

TABLE OF CONTENTS

ACKNOWLEDGEMENT

ABSTRACT

ABSTRACT

DECLARATION

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION

1.1 General Introduction

1.2 Importance of the Study

1.3 Objectives of the Study

1.4 Scope

1.5 Organization

1.6 Summary

1.7 References

1.8 Conclusion

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

2.2 Importance of the Study

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
ABSTRAK	Iv
TABLE OF CONTENTS	Vi
LIST OF TABLES	Xii
LIST OF FIGURES	xv
LIST OF APPENDICES	xx
ABBREVIATIONS	xxi
CHAPTER 1 INTRODUCTION	1
1.1 General Introduction	1
1.2 Constructed Wetlands in Putrajaya	2
1.3 Objectives of the Putrajaya Wetlands	3
1.4 Location	4
1.5 Topography	6
1.6 Drainage	6
1.7 Existing Landuse	6
1.8 Importance and Aims of the Study	8
CHAPTER 2 LITERATURE REVIEW	9
2.1 Definitions of Wetlands	9
2.2 Importance of Wetlands	11

2.3	Constructed Wetlands	13
2.3.1	Development of Constructed Wetlands	14
2.3.2	Type of Constructed Wetlands	15
2.4	Constructed Wetlands for Water Pollution Control	17
2.4.1	Constructed Wetlands for Wastewater Treatment	17
2.4.2	Constructed Wetlands for Stormwater/Runoff Treatment and Control	20
2.5	Treatment Processes	21
2.5.1	Biological Processes	22
2.5.2	Chemical Processes	24
2.5.3	Physical Process	25
2.6	Factors Influencing Wetlands Treatment Processes	26
2.6.1	Climate	26
2.6.2	Oxygen	27
2.6.3	pH	29
2.6.4	Temperature	29
2.7	Pollutant Removal	29
2.7.1	Gross Pollutants	29
2.7.2	Suspended Solids	30
2.7.3	Biochemical Oxygen Demand (BOD)	31
2.7.4	Phosphorus	31
2.7.5	Nitrogen	32
2.7.6	Heavy Metals	32
2.7.7	Hydrocarbons	33
2.7.8	Pathogens	33

2.8	Role of Wetland Vegetation	34
2.9	Putrajaya Constructed Wetland and Design Strategy	36
2.9.1	Wetland Components	36
2.9.2	Wetland Design	39
2.9.3	Hydraulic Efficiency	39
2.9.4	Vegetation Layout	39
2.9.4.1	Upper North (UN) Wetland Arm	40
2.9.4.2	Central Wetlands (CW)	40
2.9.4.3	Wetland Treatment Zones	42
2.9.5	Inlet Zones, Primary Sedimentation Basins and Outlet Design	46
2.9.6	Water Re-circulation System	49
2.9.7	Mosquito Control	51
2.10	Wetland Species and Planting	51
2.11	Limitations of Wetland Processes in Improving Water Quality	53
2.11.1	Rates of Processes	53
2.11.2	Hydrological Limitations	53
2.11.3	Environmental limitations	55
CHAPTER 3	MATERIALS AND METHODS	56
3.1	Introduction	56
3.2	Sampling Strategy	56
3.3	Environmental Data Collection	78
3.3.1	Water Quality	78
3.3.2	Atmospheric Parameters	78

3.4	Sampling Parameters and Methodologies	78
3.5	Laboratory Analysis	83
3.5.1	pH	83
3.5.2	Dissolved Oxygen (DO)	83
3.5.3	Biochemical Oxygen Demand (BOD)	84
3.5.4	Chemical Oxygen Demand (COD)	84
3.5.5	Total Suspended Solids (TSS)	85
3.5.6	Ammoniacal Nitrogen (AN)	85
3.6	Statistical Analysis	86
 CHAPTER 4 RESULTS		88
4.1	Description of the Putrajaya Freshwater Ecosystem	88
4.1.1	Before Wetlands Construction	88
4.1.2	After Wetlands Construction	88
4.2	Baseline Information on River Water Quality	92
4.3	Trend in Water Quality Index (WQI)	93
4.3.1	Pre-construction of Wetland Cells	94
4.3.2	During Construction of Wetland Cells	94
4.3.3	After Construction of Wetland Cells	95
4.4	Trend of Water Quality Parameters	102
4.4.1	Water Quality Parameters for Pre-construction of Wetland Cells	102
4.4.1.1	pH	102
4.4.1.2	Dissolved Oxygen (DO)	104
4.4.1.3	Biochemical Oxygen Demand (BOD)	106

4.4.1.4	Chemical Oxygen Demand (COD)	108
4.4.1.5	Ammoniacal Nitrogen (AN)	110
4.4.1.6	Total Suspended Solids (TSS)	112
4.4.2	During Construction of Wetland Cells	114
4.4.2.1	pH	114
4.4.2.2	Dissolved Oxygen (DO)	116
4.4.2.3	Biochemical Oxygen Demand (BOD)	118
4.4.2.4	Chemical Oxygen Demand (COD)	120
4.4.2.5	Ammoniacal Nitrogen (AN)	122
4.4.2.6	Total Suspended Solids (TSS)	124
4.4.3	After Construction of Wetland Cells	126
4.4.3.1	pH	126
4.4.3.2	Dissolved Oxygen (DO)	128
4.4.3.3	Biochemical Oxygen Demand (BOD)	130
4.4.3.4	Chemical Oxygen Demand (COD)	132
4.4.3.5	Ammoniacal Nitrogen (AN)	133
4.4.3.6	Total Suspended Solids (TSS)	135
4.5	Meteorological Data	137
4.5.1	Rainfall	137
4.5.2	Temperature	137
4.5.3	Solar Radiation	138
4.5.4	Cloud	138
4.6	Statistical Analysis	140
4.6.1	Simple Correlation between WQI with Water Quality Parameters and Meteorological Data	140

4.6.2	Simple Correlation among Water Quality Parameter with Meteorological Data	141
4.6.3	Analysis of Variance (ANOVA)	142
4.6.4	Principal Components Analysis (PCA)	162
4.7	Performance of Constructed Wetlands	168
CHAPTER 5 DISCUSSION		175
5.1	Trend of Water Quality Index (WQI)	175
5.2	Trend of Water Quality Parameters	177
5.2.1	Temporal, Spatial and Seasonal Effects on pH	178
5.2.2	Temporal, Spatial and Seasonal Effects on Dissolved Oxygen (DO)	180
5.2.3	Temporal, Spatial and Seasonal Effects on Biochemical Oxygen Demand (BOD)	182
5.2.4	Temporal, Spatial and Seasonal Effects on Chemical Oxygen Demand (COD)	184
5.2.5	Temporal, Spatial and Seasonal Effects on Ammoniacal Nitrogen (AN)	185
5.2.6	Temporal, Spatial and Seasonal Effects on Total Suspended Solids (TSS)	187
5.3	Performance of Constructed Wetlands in Removing Pollutants	189
5.4	Conclusion/Future Areas for Research	191
CHAPTER 6 CONCLUSION		194
REFERENCES		198
APPENDICES		205