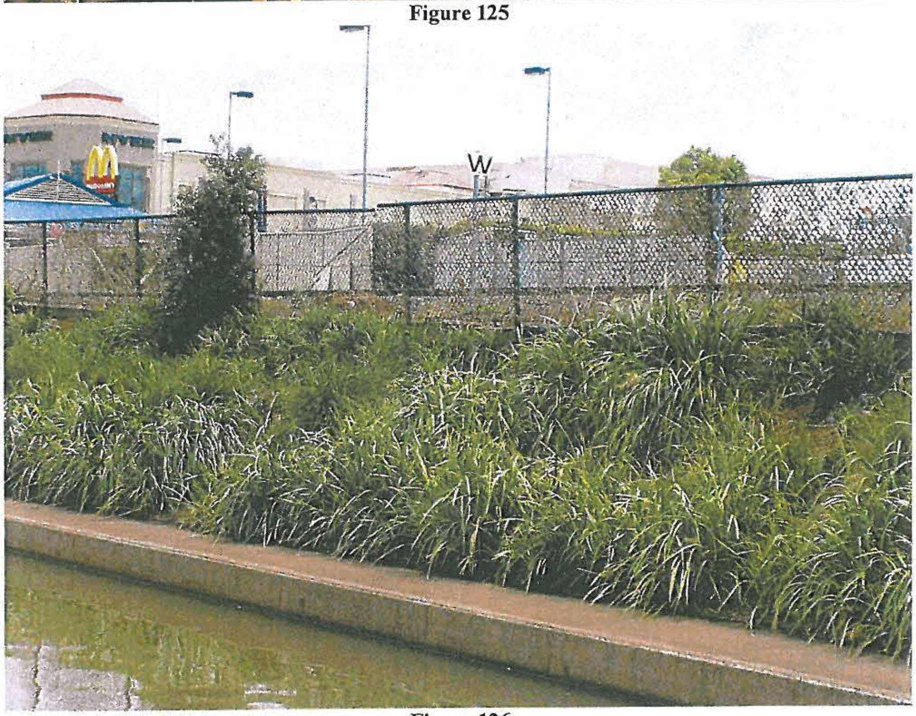

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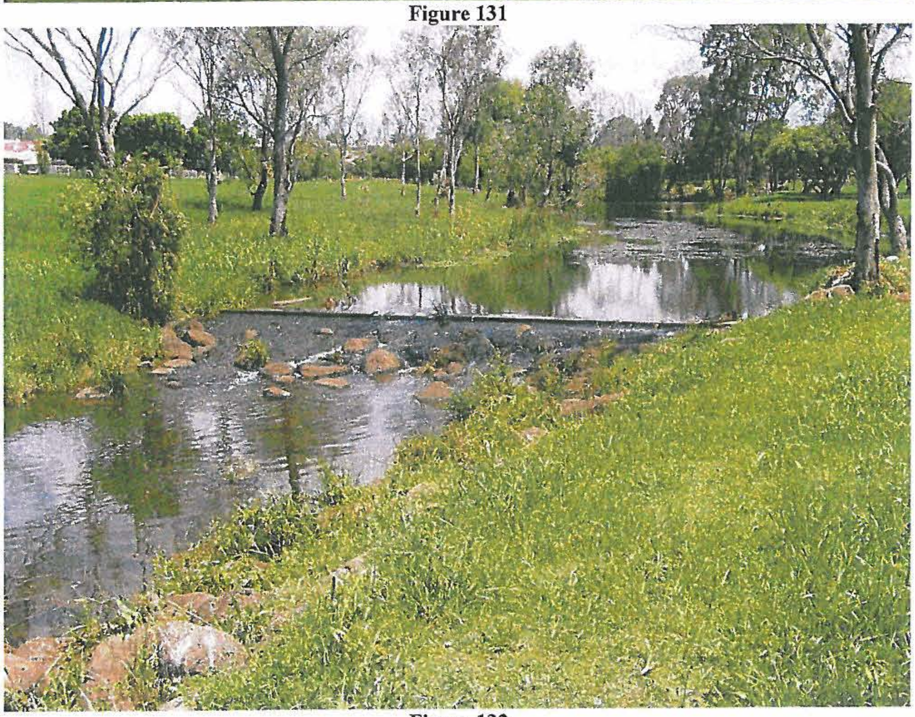

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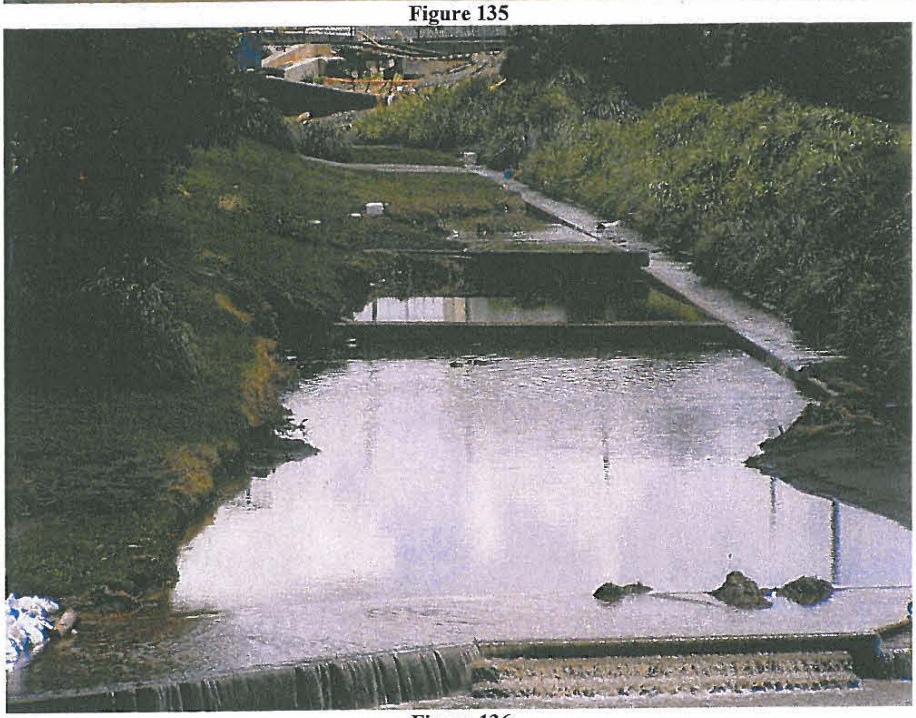

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APPENDIX B
Miscellaneous Photographs

Figure 139

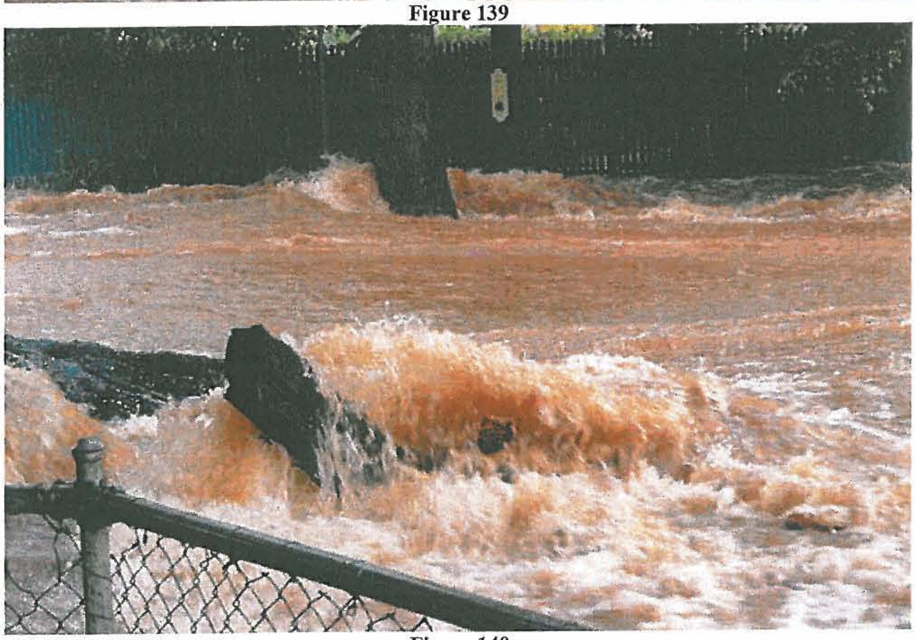

Figure 140

Figure 141

Figure 142

Figure 143

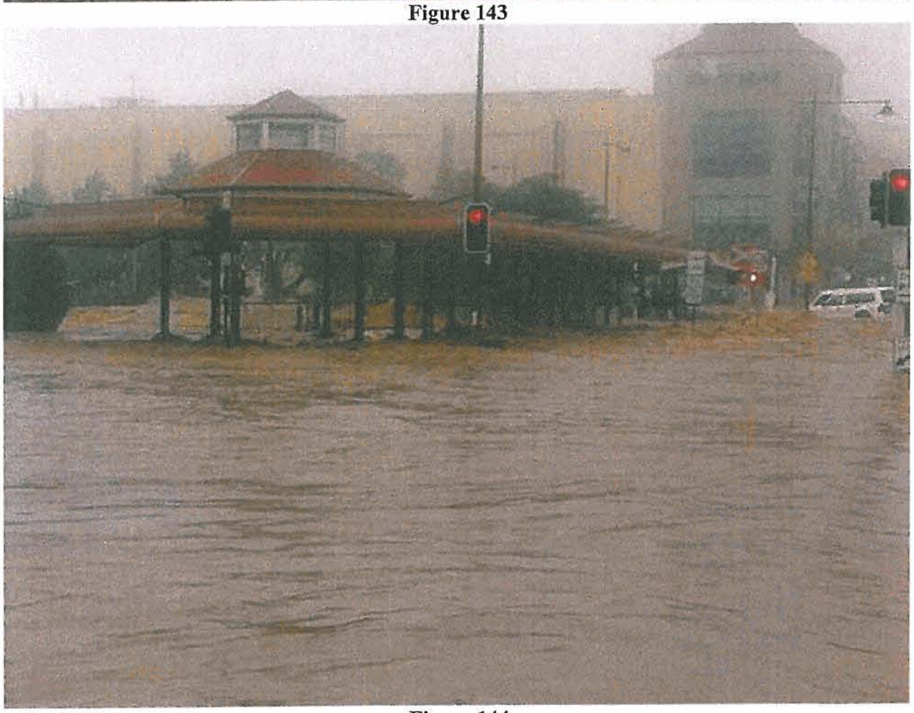

Figure 144

Figure 145

Figure 146

Figure 147

Figure 148

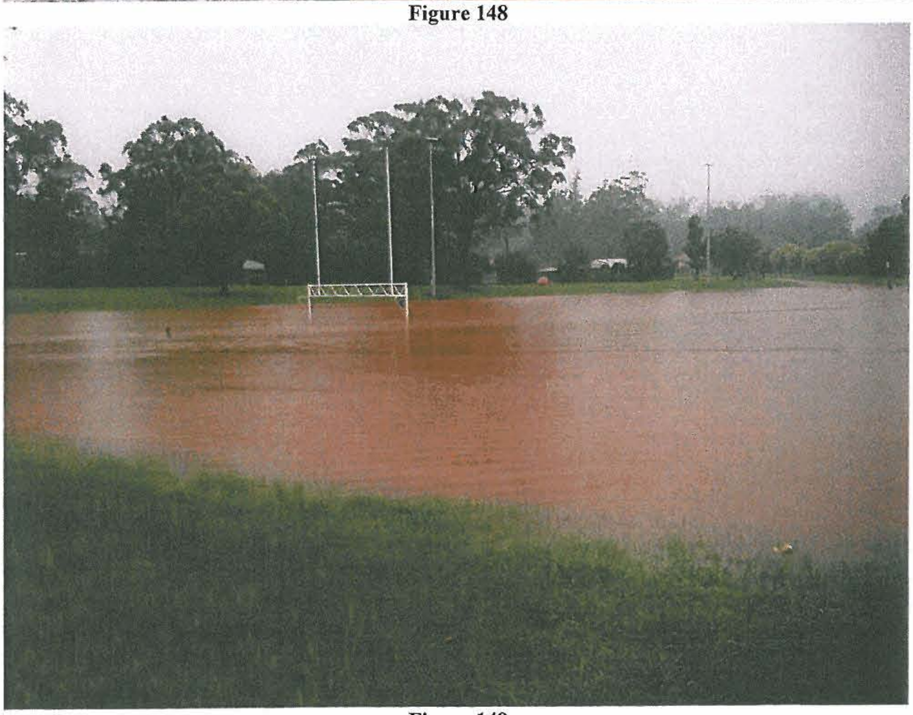

Figure 149

Figure 150

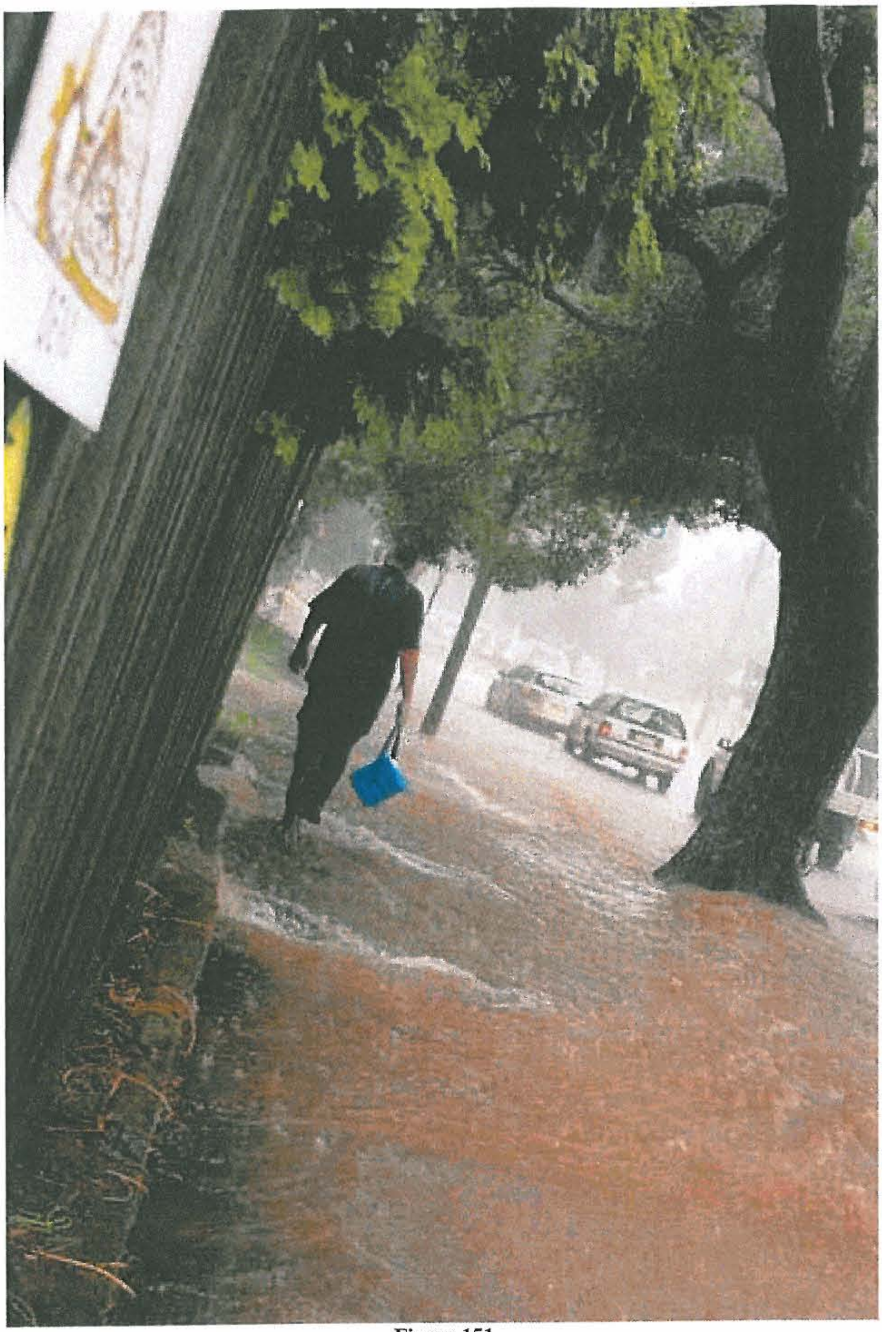

Figure 151

Figure 152

Figure 153

Figure 154

Figure 155

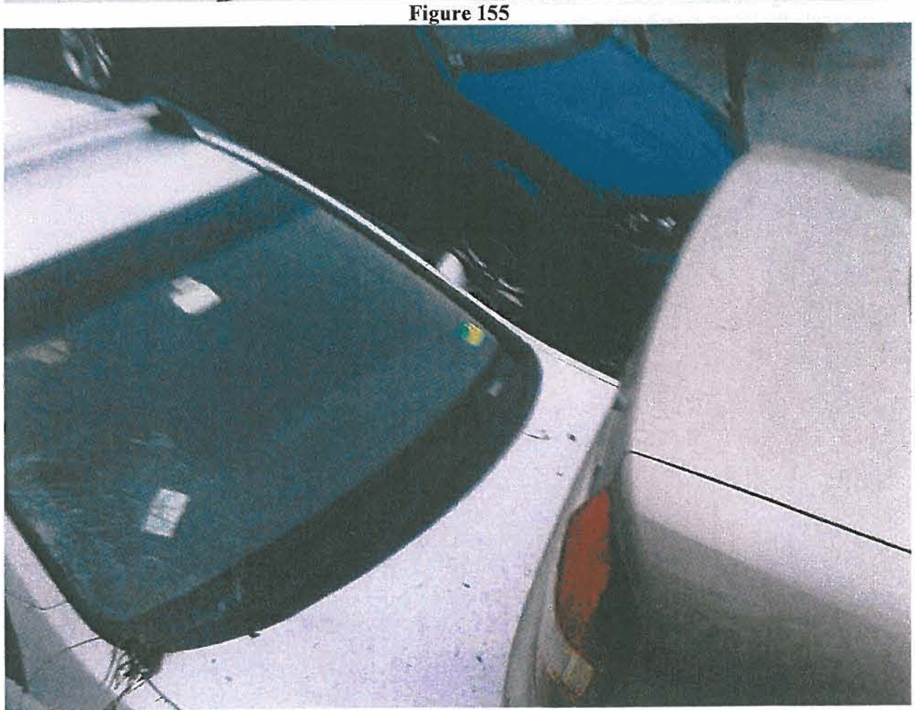

Figure 156

Figure 157

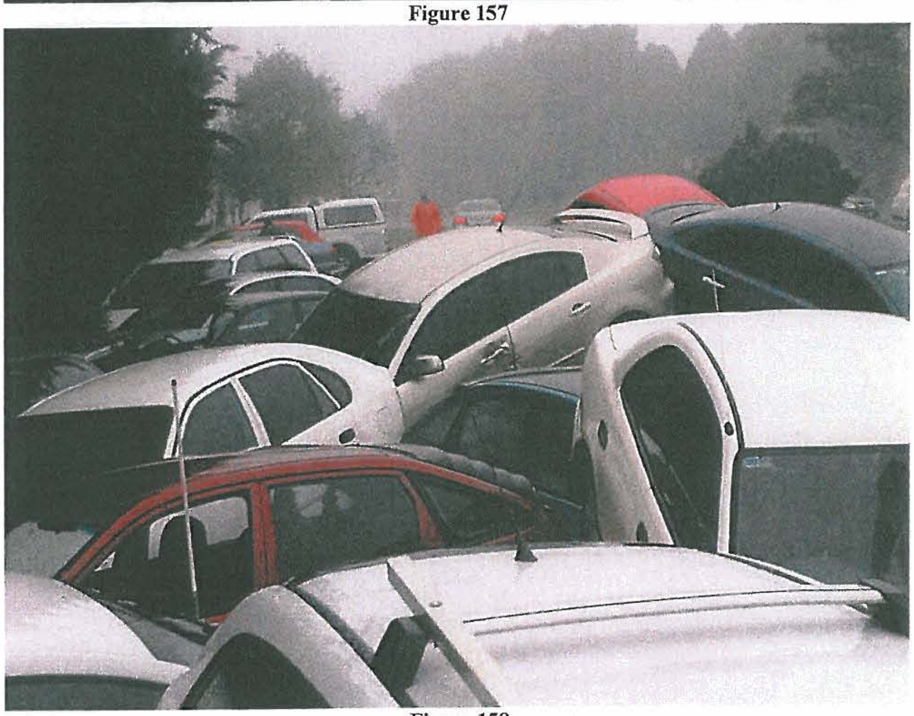

Figure 158

Figure 159

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Figure 173

Figure 174

Figure 175

Figure 176

Figure 177

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Figure 180

Figure 181

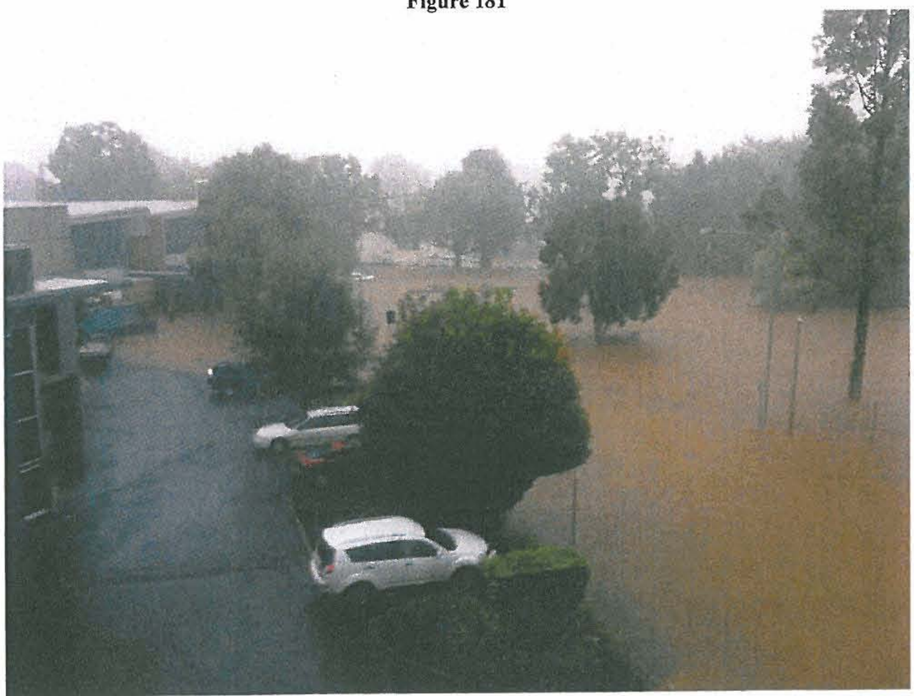

Figure 182

Figure 183

Figure 184

Figure 185

Figure 186

Figure 187

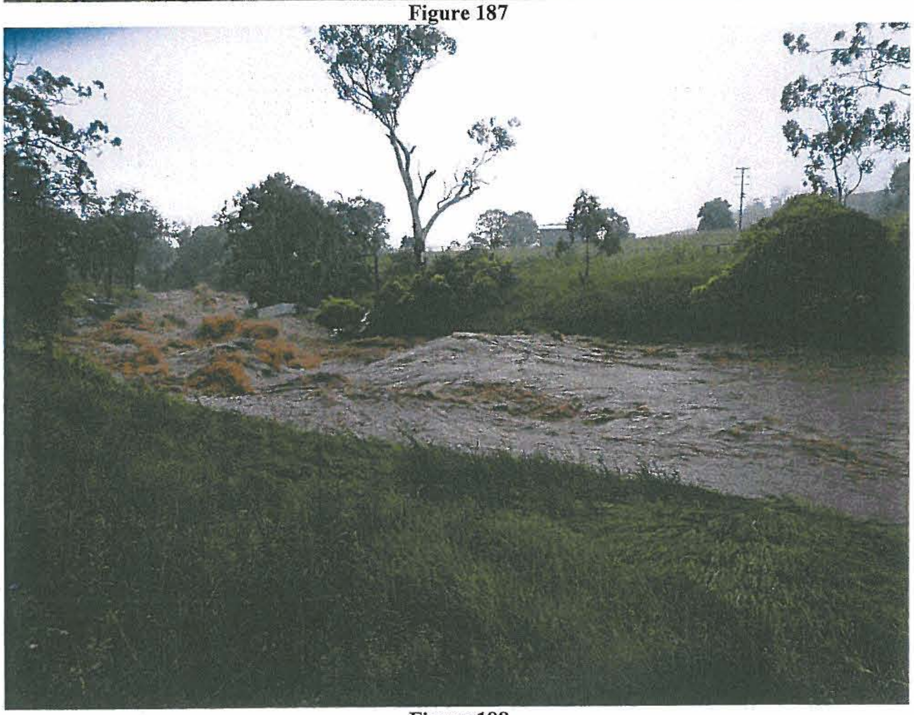

Figure 188

Figure 189

Figure 190

Figure 191

Farm Dam Incidents

Dam Owner	Location	RPD	Latitude	Longitude	Dam Id / OID No	Complainant	RPD	Incident Descripton	Action Officer	Action
XXXXXXXXXXXXXXXXX	Euri Creek Near Bowen	10 RP742867	20°04'29"	148°06 '50"	RDR2261	Minister [Robertson/Jones]		Spillway of dam severly eroded with increased potential for dam failure adjacent to Euri Creek.	Guy Bignell / Glen Griffin	Assessment of potential failure flows (if breach were to occur) was conducted. No PAR was confirmed but high flows at two road crossings downstream, as result of possible failure, was predicted. Peter Allen communicated these findings to QPS contacts in Bowen. As roads are beyond WS(S&R) Act jurisdiction QPS would need to invoke road closures as need occurs. Further two dimensional hydraulic modelling is scheduled for DERM Dam Safety Engineers.
XXXXXXXXXXXXXXXXX	Near Applethorpe	2 RP160263	28°36'19.376"	151°55'45.367"	OID19400 (RDR2325)	XXXXXXXXXXXXXXX	2 RP148412	Dam failed and caused flooding to a house downstream	Darcy Smith	Survey of dam/downstream areas and preliminary failure impact assessment commenced. Modelling and report not completed yet.
XXXXXXXXXXXXXXXXX	Kandanga	1\RP882444	26°24'13.309"	152°40'44.63"	RDR2325	XXXXXXXXXXXXXXX		Dam Causing Flooding upstream	Mark Perry	Inspection and DG Response Letter (CTS02303/11)
XXXXXXXXXXXXXXXXX	Stanthorpe	96 B3441 291 B34298	28°42'02"	152°00'36"	OID_18844	Stanthorpe Police	N/A	Dam on Thirteen Mile Creek dam overtopped - did not fail. QPS concerned about possiblity of failure	Darcy Smith	Not action taken as dam did not fail
XXXXXXXXXXXXXXXXX	Stanthorpe	31 B34186	28°42'50"	152°01'00"	OID_18878	Stanthorpe Police	N/A	Dam on Thirteen Mile Creek - badly eroding spillway. QPS concerned about possiblity of failure	Darcy Smith	Spillway widened using Stanthorpe Shire Council excavator that was brought on-site.
XXXXXXXXXXXXXXXXX	Stanthorpe	1 SP129351	28°42'27"	152°00'43"	OID_18877	Stanthorpe Police	N/A	Dam on U/T of Thirteen Mile Creek - eroding spillway. QPS concerned about possiblity of failure	Darcy Smith	Dam owner demolished 1.5m rock and concrete nib across spillway, thereby lowering the water level of the dam. Owner intends seeking advice on how spillway can be safely reinstated so it has much greater capacity.
XXXXXXXXXXXXXXXXX	Cliffton Rd Mount Whitestone	315 CC3196	27°40'48.972	152°9'6.994"	N/A	Dep't Transport & Main Roads - XXXXXXXXXXX	N/A	Main Roads concerned about impact on road caused by upstream farm dam. Dam showing signs of damage including longitudinal cracks on the embankment.	Darcy Smith	MRD inquiry invoked Dam Safety to conduct a site inspection to determine if downstream PAR existed. Darcy Smith inspected nearby downstream house and confirmed by report no PAR. Report now endorsed and communicated back to MRD. Concerns about road integrity not included in DERM inspection.
XXXXXXXXXXXXXXXXX	West Talgai Via Allora	2CP901461	28°03'45.93"	151°54'21.40"	OID_18738	XXXXXXXXXXX	2CP901461	Dam owner contact Warwick Office (Darcy Smith) seeking advice about erosion occuring on the spillway of his dam	Darcy Smith	Darcy Smith inspected the dam and provided general advice to the dam owner about how the spillway should be repaired
XXXXXXXXXXXXXXXXX	Hattonvale adjacent to X Nathan Court Plainland	16SP104817	27°33'25.194"	152°26'30.061"	N/A	XXXXXXXXXXX	82\RP856357	Dam failed during floods and caused concern for neighbouring residents about the potential risks.	Darcy Smith	Inspection of dam occurred on 11 February 2011, including survey and breach model assessment. Assessment confirmed no PAR downstream.
XXXXXXXXXXXXXXXXX	Norman Street Cordalba	404C3581	25°09'26.676"	152°12'40.208"	N/A	XXXXXXXXXXX	407C3581	Rang complaining that a neighbouring dam was waterlogging her yard preventing her from getting to her vegetable garden	Mark Perry	Inspected on 17/01/2011 - no dam safety issue identified, it is a common law matter
XXXXXXXXXXXXXXXXX	King Parrot Close_Starling Drive and Wagonwheel Road Borland	60RP895967	27°57'05"	153°9'17"	N/A	XXXXXXXXXXX	22\SP169274	Rang DERM seeking advice about spillway of her dam that was eroding	Bryan Potter	Inspection of dam occurred on 17 March 2011. Inspection confirmed no PAR downstream.
XXXXXXXXXXXXXXXXX	Milford Middle Road Milford	31 SP177126	28° 01' 59.53"	152° 41' 44.62"	N/A	XXXXXXXXXXX	7 SP133765	Complaint that small dam on neighbouring property was water logging part of her land killing trees	John McKenna	Advised XXXXXXXXXXX that DERM had no jurisdiction - dam not on watercourse and did not require authorisation under Moreton ROP. XXXXXXXXXXX said her solicitor was writing to dam owner.
XXXXXXXXXXXXXXXXX	South Nanango	34 RP185316	26°42'22.43"	152° 0'9.59"	N/A	XXXXXXXXXXX	34 RP185316	Complaint that neighbouring dam was causing flooding on their property affecting access	Mark Perry	Inspected on 20/01/2011 - no dam safety issue identified, it is a common law matter
XXXXXXXXXXXXXXXXX	XX Seraya Court, Closeburn	8 SP222792	27°20'29.27"	152°51'18.08"	N/A	XXXXXXXXXXX	1 SP137099	XXXXXXXXXXX rang the Brisbane office on 25 Jan 2011concerned about flooding of her access road caused by a neighbouring dam.	John McKenna	Rang XXXXXXXXXXX on 3 Feb 2011 to say an inspection wuld be arranged - advised XXXXXXXXXXX that flooding issue was unlikely to be a dam safety issue.
XXXXXXXXXXXXXXXXX	XX Gavin Rd Plainlands	24RP160225	27°34'45.51"	152°23'43.60"	N/A	XXXXXXXXXXX	24 RP 160225	XXXXXXXXXXX rang complaining that her family had to evacuate their house which was threatened by nearby dams	Ron Guppy / Bryan Potter	Dam Safety officer inspected XXXXXXXXXXX's house and two neighbouring dams one of which failed. Assessment determined no 'population at risk'. Results of inspection conveyed to XXXXXXXXXXX via letter.
XXXXXXXXXXXXXXXXX	XX McLauchlans Rd Monogorilby	21 NT33	26°05'46.174"	151°01'18.983"	OID_18432	XXXXXXXXXXX		Complaint that a neighbouring dam appeared to be collapsing - complainant concerned that his family travelled along the road downstream of the dam	Mark Perry	Dam inspected on 25/01/2011. Embankment poorly constructed, Seepage evident in several places along embankment. Recommended immediately lowering spillway by about 2m. Phone on 31/01/11 established spillway had been lowered.
XXXXXXXXXXXXXXXXX	Tenthill Creek Road Lower Tenthill	4RP209378	27°37'54.758"	152°13'49.024"	OID_13908	XXXXXXXXXXX	5RP209378	[redacted] contacted DERM Gatton office to say he had breached his neighbour's dam because he believed it was causing flooding of his house.	John McKenna Darcy Smith Robert Fowden	On 21/01/11 Dam Safety officers met on-site with several landowners to discuss the situation; resolution reached that XXXXXXXXXXX would repair breach; DERM would undertake 2D modelling to determine if dam should be regulated as a referable dam.
XXXXXXXXXXXXXXXXX	XX Nash Road Jimboomba	19 RP138033	27°47'59"	153°02'00"	N/A	XXXXXXXXXXX	20 RP138033	Drainage Problem and Diversion of Flow at boundary between properties. Dam very small (<0.5 megalitres <1.5metre high)	Kevin Bartlett	Photos obtained, desktop assessment. No PAR confirmed.

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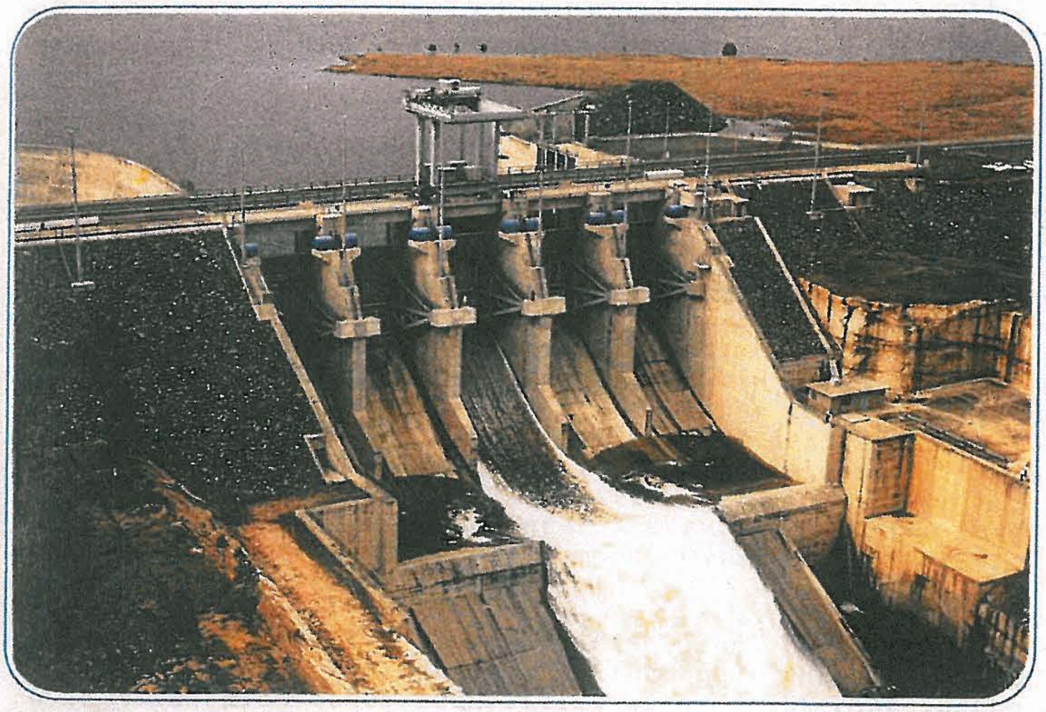
Water Resources Commission

INTERIM REPORT

ON

OPERATION OF WIVENHOE DAM DURING FLOODS (APRIL - MAY 1989)



1989

Water Resources

WATER RESOURCES COMMISSION

INTERIM REPORT

ON

OPERATION OF WIVENHOE DAM

DURING FLOODS (APRIL - MAY 1989)

1.0 INTRODUCTION

Flood inflows into Wivenhoe Dam resulted from three separate rainfall events during April and May 1989. During these events, it was necessary to operate the spillway gates at the dam to discharge excess storage. These were the first such flood discharges from the dam since its completion in 1985.

This interim report summarizes these events and reviews a number of issues arising from the dam's operation. Further action desirable as a result of this review is also outlined.

2.0 BACKGROUND

The primary objectives of Wivenhoe Dam identified in planning of the project in the early 1970's were to;

- provide an assured water supply to Brisbane and surrounding shires into the 21st century.
- protect communities along the Brisbane River from overbank flooding.
- provide a lower pool for the Wivenhoe Pumped Storage Power Station.

The Queensland Government approved in 1973 that the then Co-Ordinator Generals' Department be the constructing authority for the project. Responsibility for design and construction supervision of the dam was in turn delegated to the Water Resources Commission. In addition, the Commission has general responsibilities under the Water Act relating to the water course and water users and specific responsibilities with respect to dam safety.

During the detailed investigation and design phase of the project, close liaison was maintained through a number of committees with other authorities with an interest in the project including the Brisbane City Council and Main Roads Department.

In 1979 the Brisbane and Area Water Board was established as a funding agency for the dam and now owns, operates and maintains the dam and recreational facilities.

Recognizing the complexities of flood management arising from the presence of both Somerset and Wivenhoe Dams, the substantial part of the catchment not controlled by the dam and the extent of development on flood prone land downstream, an Advisory Committee involving officers of the Commission, Brisbane City Council and Bureau of Meteorology was formed in accordance with the provisions of the Brisbane and Area Water Board Act in 1983 to develop operating rules for both Somerset and Wivenhoe Dams during flood events. These rules were set down in the document "Manual of Operational Procedures for Flood Mitigation for Wivenhoe Dam and Somerset Dam".

In formulating these rules, the key priority areas were seen in order as;

- the restoration of the flood mitigation capacity of the dams as quickly as possible.
- the re-opening of downstream bridges which serve isolated communities as quickly as possible (e.g. Burton's Bridge).
- the re-opening of other downstream bridges.

In accordance with the Manual, control of the spillway gates at both dams for the purposes of flood management rests with the Brisbane City Council.

It was also determined by the Advisory Committee that the Manual be reviewed at five year intervals in light of actual operating experience.

3.0 THE FLOOD EVENTS

Three periods of major storms occurred over the April-May period (Figure 1).

Sustained rainfall over several days from 2nd April to 8th April, 1989 caused significant storage rise above full supply level in both Wivenhoe and Somerset Dams.

Because of the presence of both dams and their flood routing effect there is no direct record of what flood would have occurred had the dams not been in place. However, by using the recorded outflows from Wivenhoe Dam (at Savages Crossing) and taking into account the routing effect of the storage, it is possible to estimate what the flood would have been for the "no dams" case.

Figure 2A shows the recorded flood hydrograph at Savages Crossing (with dams) and the derived hydrograph for the "no dams" case. As can be seen, without Wivenhoe Dam, the flood would have peaked at nearly 3 000 cubic metres per second. The flood was of relatively long duration with a total volume of runoff approaching 600,000 megalitres.

The second April flood resulted largely from an intense storm event on the evening of 25th April. Figure 2B shows, again, the recorded flood hydrograph at Savages Crossing (with dams) and the derived "no dams" hydrograph. This second flood was of shorter duration but would have peaked at some 4 600 cubic metres per second had Wivenhoe Dam not been in place. The total volume of runoff in this second flood approached 1 million megalitres.

The third flood was smaller by comparison and the releases from Wivenhoe Dam were adjusted so as not to inundate Fernvale Bridge.

Considered separately, no flood could be described as an "extreme" event although the middle flood would have caused a degree of overbank flooding downstream. However, considering the relatively brief time interval between all events, the total volume of runoff within the months, 1.8 million megalitres was certainly a "major" event in the period of record. The volume of runoff was by some margin, the largest ever recorded at Savages Crossing for the month of April for the period of record (1909 to date) and ranks third in terms of volume of runoff for all months in the period of record. (Runoff in the January 1974 event was 2 500 000 megalitres and in February 1971, 1 756 000 megalitres.)

4.0 POSITIVE IMPACTS OF WIVENHOE DAM OPERATION

The performance of the dam itself, and in particular the spillway, during the April flood events was very satisfactory. All elements of the structure including gates, gate hoists, dissipator and discharge channel performed entirely as predicted by the dam's designers.

Indeed, the primary objectives of assuring water supply into the 21st century and of protecting communities along the river have clearly been demonstrated.

It is also now evident that the complex matter of flood management was, given the information available at the time, well addressed in that the objectives regarding protection of the dam itself and the downstream bridges were also quite reasonably met. It was always anticipated that some modification to operating procedures may be necessary in the light of operational experience and indeed, amendments were made to the spillway gate closing rules after the first of the flood events.

5.0 ASPECTS OF WIVENHOE DAM OPERATION

A number of matters received wide publicity during the flood events, namely extensive land slips along the river banks downstream of the dam and the prolonged inundation of bridges downstream of the dam.

These problems were widely perceived and portrayed in the media as having been worse than "before" and worse because of the presence of Wivenhoe Dam. Each is discussed in some detail in the following sections.

5.1 River Bank Slips

Many bank slips were reported after the first gate closing at Wivenhoe Dam. All slips reported were located, inspected and photographed. Slips were mostly in the areas indicated on the attached Figure 3.

For the most part, slips were 30 to 50 metres long and quite shallow. Although the slips are certainly unsightly 'scars' along the banks, little useable land above the high bank has been lost. Photographs of a number of typical slips are attached as Figures 4 and 5.

The extent to which the slips can be attributed either to the presence of Wivenhoe Dam or the procedure for gate operation is questionable.

There is no doubt that the presence of Wivenhoe Dam will cause (over a long period of time) changes to the natural river processes just as will many other land management practices associated with land riparian to the stream and elsewhere in the catchment. The shape of the river (called the regime) can change in response to;

- farming and other land use practices in the catchment;
- changes to the sediment flow in the river (the dam will trap a percentage of the normal sediment load).
- changes in the range and duration of flood flows.
- whatever spillway gate operating procedures are adopted.

The partial trapping of sediment by the dam means that sediment that would have normally been moved downstream primarily during flood events, is not entirely replaced as previously. The river bed will gradually change until a new stable regime is established. This will to some extent cause changes to the banks and stream bed/bank configurations.

This process will be accompanied by the development of different channelized meanders which will be a function both of sediment transport and of river flows. Where the points of these meanders are deflected by barely stable erodible banks, it is possible that undermining will cause bank collapses as part of this process.

River bank shapes (and stability) are primarily determined by the materials within the banks and the rate of river level fall experienced at different levels of the banks. There is considerable evidence along the river (and in other streams) that bank collapses have occurred prior to the recent floods and that they are part of the natural processes of river development.

Many of the people who reported bank slips after the first gate closing believed that the slips were wholly attributable to the rapid closure of the dam gates which caused water levels to fall faster than usual.

After an urgent review of the gate operating rules and of water level records along the river, it was concluded that the rate of gate closure should be slowed, although clearly, this would increase the period of inundation of the lower level bridges downstream. A slower rate of gate closure (see Figure 6) was used after the second flood. No new bank slips were reported.

Superficially, it might be concluded that the rate of gate closure in the first event was excessive and the cause of bank slips. However, it is much more likely that the rate of gate closure was only a contributory factor and certainly not the only factor or even the most important factor.

This conclusion is strongly supported by the following;

- bank slips even occurred well downstream of Savages Crossing where the rate of river level fall was slower than pre-Wivenhoe Dam events.

- bank slips along other streams in S.E. Queensland, e.g. Mary River and Logan and Albert Rivers, were reported as being much more severe than along the Brisbane River during the same period.

- bank instability has no doubt built up over a long period of low river flow in recent years and all unstable banks would have slipped during the first flood event irrespective of the rate of gate closure.

In summary, it is considered that the bank slips were a result of a combination of several factors including;

- ongoing river processes present in any river system;

- the generally unstable shape of the banks along some sections of the Brisbane River.

- the rate of change of river level during the first April flood.

Ongoing river processes, which will be modified by the presence of Wivenhoe Dam as discussed above, will also contribute to future occurrences of bank slips to some extent.

The degree to which the cause of the recent slips can be attributed to Wivenhoe Dam cannot be quantified. However it is clear that the operation of Wivenhoe Dam is only one of the contributory factors.

5.2 Effect on Downstream Bridges

Brisbane River flooding downstream of Wivenhoe Dam affects six bridges as detailed hereunder and whose locations are shown in Figure 3. For each bridge, the flood flow at which the bridge is inundated (flood immunity) is also shown.

Bridge	Owner	Flood Immunity (cumecs)	Alternative Access
Twin Bridges	Esk Shire Council	25	Lowood/Wivenhoe detour (additional distance 6.5 km)
Fernvale	M.R.D.	1020	Lowood detour (additional distance 11 km)
Savage's Crossing	Esk Shire Council	150	No practical alternative
Burtons Bridge	Moreton Shire Council	250	No practical alternative
Kholo Bridge	Moreton Shire Council	550	Mt Crosby Weir detour (additional distance 5 km)
Crosby Weir	Brisbane City Council	1600	No practical alternative

(The additional distances shown above for each detour are indicative. Actual detour distances may vary depending on origin and destination.)

Colleges Crossing which provides a direct connection between the Karana Downs area and Ipswich has an immunity of only 100 cumecs but alternative access is available via Crosby Weir as above.

It should be noted, that all crossings are affected by substantial areas of the catchment not controlled by Wivenhoe Dam, including the Lockyer Creek catchment and that the crossings were subjected to relatively frequent inundation prior to the completion of Wivenhoe Dam.

During and subsequent to the flood events, a number of complaints from various areas downstream of Wivenhoe Dam have suggested that the dam's operation has aggravated flooding of the crossings and community disruption.

Although an exhaustive examination of the frequency and duration of inundation for "no dam" and "with Wivenhoe Dam" cases for each crossing has not been completed, it is already evident that any increase in inundation attributable to Wivenhoe Dam was insignificant. In fact, in many events, the duration of inundation, particularly of the lower crossings, will be reduced as flow which would have caused inundation will be retained in the storage.

For example, Burtons Bridge which services a community of some 36 people, would have been inundated for some 25 days this year to early May, 1989 compared with 20 days actual inundation. During the first April flood, the period of inundation was reduced by some 2 days whereas it was lengthened for the later April flood by a little more than 1 day, as per Figures 1 and 2.

It is the case however, that a number of the higher level bridges were inundated for marginally longer periods. In developing the original operating rules for the dam, it was recognized that;

- it is of critical importance for the safety of the dam that any temporary flood storage be discharged before any subsequent flood event.
- damaging overbank flooding does not occur for flows less than 3 500 cubic metres per second.
- reasonable alternative access is available for Fernvale and Kholo Bridges but not for Crosby Weir.

For these reasons, discharges from Wivenhoe Dam were managed at the maximum rate which would not inundate the Crosby Weir crossing, i.e. at up to 1 600 cubic metres per second. Certainly, if discharges at up to 3 500 cubic metres per second were made, water held in temporary flood storage could be discharged more quickly and the total period of inundation of all bridges reduced but, as above, inundation of the Crosby Weir crossing would cause major disruption and it is not proposed therefore that the current approach be varied.

The total period of inundation at Fernvale and Kholo Bridges during April was some 2-3 days longer that would have been the case without Wivenhoe Dam. Clearly, this increased disruption needs to be considered in light of the probability of similar major events occurring again.

An exhaustive study of the frequency and duration of inundation for each bridge would be required to determine whether the operation of Wivenhoe Dam was in any way likely to be such as to justify in itself raising or replacement of any of the downstream bridges.

It is desirable that such a study be undertaken in conjunction with the Authorities responsible for each of the bridges to establish what further action, if any, should result.

6.0 OTHER OPERATIONAL ISSUES

A number of other issues have become apparent during the flood events. These are briefly discussed as follows:

6.1 Public Awareness

From many of the letters received and from comments made during a well attended public meeting at the Pine Mountain Hall, it is clear that many misconceptions exist concerning Wivenhoe Dam.

These have ranged from "**Wivenhoe Dam should have prevented all flooding**", to "**Wivenhoe Dam has caused the flooding.**"

It has even been suggested that "**the reservoir should be emptied in advance of cyclones.**"

It is probable that public perceptions are largely shaped by what is published in the media. It is also the case that the media has in the case of the recent floods been very selective in treatment of the issues. Bank slips received far more publicity than any of the positive aspects of the dam's operation.

A public awareness campaign to inform the public of the benefits of Wivenhoe Dam could create a more informed community able to make better judgements when future flood events occur.

6.2 Warning Systems

It has been reported that the downstream bridges were flooded without prior warning. Initial flooding of the lower level bridges most probably resulted from runoff in the lower Brisbane catchment with the period of subsequent inundation being sustained by releases from Wivenhoe Dam.

It is the case that no early warning procedures are in place to warn people of possible isolation as a result of natural flood events. However, action is taken to warn authorities and the public when gate operation at Wivenhoe will create traffic and other difficulties.

6.3 Operational Manual Review

The operational manual is due for review in 1989, it being 5 years since its formulation. The recent floods have provided operational experience which will be considered in such a review. A number of issues to be considered have been identified by this report.

As part of the review of operational strategy, existing procedures to warn those likely to be affected by releases as early as possible and to provide a contact centre where reliable and up to date information can be obtained, will be examined.

7.0 CONCLUSIONS

It is concluded that;

- river bank slips downstream of Wivenhoe Dam were a result of several factors. The rate of gate closure at the dam was possibly a contributory factor but only one of the factors.

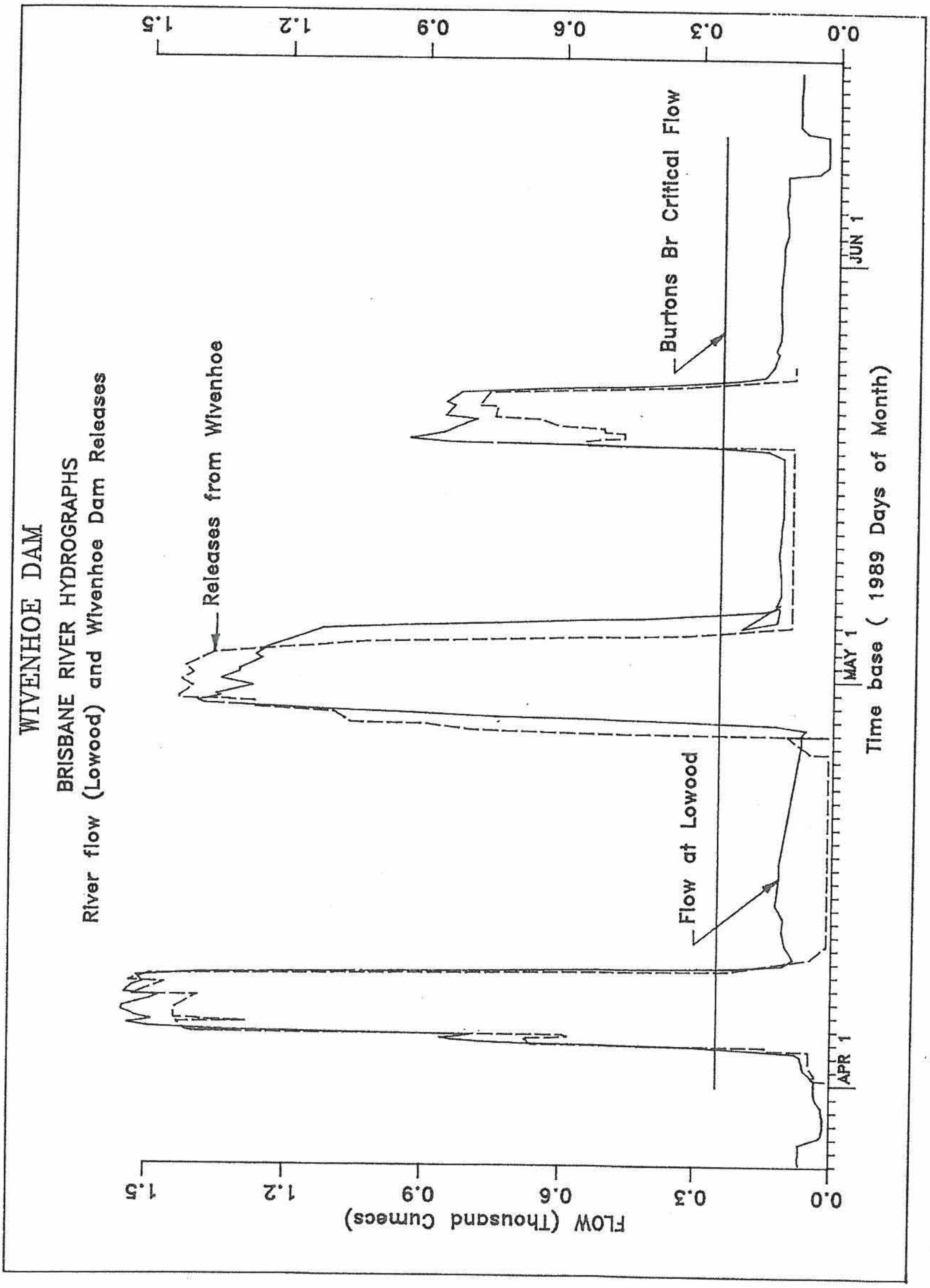
- the Water Resources Commission should continue to investigate reports of bank slumping as and when they may occur and if desirable, review further variations to the gate operating rules.

- based on a preliminary study, the effect of Wivenhoe Dam operation on flood immunity of the various downstream bridges was minimal.

- the Water Resources Commission should in conjunction with authorities responsible examine more exhaustively the effect of Wivenhoe Dam on the downstream bridges.

- a review of the flood operation manual should be undertaken as planned this year taking into account the issues identified in this report as being worthy of further consideration.

FIG. 1


WIVENHOE DAM
BRISBANE RIVER HYDROGRAPHS
River flow (Lowood) and Wivenhoe Dam Releases
Releases from Wivenhoe
Flow at Lowood
Burtons Br Critical Flow
FLOW (Thousand Cumecs)
0.0
0.3
0.6
0.9
1.2
1.5
APR 1
MAY 1
JUN 1
Time base (1989 Days of Month)

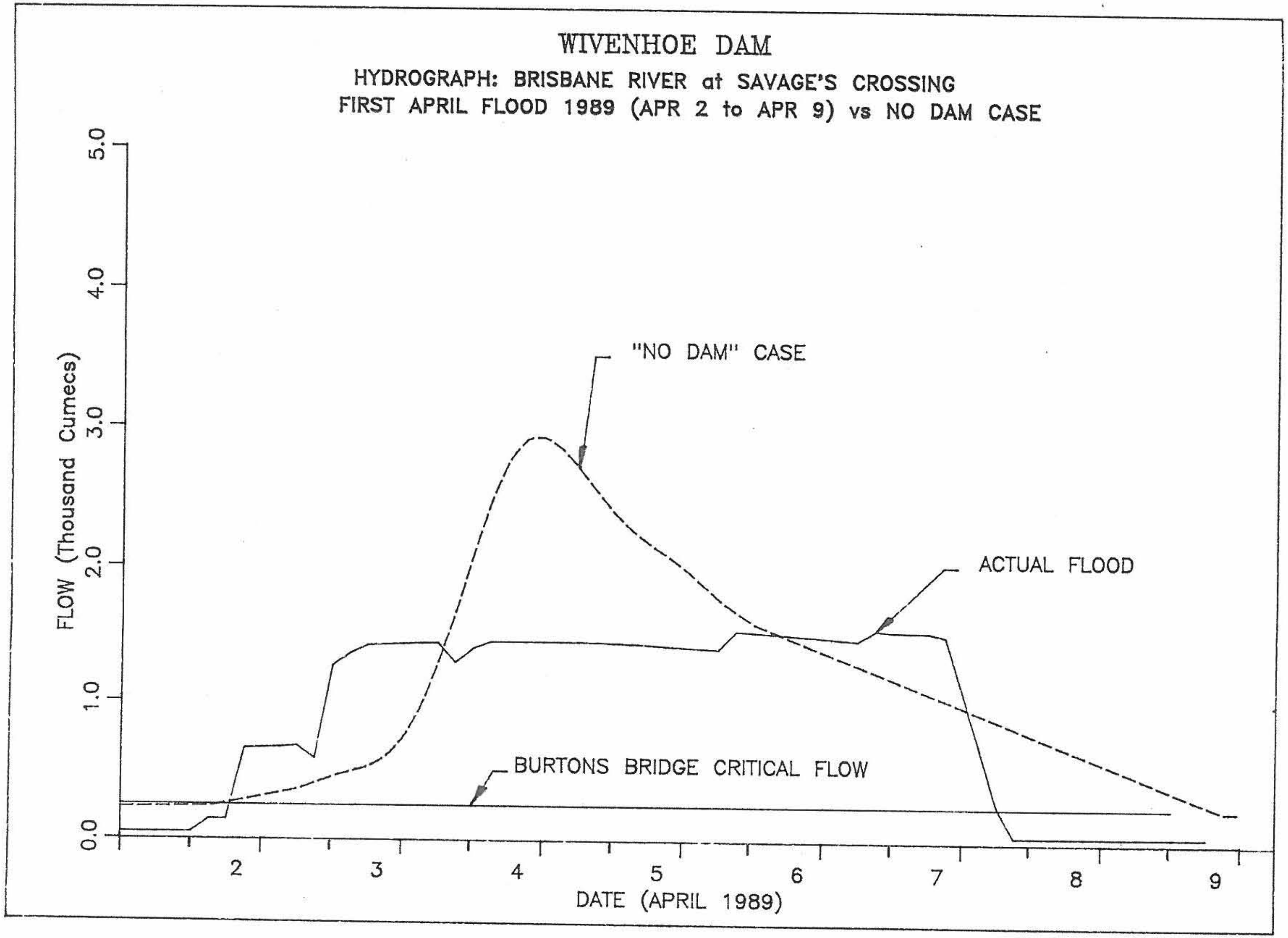

WIVENHOE DAM
HYDROGRAPH: BRISBANE RIVER at SAVAGE'S CROSSING
FIRST APRIL FLOOD 1989 (APR 2 to APR 9) vs NO DAM CASE
"NO DAM" CASE
ACTUAL FLOOD
BURTONS BRIDGE CRITICAL FLOW
FLOW (Thousand Cumecs)
0.0
1.0
2.0
3.0
4.0
5.0
2
3
4
5
6
7
8
9
DATE (APRIL 1989)

FIG. 2A

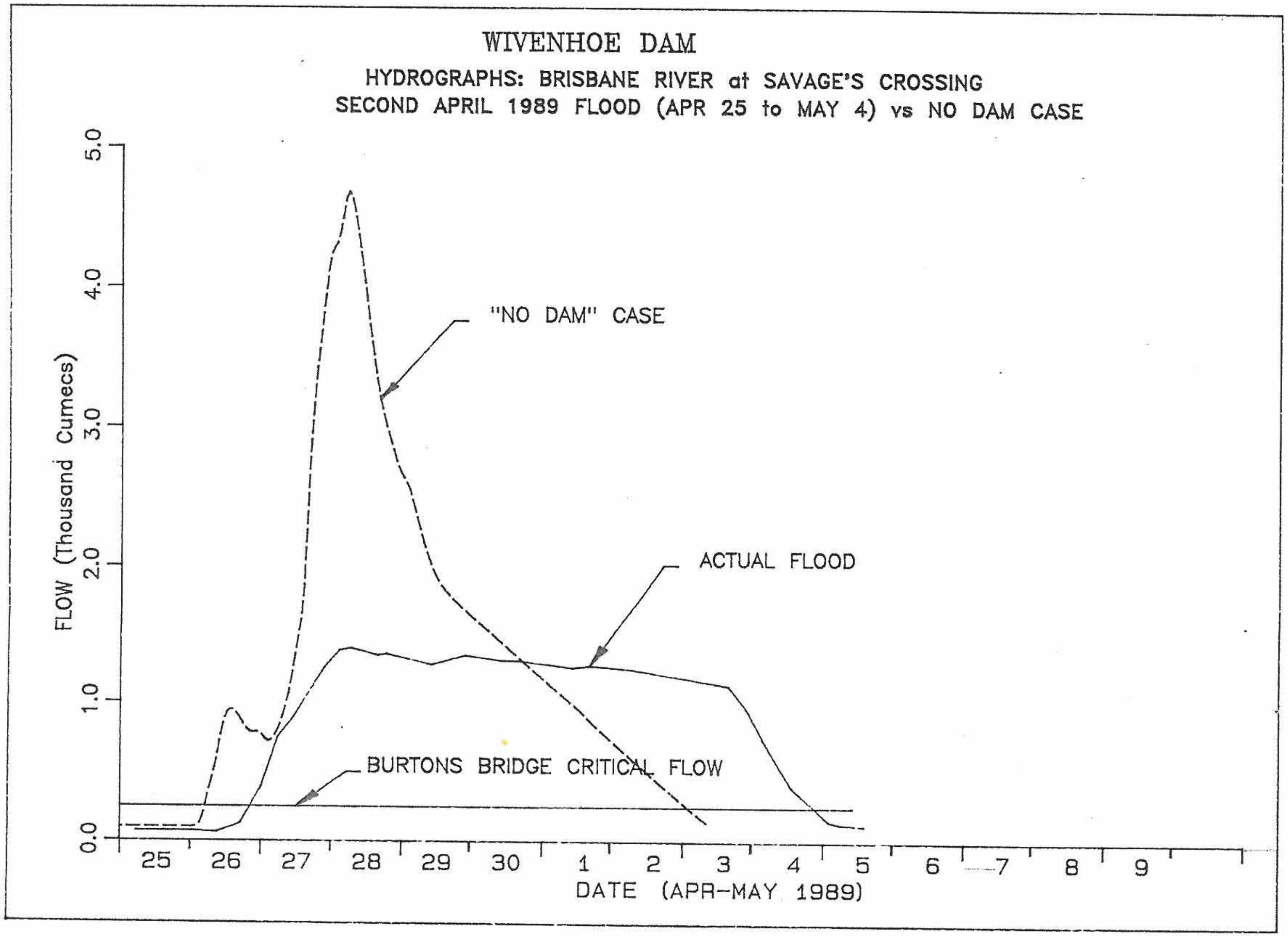
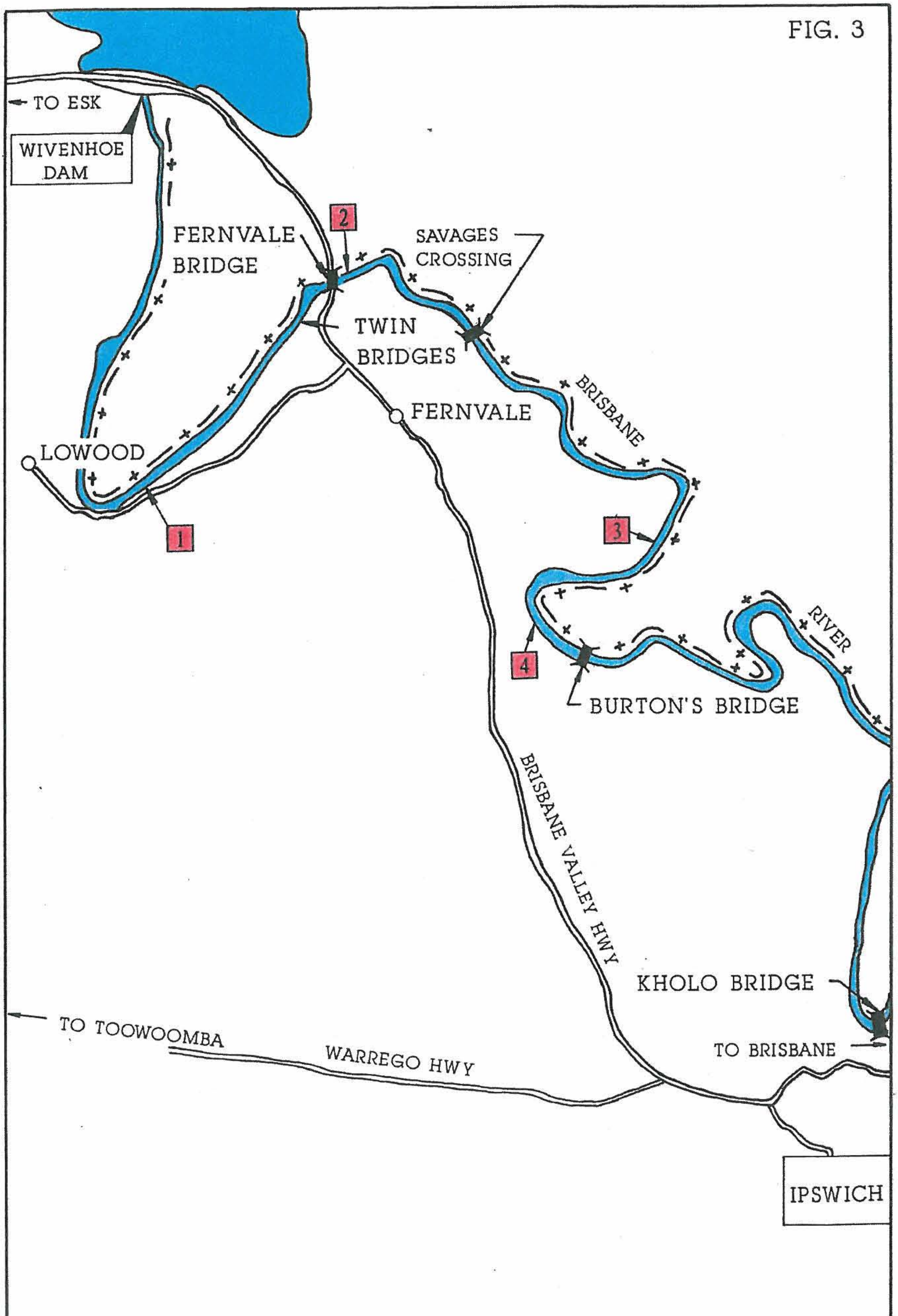

WIVENHOE DAM
HYDROGRAPHS: BRISBANE RIVER at SAVAGE'S CROSSING
SECOND APRIL 1989 FLOOD (APR 25 to MAY 4) vs NO DAM CASE
FLOW (Thousand Cumecs)
0.0
1.0
2.0
3.0
4.0
5.0
"NO DAM" CASE
ACTUAL FLOOD
BURTONS BRIDGE CRITICAL FLOW
25
26
27
28
29
30
1
2
3
4
5
6
7
8
9
DATE (APR-MAY 1989)

FIG. 2B



LOCATION OF BRISBANE RIVER BRIDGES & LANDSLIPS
LANDSLIP PHOTOGRAPH LOCATIONS SHOWN THUS 1
(SEE FIGURES 4 & 5)

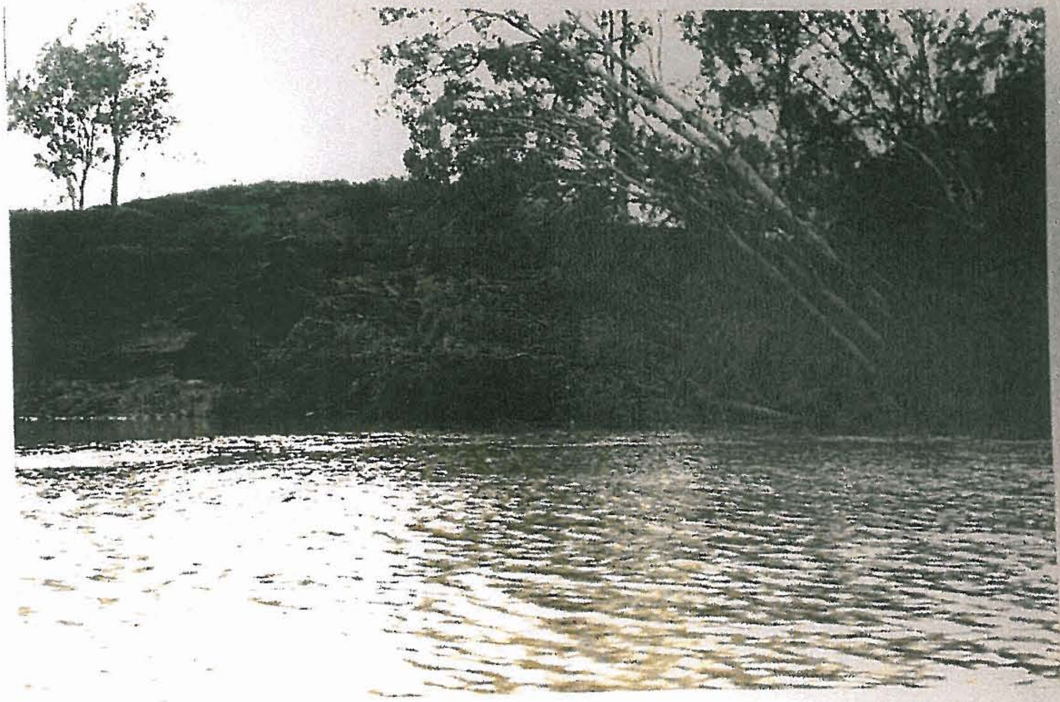
FIG. 4

LOCATION 1

LOCATION 2

BANK SLIPS BRISBANE RIVER

FIG. 5



LOCATION 3

LOCATION 4

BANK SLIPS BRISBANE RIVER

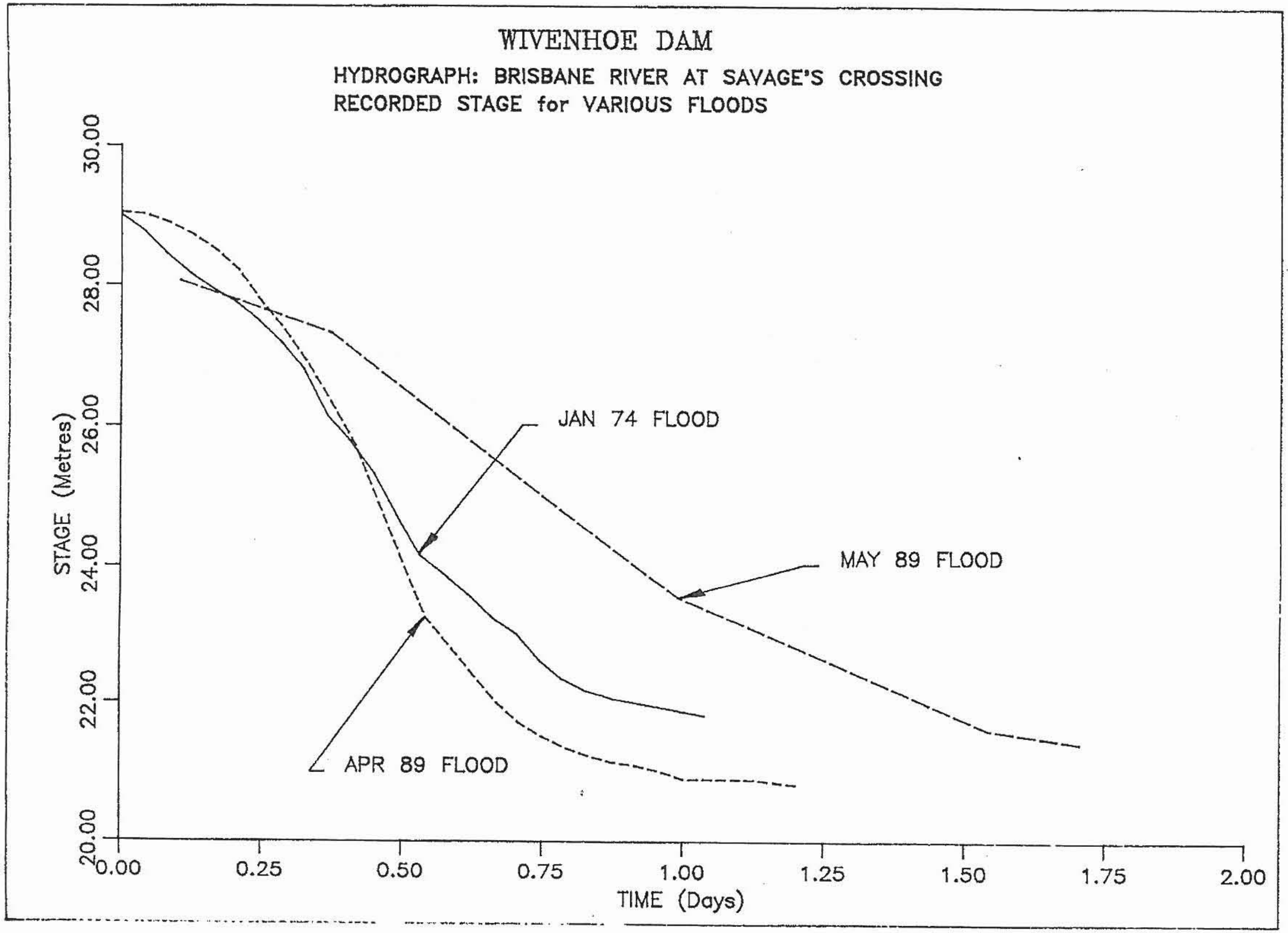

WIVENHOE DAM
HYDROGRAPH: BRISBANE RIVER AT SAVAGE'S CROSSING
RECORDED STAGE for VARIOUS FLOODS
STAGE (Metres)
30.00
28.00
26.00
24.00
22.00
20.00
JAN 74 FLOOD
MAY 89 FLOOD
APR 89 FLOOD
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
TIME (Days)

FIG. 6

'DERM-18'

September 1999

STATE WATER PROJECTS

NATURAL RESOURCES

REPORT to SOUTH EAST QUEENSLAND WATER BOARD

on

FLOOD EVENTS of FEBRUARY and MARCH 1999

at Somerset Dam, Wivenhoe Dam & North Pine Dam

Contract T5 - 95/96

Date 14 September, 1999
Reference:

THE OPERATION OF WIVENHOE, SOMERSET AND NORTH PINE DAMS IN THE FEBRUARY 1999 AND MARCH 1999 FLOOD EVENTS

1. GLOSSARY OF TECHNICAL TERMS

• Real Time Flood Management Model	The suite of programs used to collect rainfall and river height data and to determine required dam operations
➢ FLOODOPS	The hydrologic and hydraulic model component of the Real Time Flood Management Model
➢ FLOODCOL	The data collection and verification package
➢ FLOODPC	The version of FLOODCOL mounted on a PC platform designed to be able to download data remotely from the Flood Control Centre
• NOAH	The name given to the primary system computer housed in the Flood Control Centre
• SWAGGY	The name given to the back-up system computer housed in Charlotte Chambers

2. LIST OF ABBREVIATIONS

AEP	Annual Exceedence Probability
ALERT	Automated Local Evaluation in Real Time (The name given to the event reporting radio telemetry system)
ARI	Average Recurrence Interval
BCC	Brisbane City Council
BoM	Bureau of Meteorology
DE	Duty Engineer
DNR	Department of Natural Resources
FCC	DNR's Flood Control Centre (Located on Floor 2 of Mineral House)
FSL	Full Supply Level
OOA	Out of Action
QPF	Quantitative Precipitation Forecast
RTFM	Real Time Flood Model
SEQWB	South East Queensland Water Board
SES	State Emergency Service
SFOE	Senior Flood Operations Engineer
SIS	Streamflow Information System
SWP	State Water Projects (the Headworks Operator)

3. EXECUTIVE SUMMARY

The South East Queensland Water Board (SEQWB) has contracted State Water Projects to operate Wivenhoe, Somerset and North Pine Dams. The dams are all gated structures requiring gate, sluice or regulator operations to release flood inflows.

All dams are operated to maximise flood mitigation benefits, with the primary objective of maintaining the structural integrity of the dams. While the North Pine Dam operates independently, Somerset Dam is upstream of Wivenhoe Dam and the two dams need to be operated in tandem to maximise flood mitigation benefits.

Two flood events occurred during February and March 1999 that required gate operations. The first flood event in February was a significant flood event, with rainfalls in parts of the catchment exceeding the 200 year ARI. The second event at the beginning of March was only a minor event, which primarily resulted from a combination of a wet catchment and full dams.

Overall summary statistics for the events are as follows:-

Item	February Event	March Event
Wivenhoe Dam		
Maximum Inflow	7274 m^3/sec	650/sec
Maximum Outflow	1800 m^3/sec	170 m^3/sec
Maximum Storage Level	EL 70.38 m AHD	EL 67.60 m AHD
Time of Maximum Level	1600 hrs 10/2/99	1600 hrs 8/3/99
Volume of Inflow	1,140,000 ML	159200 ML
Storage Deficit at start of event	287,000 ML	0 ML
Volume of Outflow	853,000 ML	159200 ML
Somerset Dam		
Maximum Inflow	4140 m^3/sec	342 m^3/sec
Maximum Outflow	857 m^3/sec	70 m^3/sec
Maximum Storage Level	EL 103.03 m AHD	EL 99.87 m AHD
Time of Maximum Level	1200 hrs 10/2/99	0300 hrs 5/3/99
Volume of Inflow	501,500 ML	62360 ML
Storage Deficit at start of event	207,800 ML	0 ML
Volume of Outflow	293,700 ML	62360 ML[1]
North Pine Dam		
Maximum Inflow	1053 m^3/sec	486 m^3/sec
Maximum Outflow	80 m^3/sec	80 m^3/sec
Maximum Storage Level	EL 39.75 m AHD	EL 39.75 m AHD
Time of Maximum Level	1400 hrs 10/2/99	1630 hrs 2/3/99
Volume of Inflow	99,470 ML	13280 ML
Storage Deficit at start of event	88,960 ML	0 ML
Volume of Outflow	10,510 ML	13280 ML

As indicated in the above Table, the February event was a significant flood event in the Brisbane River. This was especially so in the upper Brisbane River and Stanley River catchments. Rainfalls in the upper Brisbane catchments were typically greater than those associated with 2% AEP events and at Devon Hills rainfalls were greater than the

[1] Note that this volume of outflow includes the volume drained from the storage (to FSL) by the hydro station after the closure of the regulators at EL 99.22 mAHD.

0.5% AEP event. The resultant flood in the upper Brisbane was of a similar magnitude to the January 1974 event although the volume was not as big.

Below Wivenhoe Dam there were only minor rainfalls and this only generated minor flows in Lockyer Creek and the Bremer River. This avoided any repeat of the January 1974 event type flooding.

The February event was essentially handled in accordance with the Manual of Flood Operational Procedures for Flood Mitigation for Wivenhoe Dam and Somerset Dam. However, some changes need to be made to this manual to accommodate some minor difficulties encountered during the event. The March event was not well covered in the manual and it became an exercise in draining out the Somerset flood storage with a minimum of disruption to the public. This produced a long drainage time, but it was done with one eye on the weather and in full consultation with the SEQWB.

Overall, the February event was an ideal demonstration of what Wivenhoe Dam can deliver in terms of flood mitigation.

Both events at North Pine Dam were handled in complete accordance with the Manual of Operational Procedures for Flood Releases from North Pine Dam. While the magnitude of releases was similar for both events, this was only due to the drawn down state of North Pine Dam prior to the February event. The March event was relatively small and only required releases because it was completely full at the start of the event.

4. SUMMARY OF RECOMMENDATIONS

The following summary is a collation of the recommendations made in this report. The reader is referred to particular sections of this report for more detail and the reasons behind particular recommendations.

No.	Referenced Section	Recommendation
1	8.1	• SEQWB may wish to consider formal access to BoM weather briefings prior to and during major heavy rainfall weather events.
2	9.2.2	• A mechanism needs to be found to ensure the maximum availability of ALERT station #2168, David Trumpy Bridge[2] • Radio communication from Somerset Dam need to be improved as a matter of priority.
3	9.2.4	• A number of new ALERT river height stations are proposed. The list of these stations includes Linville, Kholo Bridge, Burton's Bridge, Buaraba Creek and Splityard Creek Dam
4	9.7	• A better, more accurate means of reading Wivenhoe Dam water levels needs to be provided to ensure consistency of manual readings

[2] Discussions following the event have indicated that BoM are maintaining the station and that updated calibration data can be obtained from BoM.

No.	Referenced Section	Recommendation
5	11.3	• The WIVOPS gate operations routines need to be incorporated into the FLOODOPS system. • Inclusion of a 'user-edited' gate operation sequence into FLOODOPS
6	11.5	• The rating curves for a number of stations downstream of Wivenhoe Dam need to be reviewed to ensure consistency between the stations.
7	17	• An arrangement needs to be formalised with DNR Surface Water Assessment group for the ongoing maintenance and technical support of the RTFM.
8	18.1	• Changes are made to the recommended gate opening sequences to limit the impact of the flow on the side wall of the spillway
9	18.2	• Provision should be made in the Wivenhoe and Somerset Manuals of Operations to allow for the closure of regulators and the immediate opening of a gate to replace the discharge rather than waiting for the minimum operating intervals (plus the reverse operation).
10	18.3	• Mention should be made in Somerset Dam operations of the D'Aguilar Highway bridge (Mary Smokes Bridge) at the upstream end of the storage. The SFOE can then consider the bridge in dam operations.
11	18.4	• Consideration should be given to the operation of Somerset Dam in the event of no or minimal inflows into Wivenhoe Dam.
12	18.5	• Consideration should be given to the definition of FSL in Wivenhoe Dam and to what level does this correspond to in Splityard Creek Dam.
13	18.6	• The close down sequence for North Pine Dam could be better defined.

5. REASON FOR THE REPORT

This report is prepared in accordance with the requirements of the following Flood Operations Manuals:-

- Manual of Operational Procedures for Flood Mitigation for Wivenhoe Dam and Somerset Dam, Revision No.2, 13 November 1997
- Manual of Operational Procedures for Flood Releases from North Pine Dam, Revision No.2, 13 November 1997.

Section 2.9 of both of these Manuals requires the Senior Flood Operations Engineer to submit a report to the Headworks Operator within six weeks of the completion of a flood event. The *"report shall contain details of the procedures used, the reasons therefore and other pertinent information."*

Because the one team directed the operations at all three dams using the same data collection system and operational software, a combined report has been prepared for all dams. The proximity of the events also meant that it was practical to combine both events into the one report.

6. MOBILISATION AND STAFFING OF THE FLOOD CONTROL CENTRE AND THE SEQWB DAMS

6.1 February 1999 event

The DNR flood response team was formally mobilised on the afternoon of Monday 8th February. While heavy rain started occurring in the Wivenhoe, Somerset and North Pine catchments from about 1800 hrs the night before, there was a considerable storage buffer in all three dams and only minor inflows into Somerset and North Pine Dams occurred before midnight of 7th February.

The heavy rain continued through into the next morning with the Duty Engineer (Peter Allen) periodically monitoring the event by downloading data through *FLOODPC* from home. Rainfall and river heights were continuously monitored in the Flood Control Centre (FCC) from about 0800 hrs on the Monday morning. As noted in the attached abridged FCC logs, the DNR Contract Manager was notified at 1045 hours that flood operations were likely and Dam Supervisors should be mobilised to all three dams. The Dam Supervisors progressively reported in the status of their dams and their operational readiness as follows:-

1205 hrs: North Pine fully staffed and operational
1205 hrs: Wivenhoe fully staffed and operational
≈1300 hrs: Somerset[3]

Formal mobilisation was delayed until it was evident that gate operations would be needed. SEQWB were notified of the mobilisation through a phone call to David Gill and Garry Grant (SEQWB) at 1700 hours on Monday afternoon.

Once mobilised, the following staffing arrangements applied: -

(a) Duty Engineers: Two Duty Engineers were on duty at all times at the FCC until midnight on Saturday 13th February when Wivenhoe peaked. Once the drainage phase began generally only one Duty Engineer was on duty at any one time.

(b) Data Collectors Two data collectors were on duty from the start of the event until 0800 hrs on the morning of 9th February. A third data collector was then mobilised to assist the data collection and verification operations and the notification of affected authorities. This was dropped back to two data collectors at 0800 hrs on 10th February when the gate operation strategy for Wivenhoe Dam had been developed and most of the significant rain had fallen. This was then dropped back to one data collector at 1730 hours on 12th February when the workload dropped sufficiently to be handled by one data collector.

(c) Two DNR dam operators were on duty at all times on a shift basis (2 operators per 12 hour shift; 0700 hrs to 1900 hrs and 1900 hrs to 0700 hrs) at each of the dams until gate operations were completed and no more significant inflows were expected.

The event was declared over at 1230 hrs on 19th February. This occurred once the SFOE was happy that 'dribble inflows' into Wivenhoe Dam were not going to cause any

[3] The Dam Supervisor was in Toogoolawah earlier in the day getting spare parts and was returning to Somerset when he advised the FCC of such at 12:18 hrs.

problems over the next several days. Following this declaration, the monitoring of the dams and the ongoing weather reverted to the control of the Duty Engineer on close call.

6.2 March 1999 Event

The March event was different from the February event by the fact that the catchment was still relatively wet from the February event, and all the storages had crept marginally above their set Full Supply levels. This meant that initial losses were minimal (i.e. a high percentage of what rain fell, ran off), and there was no storage capacity deficit to fill prior to operations. As a result, DNR were forced to mobilise once run-off occurred and reservoir rises were noted.

Significant rainfall had fallen in the Somerset and North Pine catchments in the several days prior to 1st March. SFOE Peter Allen discussed the emerging situation with Garry Grant (SEQWB) at 2100 hrs on the night of Sunday 28th February. SFOE Allen indicated that at that time:-

(a) An inflow of approximately 80 m^3/sec was expected into Somerset Dam, producing a rise of about 0.2 metre. A regulator may need to be opened tomorrow to pass the inflow through the Storage.

(b) DNR were likely to open a gate at North Pine Dam the next day anyway to reduce the storage level back to below EL 39.6. The storage level had crept up from its closing level of EL 39.557 on 14th February to EL 39.63.

The decision to mobilise North Pine Dam was made by Duty Engineer John Ruffini (after consultation with SFOE Peter Allen) on the morning of 1st March once heavy rain again began to fall in the North Pine catchment.

Once mobilised, the following staffing arrangements applied:-

(a) Duty Engineers: Two Duty Engineers were on duty for the first shift while the magnitude of the event was being assessed. Once this first shift was over, only one Duty Engineer was rostered to be on duty at any one time.

(b) Data Collectors Similarly to the Duty Engineers, two data collectors were used on the first shift and then this was scaled back to one for the duration of the event. Additional data collectors were available if required.

(c) The initial mobilisation was for North Pine Dam at 0630 hrs on 1st March. Two DNR dam operators were on duty at all times, on a shift basis (2 operators per twelve-hour shift; 0700 hrs to 1900 hrs and 1900 hrs to 0700 hrs) until gate operations were completed at 1145 hrs on 5th March. They were then stood down and proceeded to report lake levels at the start and finish of normal working hours.

(d) Dam operators were mobilised to Wivenhoe dam on 4th March when it was decided to operate the radial gates to release floodwaters on the Lockyer Creek recession. Up until this time, releases had been through the regulators and it was not considered necessary to permanently staff the dam. Mobilisation of the dam operators was discussed with representatives of the SEQWB (meeting 0900 3rd March) when it was agreed that Dam Supervisors would need to be on duty at all times releases through the radial gates were in progress.

(e) At no time during the event did Dam Supervisors mobilise to Somerset Dam. All releases from Somerset Dam were through the regulators and it was not considered necessary for dam staff to be present at all times for these releases.

Releases through the Somerset regulators were stopped at 1050 hrs on 10th March when a direction to do so came from the Chairman of the SEQWB who had discussed the issue with Director General of the DNR. The reservoir level at the time was 99.22 mAHD. Subsequent releases were all made through the Somerset hydro station. It is understood the hydro station discharges at a rate of approximately 13.5 m^3/sec on a 24 hour basis.

Full time monitoring of the event was finalised at 1800 hrs on 16th March when discharge control at Wivenhoe was transferred from the radial gates to the regulators. Mobilisation for the event was declared over at 1200 hrs on the 16th March once the regulator discharge was reduced to 30 m^3/sec and the SFOE was happy that dribble inflows into Wivenhoe Dam were not going to cause any problems over the next several days. Following this declaration, the monitoring of the dams and the ongoing weather again reverted to the control of the Duty Engineer on close call.

7. THE STORAGE SITUATION PRIOR TO THE FEBRUARY 1999 EVENT

In the days preceding the February flood, the catchment had been 'wetted up' by falls of 50 to 80 mm over the period 1st to 3rd February. In particular, these rains produced minor inflows into Somerset (≈ 1.0 metre rise) and North Pine (≈ 0.5 metre rise) over the period 1st to 4th February.

The following Table summarises the storage situation prior to the flood event of 7th February. It shows that there was significant storage capacity available at all dams before gate operations were required.

DAM	Level @ 1630 hrs 7/2/99 EL (mAHD)	% Full Supply Storage	Runoff required to Fill (mm)	Antecedent Precipitation Index	Expected Initial Loss (mm)	Required Rain at 5mm/hr to reach FSL (mm)	Required Rain at 10mm/hr to reach FSL (mm)	
Somerset Dam (FSL 99.0 m)	93.67	53	158	61	36	299	233	
Wivenhoe Dam	64.02	75.4	43	35	47	150	112	Inclusive of Somerset catchment
(FSL 67.0 m)			53			166	125	Exclusive of Somerset catchment
North Pine Dam (FSL 39.6 m)	34.78	58.9	272	80	27	368	330	

This information was forwarded by fax to the Bureau of Meteorology on the evening of Sunday 6th February.

8. THE WEATHER SITUATION

8.1 General

January 1999 had rainfall totals above average in the south east corner of Queensland. The beginning of the month of February, 1999 presented a situation where the Pine River and Brisbane River catchments were wet, the sea surface temperatures off the south-east coast of Australia were above average and the monsoonal trough was active in northern Australia.

The Bureau of Meteorology has access to four global circulation models that are used to provide information that allows rainfall predictions for periods of up to seven days to be made. These forecasts can be quite diverse but under some circumstances when all models are predicting heavy rainfall x days out then there can be some confidence in the fact that heavy rainfall will occur. The closer the rainfall predictions for the four models are then the more confidence the BoM has in its predictions.

The Duty Senior Meteorologist at the BoM Brisbane briefs the BoM hydrology daily at 0930 hrs. He was predicting significant rainfall in South East Queensland four days before the February event. The Duty Flood Engineers have access to this information through contact with the Duty Flood Engineer BoM and have been invited to attend briefings at the Bureau when significant rainfall is predicted. This arrangement is somewhat informal and is currently being conducted on an officer to officer basis. The SEQWB may wish to consider a more formal arrangement with the BoM. It is unclear how the BoM would respond to such a request as they may resist an arrangement that has compunction in it. We believe that access to accurate medium range forecasts provided by the global circulation models would greatly enhance the ability of the Flood Engineers to plan an ordered response to a potential flood event (eg members of the team could organise normal work commitments ahead of coming on duty). Similarly during a flood event medium range forecasts can be used to modify release strategies where appropriate to minimise the disruption to residences downstream of the dams.

The Quantitative Precipitation Forecasts are a service, which the BoM provides to the Flood Operations Engineers twice a day. These forecasts provide a 24 hour prediction for the Upper Brisbane/Stanley and Pine Rivers catchments. These forecasts have proved useful over the past two years. They did however fail to forecast the largest rainfall days in early February. The reasons for this are yet to be resolved.

8.2 February 1999 Event

The monsoonal trough lay across northern Cape York Peninsula and linked up to tropical lows in the Coral Sea that combined with an upper level cutoff low over south-east Queensland to produce heavy rainfall. Cyclone Rona subsequently formed and crossed the coast just north of Cairns on Friday the 12th, degenerated into a rain depression and proceeded down the coast threatening to create more flooding rains. On Sunday the 14th the ex-tropical cyclone moved out to sea just south of Rockhampton.

The majority of the rainfall for this event fell over a three day period from 0900 hrs on the 07/02/1999 to 0900 hrs 09/02/1999. The rainfall temporal patterns, cumulative totals, intensity /frequency/duration analyses and sub-catchment rainfall totals for the alert stations in the Brisbane River and Pine River Basins are presented in Appendices B and C.

8.3 March 1999 Event

A series of upper trough systems moved east across the south-east in an easterly direction resulting in a series of moderate to heavy rainfall events.

The majority of the rainfall for this event fell over a five day period from 0900 hrs on the 28/02/1999 to 0900 hrs 04/03/1999. The rainfall temporal patterns, cumulative totals, intensity /frequency/duration analyses and sub-catchment rainfall totals for the alert stations in the Brisbane River and Pine River Basins are presented in Appendices F and G.

9. THE DATA COLLECTION SYSTEM

9.1 General

A range of data systems was available to the Flood Operations Engineers. These data systems included:-

(a) The SEQWB ALERT rainfall and river height network
(b) The DNR Hydromet Telephone Telemetry System
(c) RAPIC weather radar imagery
(d) BoM weather forecasts and warnings
(e) BoM Quantitative Precipitation Forecasts
(f) Manually observed storage levels and river heights

Each of the following sections discusses the performance and usefulness of the above systems in more detail.

9.2 The SEQWB ALERT rainfall and river height network

9.2.1 Description of ALERT Network

The SEQWB ALERT network is the most important element of the overall data collection system available to the DNR Flood Control Room.

The network consists of 73 rainfall and 52 river height sensors spread throughout the Pine River and Brisbane River catchments. The system was supplied and installed by the SEQWB in 1996, and is now maintained by the SEQWB.

9.2.2 Performance of ALERT Stations during the February 1999 Event

Performance data has been extracted for the network and it is summarised in the following Tables.

Sensor Network	No. of Stations	Overall Station Availability
Main Rain	60	90%
Main River	41	78.5%
Back-up Rain	13	85%
Back-up River	11	100%