

# CONTENTS

<b>ACKNOWLEDGMENTS .....</b>	<b>v</b>
<b>SUMMARY .....</b>	<b>1</b>
<b>1. INTRODUCTION .....</b>	<b>6</b>
1.1 The Great Barrier Reef – An Ecological System.....	6
1.2 The GBR Catchment .....	6
1.3 The Great Barrier Reef Lagoon .....	7
1.4 Why are Rivers and Flood Events Important?.....	11
1.5 Extent of River Plumes in the Great Barrier Reef .....	13
1.6 Changes in the Great Barrier Reef Catchment .....	14
1.7 Potential Impacts on the Great Barrier Reef from Changes in Water Quality Associated with Flood Plumes.....	17
1.8 The Present Study .....	19
<b>2. HISTORY OF RESEARCH AND MONITORING OF CYCLONES AND FLOOD PLUMES IN THE GREAT BARRIER REEF .....</b>	<b>21</b>
<b>3. METHODOLOGY .....</b>	<b>25</b>
3.1 Flood Plume Monitoring Program .....	25
3.2 Aerial Mapping and Distribution of Flood Plumes .....	25
3.3 Long term Patterns of Cyclones and Rainfall .....	26
3.4 Water Sampling.....	26
3.5 Analytical Methods.....	28
<b>4. RESULTS .....</b>	<b>29</b>
4.1 Movement and Physical Characteristics of Flood Plumes .....	29
4.1.1 January 1991 – Cyclone Joy .....	30
4.1.2 February 1994 – Cyclone Sadie .....	30
4.1.3 February 1995 – Cyclone Violet.....	32
4.1.4 March 1996 – Cyclone Ethel .....	32
4.1.5 March 1997 – Cyclone Justin .....	37
4.1.6 December 1997/January 1998 – Cyclones Sid and Katrina .....	37
4.1.7 February 1999 – Cyclone Rona .....	43
4.2 Plumes, Hydrological Conditions and Distribution of Plume Waters.....	43
4.3 Plumes and Water Quality Processes.....	43
4.4 Spatial Dynamics of Materials in Plumes .....	44
4.4.1 Vertical Distribution.....	44
4.4.2 Spatial Distribution of Water Quality Parameters in Flood Plumes .....	45
<b>5. DISCUSSION .....</b>	<b>63</b>
5.1 Spatial Characteristics of Flood Plumes .....	63
5.1.1 Influences on the Spatial Distribution of Plumes.....	63
5.1.2 Steering of Plumes .....	63
5.1.3 Empirical Model of Plume Movement and Characteristics.....	63
5.1.4 Plume Coverage and Reefs .....	72
5.2 Water Quality and Plumes .....	76
5.2.1 River Dynamics, First Flush and Changes in River Concentrations .....	76
5.2.2 Sediment and Nutrient Concentrations Measured in Plume Waters .....	76
5.2.3 Mixing Processes Occurring in the Plumes .....	77

5.3	Implications of Changed Land-use for River and Plume Waters .....	81
5.4	Implications of Changed Land-use in the Catchment for GBR Ecosystems ....	82
5.5	Further Research .....	98
5.6	Management Implications .....	99

<b>GLOSSARY</b> .....	100
-----------------------	-----

<b>REFERENCES</b> .....	101
-------------------------	-----

## FIGURES

1.	Map of the Great Barrier Reef Catchment and major rivers draining into the Great Barrier Reef Lagoon .....	8
2.	Landuse characteristics of the Great Barrier Reef Catchment .....	9
3.	Differences in flow rate between the Tully (Wet Tropics), Herbert (intermediate) and the Burdekin River (Dry Tropics).....	10
4.	Seasonal extremes in the Barron River, from the Atherton Tablelands the Barron River flows through the World Heritage rainforest (a) dry season – October 1994 (b) wet season – March 1995 floods .....	11
5.	Aerial photograph of plume boundary intersecting with oceanic water, Fitzroy River area, 1991 .....	12
6.	Nutrient concentration in response to flow rate from the Burdekin and Tully Rivers .....	13
7.	Changes in vegetation cover of the Herbert Catchment for Melaleuca and rainforest since pre-European times.....	15
8.	Increases in the application of nitrogen and phosphorus fertilisers to the Great Barrier Reef Catchment .....	15
9.	Observable plume in aerial flyover (Russell-Mulgrave River plume) .....	26
10.	Tracks of cyclones over the Queensland coast.....	29
11.	Flood plume associated with cyclone Joy (1991) from the Fitzroy River .....	33
12.	Flood plume associated with cyclone Sadie (1994) from Wet Tropics Rivers .....	34
13.	Flood plume associated with cyclone Violet (1995) from Wet Tropics Rivers .....	35
14.	Flood plume associated with cyclone Ethel (1996) from Wet Tropics Rivers.....	36
15.	Flood plume associated with cyclone Justin (1997) from Burdekin River .....	38
16.	Flood plume associated with cyclone Justin (1997) from Wet Tropics Rivers .....	39
17.	Flood plume associated with cyclone Sid (1998) from Wet Tropics and Burdekin Rivers .....	40
18.	Flood plume associated with cyclone Sid (1998) from Burdekin River.....	41
19.	Flood plume associated with cyclone Rona (1999) from Wet Tropics Rivers .....	42
20.	Depth profiles of salinity, temperature and turbidity on a transect out from the Barron River mouth .....	45
21a.	Cyclone Joy 19/01/91 – Fitzroy River hydrological conditions and sampling locations.....	46
21b.	Concentrations of water quality parameters adjacent to the Fitzroy River in the flood plume associated with cyclone Joy (1991).....	47
21c.	Concentrations of water quality parameters adjacent to the Fitzroy River in the flood plume associated with cyclone Joy (1991).....	48
22a.	Cyclone Justin 25/03/97 – Barron River hydrological conditions and sampling locations .....	49
22b.	Concentrations of water quality parameters adjacent to the Barron and Russell-Mulgrave rivers in the flood plume associated with cyclone Justin (1997) ..	50
23a.	Cyclone Justin 25/03/97 – Johnstone & Tully rivers hydrological conditions	

and sampling locations.....	51
23b. Concentrations of water quality parameters adjacent to the Johnstone and Murray rivers in the flood plume associated with cyclone Justin (1997) .....	52
24a. Cyclone Justin 25/03/97 – Herbert River hydrological conditions and sampling locations .....	53
24b. Water quality concentrations from the Tully and Herbert rivers taken in the cyclone Justin plume (March 1997).....	54
25. Cyclone Sid 14/01/98 – Burdekin River hydrological conditions and sampling locations .....	55
26. Cyclone Sid 23/01/98 – Burdekin River hydrological conditions and sampling locations .....	56
27a. Distribution of dissolved and particulate phosphorus on two different sampling occasions (8 days apart) following cyclone Sid in January 1998.....	57
27b. Distribution of dissolved and particulate nitrogen on two different sampling occasions (8 days apart) following cyclone Sid in January 1998 .....	57
27c. Distribution of silicate and suspended solids from two sampling occasions from the Burdekin river plume taken during cyclone Sid (1997).....	58
27d. Distribution of chlorophyll and phaeophytin from two sampling occasions from the Burdekin river plume taken during cyclone Sid (1998).....	58
28. Cyclone Justin 04/03/97 – Burdekin River hydrological conditions and sampling locations .....	59
29. Cyclone Sid 14/01/98 – Burdekin River hydrological conditions and sampling locations .....	60
30a. Distribution of dissolved and particulate phosphorus on two sampling occasions over two flood events over consecutive years (1997 and 1998) .....	61
30b. Distribution of dissolved and particulate nitrogen on two sampling occasions over two flood events over consecutive years .....	61
30c. Distribution of silicate and suspended solids on two sampling occasions over two flood events over consecutive years .....	62
30d. Distribution of chlorophyll and phaeophytin on two sampling occasions over two flood events over consecutive years .....	62
31. Frequency and distribution of plume coverage in the GBR from 1991–1999 .....	66
32. Summary of wind data measured at Cairns airport for cyclones studied from 1994–1999.....	67
33. Plume distribution for the Wet Tropics area, between and including Johnstone and Barron Rivers .....	69
34. Working example for prediction of plume distribution using historical flow and wind data from the Barron River .....	70
35. Frequencies of plume coverage for reefs within the GBR .....	73
36. Idealized representation of the relationship between concentrations of a dissolved component and a conservative index of mixing for an estuary where there are single sources of river and seawater .....	79
37. NO <sub>x</sub> (nitrate and nitrite) versus salinity from Wet Tropics river plumes associated with cyclones Violet, Justin, Sid and Rona .....	81
38. DIP versus salinity from Wet Tropics river plumes associated with cyclones Violet, Justin, Sid and Rona .....	83
39. Salinity versus PN from Wet Tropics river plumes associated with cyclones Violet, Justin, Sid and Rona .....	84
40. PP versus salinity from Wet Tropics river plumes associated with cyclones Violet, Justin, Sid and Rona .....	85
41. Water quality parameters versus salinity from Wet Tropics river plumes	

	associated with cyclones Violet, Justin, Sid and Rona .....	86
42.	Various water quality parameters versus salinity from Wet Tropics river plumes associated with cyclones Violet, Justin, Sid and Rona .....	87
43.	Water quality parameters versus salinity measured in river flood plumes from the Burdekin associated with cyclones Justin and Sid .....	88
44.	Water quality parameters versus salinity measured in river flood plumes from the Fitzroy associated with cyclone Joy .....	89
45.	Relationship between DIN concentrations and area of developed catchment within the GBR catchment .....	90
46a.	Sampling sites and plume distributions surrounding Frankland Islands through period of study, 1991–1999 .....	91
46b.	Water quality concentrations (nitrogen and phosphorus species) taken near Frankland Islands .....	92
47a.	Sampling sites and plume distributions surrounding High Island through period of study, 1991–1999 .....	93
47b.	Water quality concentrations (nitrogen and phosphorus species) taken near High Island .....	92
48a.	Sampling sites and plume distributions surrounding Pandora Reef through period of study, 1991–1999 .....	94
48b.	Water quality concentrations (nitrogen and phosphorus species) taken near Pandora Reef .....	95
49a.	Sampling sites and plume distributions surrounding Keppels and Heron Islands through period of study, 1991–1999 .....	96
49b.	Water quality concentrations (nitrogen and phosphorus species) taken near Keppel Islands on 17–18 January 1991 and surrounding Heron Island on 23–24 January .....	95

## TABLES

1.	Land use areas and other statistics for catchments of eastern Queensland .....	16
2.	History of cyclones and significant flood events in the Great Barrier Reef and their biological impacts .....	22
3.	Sampling strategies of each plume event .....	27
4.	Flood plumes and summary of characteristics .....	31
5.	Flood plumes and cited biological impacts .....	32
6.	Minimum salinities and maximum nutrients, chlorophyll and suspended particulate matter concentrations in the Wet Tropics sampled in GBR waters following cyclonic events .....	44
7.	Minimum salinities and maximum nutrients, chlorophyll and suspended particulate matter concentrations from the plumes associated with the Dry Tropics rivers sampled in GBR surface waters .....	45
8.	Fixed and random factors that determine distribution of plume extent and duration .....	64
9.	Study period with a daily discharge of > 30 000ML at Myola (Barron River) .....	65
10.	Idealised plume distribution based on the observed events 1994–1999 for the Barron and Russell-Mulgrave River section .....	69
11.	Predicted plume distribution based on the flow rates and wind data for the Barron River section for the period 1943–1999 .....	71