

## Chapter 8

# Economic Evaluation of Regional Non Point Source Load Reduction Strategies

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The results of an economic evaluation of regional, non-point-source load reduction strategies for Tampa Bay are reported. The study is sponsored by the Tampa Bay National Estuary Program (TBNEP). The objective of the study is to determine cost-effective strategies for reducing pollutant loads from non-point sources to the Bay. Average and marginal costs in dollars per kilogram of nitrogen removed are reported for a range of efforts.

### 8.1 Introduction

A matrix that identifies the optimal Best Management Practice (BMP) for each combination of land use and soil type found in the basin is produced. A Geographic Information System (GIS) is then used to

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compare attributes of polygons containing homogeneous soil and land use properties to the site criteria appropriate to each such BMP. The site criteria include depth to water table, infiltration rate, terrain slope, and land use. An optimization routine is finally applied to determine the most cost-effective BMP load reduction strategy for the Bay.

## **8.2 Project Area**

The Tampa Bay Watershed is located in west-central Florida. It consists of all or part of six counties including all of Pinellas and Hillsborough, most of Manatee, and portions of Sarasota, Polk, and Pasco. The Bay is approximately 400 square miles and the watershed is approximately 2,300 square miles. The watershed contains mostly agricultural land use with highly urbanized areas in the western portion of the study area. Non-point-source runoff from these changed land uses has adversely affected submerged aquatic vegetation in the Bay.

## **8.3 GIS Coverages**

The overlay feature of an ARC/INFO GIS was used to form the intersection of land use, soil property, and subbasin location for the entire Tampa Bay Watershed. The GIS coverages were obtained from the Southwest Florida Water Management District (SWFWMD). The maps were prepared from 1" = 200' scale aerial photography. Attributes of the LAND USE coverage include the Florida Land Use Classification System (FLUCS) code. The classification system is arranged in hierarchical levels with each level containing an increasingly detailed description of the land cover or use. SWFWMD GIS files report the most specific category that can be interpreted from infrared photography, often at level IV. Attributes of the SOIL coverage include the Soil Conservation Service (SCS) soil identification number and county code. The subbasin coverage contains a basin identification number, and bay segment designator which identifies the portion of the Bay that each subbasin drains into. The OVERLAY coverage contains attributes of soil, land use and subbasin.

## **8.4 Literature Search**

A BMP database containing efficiencies, site constraints, and cost-effectiveness data for 50 BMPs considered for use in the Tampa Bay

Watershed has been compiled from a variety of sources. BMPs for both urban and agricultural uses are included. Removal efficiencies for Total Nitrogen (TN), Total Phosphorus (TP), Total Suspended Solids (TSS), and six other water quality constituents are included (EPA 1993, Kehoe 1992, Schueler et al. 1992, and NCSU 1991). A portion of the BMP Removal Efficiency Matrix is shown in Table 8.1. The values shown in the table represent the range of removal efficiencies found in the literature for each BMP tabulated. Site constraints include depth to water table, soil infiltration rate, slope of terrain, and proximity to structural improvements. A portion of the BMP Site Constraints Matrix is shown in Table 8.2. Cost data for each BMP are shown in Table 8.3. Site cost must be included for BMPs requiring land acquisition. Abbreviations used in the tables are defined at the end of the chapter.

## 8.5 BMP Selection

A database query has been used to match records in the BMP database with properties in the SOIL database and land use compatibility defined in the LAND USE database. The result is a suitability matrix that identifies each combination of soil and land use found in the basin with every compatible BMP. Each record in the SUITABILITY matrix contains a FLUCS code, a soil identification number, a BMP number, removal efficiencies for each pollutant, and the cost per acre of land treated. Each polygon from the OVERLAY coverage was then compared to the BMP SUITABILITY matrix to determine a set of feasible BMPs for that polygon. This operation was performed by database query. The set of feasible BMPs was then evaluated for cost-effectiveness.

## 8.6 Optimization

An optimization scheme was then developed to select one BMP from the set of feasible BMPs identified. The optimization model is based on dynamic programming (Wilde and Beightler, 1992). The selection process is schematized as a serial decision making process. The stages represent the polygon groups from the OVERLAY coverage. A polygon group is a set of polygons sharing identical subbasin, soil, and land use attributes. The initial ordering is arbitrary. The decision variable is the BMP selection for the current polygon group. The input state is the capital resource available for BMP implementation at the current polygon group.

Table 8.1 BMP efficiency matrix.

BMP Code	BMP NBR	Description	TN_MIN (%)	TN_MAX (%)	TN_AVG (%)	TP_MIN (%)	TP_MAX (%)	TP_AVG (%)
AM	1	Animal Waste Systems	80	80	80	90	90	90
CT	10	Conservation Tillage	50	80	65	35	90	63
CS	13	Contour Stripcropping	26	43	35	0	50	25
CM	14	Cover & Green Manure Crop	50	80	65	30	50	40
CA	15	Critical Area Planting	50	80	65	50	50	50
DV	20	Diversions, AG	0	10	5	30	30	30
DF	21	Dry Det. w/Fil	35	80	51	19	97	52
DD	22	Dry Detention	0	60	31	0	80	30
DR	23	Dry Retention	91	91	91	61	61	61
FC	26	Field Stripcropping	26	43	35	0	50	25
FS	27	Filter Strip, AG	70	70	70	75	75	75
GW	29	Grassed Waterways	0	30	15	50	50	50
IT	33	Infil. Trench	40	80	57	40	80	57
NM	37	Nutrient Management	27	50	39	14	14	14
SB	49	Sediment Basins	44	86	65	40	40	40
TR	56	Terrace, AG	20	20	20	70	70	70
VF	58	Vegetative Filters, Urban	20	60	30	30	80	30
WP	59	Waste Storage Pond	65	65	65	60	60	60
WS	60	Waste Storage Structure	65	65	65	60	60	60
WL	61	Waste Treatment Lagoon	65	65	65	60	60	60
WW	65	Wet & Wetland	36	75	55	43	50	47
WV	66	Wet Det. w/Veg.	30	40	35	28	69	57
WD	67	Wet Detention	19	60	35	-38	99	56
WR	68	Wet Retention	35	90	56	40	90	71
CW	69	Wetland	21	21	21	7	70	41
WQ	70	WQ Inlet	5	10	8	5	10	8
DV	71	Diversions, Feedlot	45	45	45	70	70	70
FS	72	Filter Strip, Feedlot	0	60	30	85	85	85
TF	73	Terrace, Feedlot	55	55	55	85	85	85

Table 8.2 BMP site constraints.

BMP NBR	Description	FLUCS	LUDESC	DAMIN (ac)	DAMAX (ac)	SOILINF_ MIN (in/hr)	SOILINF_ MAX (in/hr)	DEPTH WT (ft)	SLOPE_ MAX (%)	SLOPE_ MIN (%)	STORM MAX (years)
21	Dry Det. w/Fil.	1100	Res, low density, < 2/acre			.50		D	M		100
22	Dry Detention	1100	Res, low density, < 2/acre			.50		D	M		100
23	Dry Retention	1100	Res, low density, < 2/acre			.50		D	M		10
33	Infil. Trench	1100	Res, low density, < 2/acre		5.0	.50		D	L		10
152	Street Clean, Street (Mech. & Vac.)	1100	Res, low density, < 2/acre					A			
153	Street Clean, Street (Mech. & Vac.)	1100	Res, low density, < 2/acre					A			
154	Street Clean, Street (Mechonly)	1100	Res, low density, < 2/acre					A			
155	Swales	1100	Res, low density, < 2/acre		5.0	.10		M	L		2
155	Swales	1100	Res, low density, < 2/acre		5.0	.10		D	L		2
58	Vegetative Filters, Urban	1100	Res, low density		5.0	.10		M		L	2
58	Vegetative Filters, Urban	1100	Res, low density		5.0	.10		D		L	2
65	Wet & Wetland	1100	Res, low density, < 2/acre	20.0			.50	S	L		100
66	Wet Det. w/Veg.	1100	Res, low density, < 2/acre	20.0			.50	S	M		100
67	Wet Detention	1100	Res, low density, < 2/acre	20.0			.50	S	M		100
68	Wet Retention	1100	Res, low density, < 2/acre					S	M		10
69	Wetland	1100	Res, low density, < 2/acre				.50	S	L		5
70	WQ Inlet	1100	Res, low density, < 2/acre		2.0			A	L		0
75	Infiltration Basin	1100	Res, low density, < 2/acre	2.0	15.0	.50		M	L		
75	Infiltration Basin	1100	Res, low density, < 2/acre	2.0	15.0	.50		D	L		
176	Concrete Grid Pavement	1100	Res, low density, < 2/acre	1.0	10.0	.50		D	L		
77	Sand Filter/Filtration Basin	1100	Res, low density, < 2/acre	.5	50.0	.10		M	L		
77	Sand Filter/Filtration Basin	1100	Res, low density, < 2/acre	.5	50.0	.10		D	L		
78	WQ Inlet w/Sand Filter	1100	Res, low density, < 2/acre		2.0	.10		M	L		0
78	WQ Inlet w/Sand Filter	1100	Res, low density, < 2/acre		2.0	.10		D	L		0
80	Extended Detention Dry Pond	1100	Res, low density, < 2/acre	10.0		.50		D	M		100
81	Extended Detention Wet Pond	1100	Res, low density, < 2/acre	10.0			.50	S	M		100
21	Dry Det. w/Fil.	1200	Res, med. density, 2-5/acre			.50		D	M		100
22	Dry Detention	1200	Res, med density, 2-5/acre			.50		D	M		100
23	Dry Detention	1200	Res, med density, 2-5/acre			.50		D	M		10

Table 8.3 BMP cost matrix.

BMP NBR	BMP Code	Description	BMP Type	Life Span (years)	CONSTR_COST (\$)	Annual O&M Cost (\$)	O&M, Constr Cost Unit (\$)	Cost/Unit (\$)	Unit (Cost/Unit)
1	AM	Animal Waste Systems	S	10	3.57	.19	\$/ton/yr	3.76	\$/ton/yr
10	CT	Conservation Tillage	C	1	16.47	.87	\$/ac/yr	17.34	\$/ac/yr
13	CS	Contour Stripcropping	C	5	11.02	.58	\$/ac/yr	11.60	\$/ac/yr
14	CM	Cover & Green Manure Crop	C	1	9.50	.50	\$/ac/yr	10.00	\$/ac/yr
15	CA	Critical Area Planting	C	5	67.17	3.54	\$/ac/yr	70.70	\$/ac/yr
20	DV	Diversions, AG	S	10	49.86	2.60	\$/ac/yr	52.09	\$/ac/yr
21	DF	Dry Det. w/Fil.	S	50					\$/cu. ft
22	DD	Dry Detention	S	50					\$/cu. ft
23	DR	Dry Retention	S	50					\$/cu. ft
26	FC	Field Stripcropping	C	5	11.02	.58	\$/ac/yr	11.60	\$/ac/yr
27	FS	Filter Strip, AG	S	5	6.94	.37	\$/ac/yr	7.31	\$/ac/yr
29	GW	Grassed Waterways	C	10	1.00	.05	\$/ft/yr	1.05	\$/ft/yr
33	IT	Infil. Trench	S	10	4.00	.36	\$/cu. f	.60	\$/cu. f/yr
37	NM	Nutrient Management	N	3	2.28	.12	\$/ac/yr	2.40	\$/ac/yr
49	SB	Sediment Basins	S	20	2.45	.07	\$/cu. ft	2.52	\$/cu. ft
56	TR	Terrace, AG	S	10	80.30	4.23	\$/ac/yr	84.53	\$/ac/yr
58	VF	Vegetative Filters, Urban	S	50	3,300.00	450.00	\$/ac	281.25	\$/ac/yr
59	WP	Waste Storage Pond	S	20	1.18	.06	\$/cu. ft	1.24	\$/cu. ft
60	WS	Waste Storage Structure	S	20	25.00		\$/cu. ft	25.00	\$/cu. ft
61	WL	Waste Treatment Lagoon	S	20	1.18	.06	\$/cu. ft	1.18	\$/cu. ft
65	WW	Wet & Wet land	S	50	.38	.01	\$/cu. ft	.04	\$/cu. f/yr
66	WV	Wet Det. w/Veg.	S	50					\$/cu. ft
67	WD	Wet Detention	S	50					\$/cu. ft
68	WR	Wet Retention	S	50					\$/cu. ft
69	CW	Wetland	S	50	.38	.01	\$/cu. ft	.04	\$/cu. f/yr
70	WQ	WQ Inlet	S	20	25.00		\$/cu. ft	25.00	\$/cu. ft
71	DV	Diversions, Feedlot	S	10	49.49	2.60	\$/ac/yr	52.09	\$/ac/yr
72	FS	Filter Strip, Feedlot	S	5	6.94	.37	\$/ac/yr	7.31	\$/ac/yr

The output state is the capital resource remaining for use in treating downstream polygon groups once the selection is made; it is the input state less the cost of the current selection. The return (objective) is the load reduction achieved through BMP implementation. Figure 8.1 represents a typical stage in the serial decision making process. A global return function is generated for each polygon group. The global return function for the last polygon group represents the load reduction possible for each value of capital resource availability. Once the capital resource availability is specified, the selections are scanned in downstream order to determine the optimal BMP selection for each polygon group (stage).

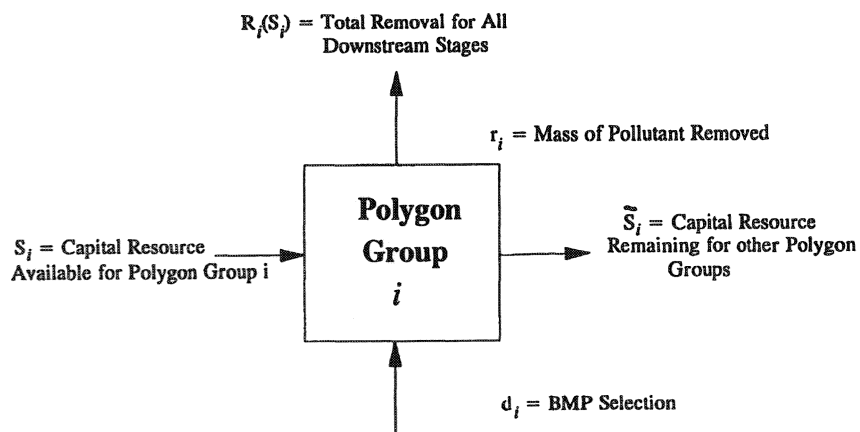


Figure 8.1  
A typical stage in the optimization serial decision making process.

## 8.7 Conclusions

The result is a pollutant load reduction strategy for the Tampa Bay Watershed. Figure 8.2 shows BMP selection for a portion of the basin, Old Tampa Bay. It shows the percent of land area to be treated by each BMP for a given annual budget. The average and marginal cost of non-point source nitrogen removal for this bay segment are shown in Figures 8.3 and 8.4. The results show how available resources might be allocated to achieve maximum load reduction for the region.

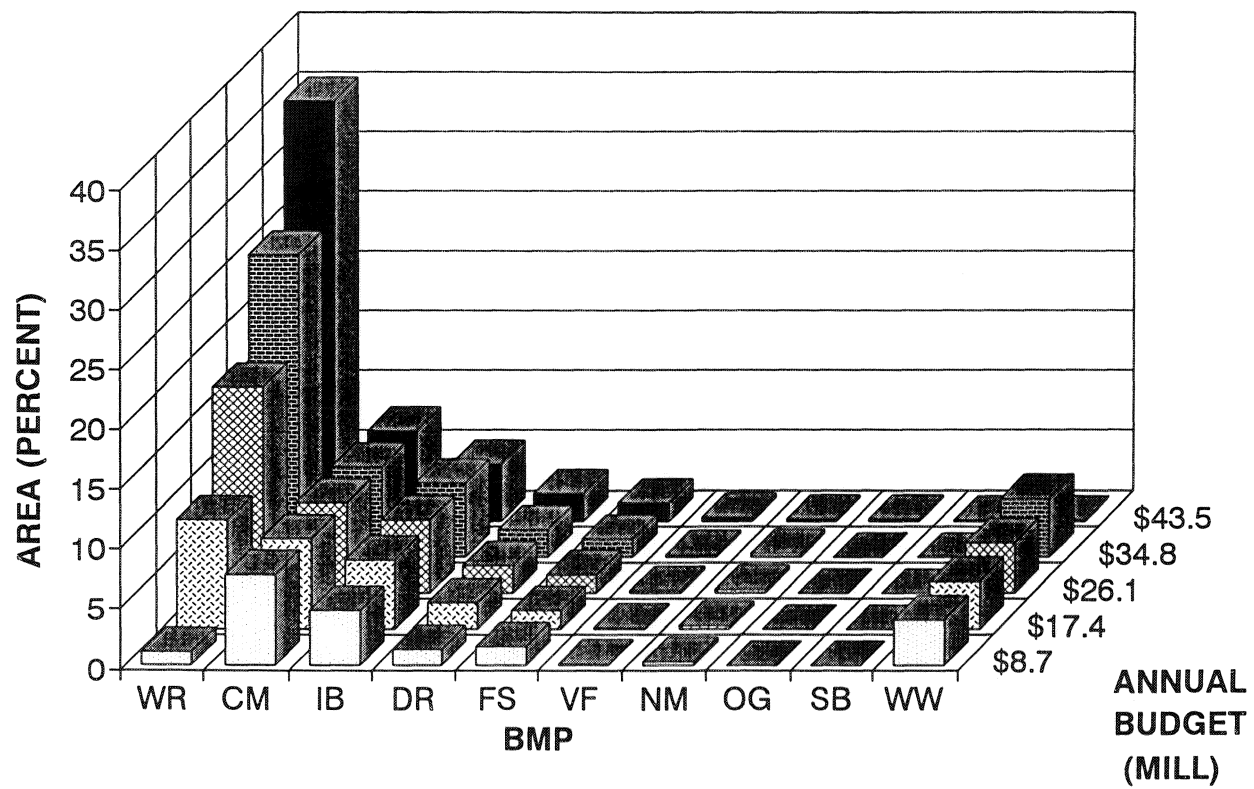


Figure 8.2 Percent of land area treated, Old Tampa Bay.

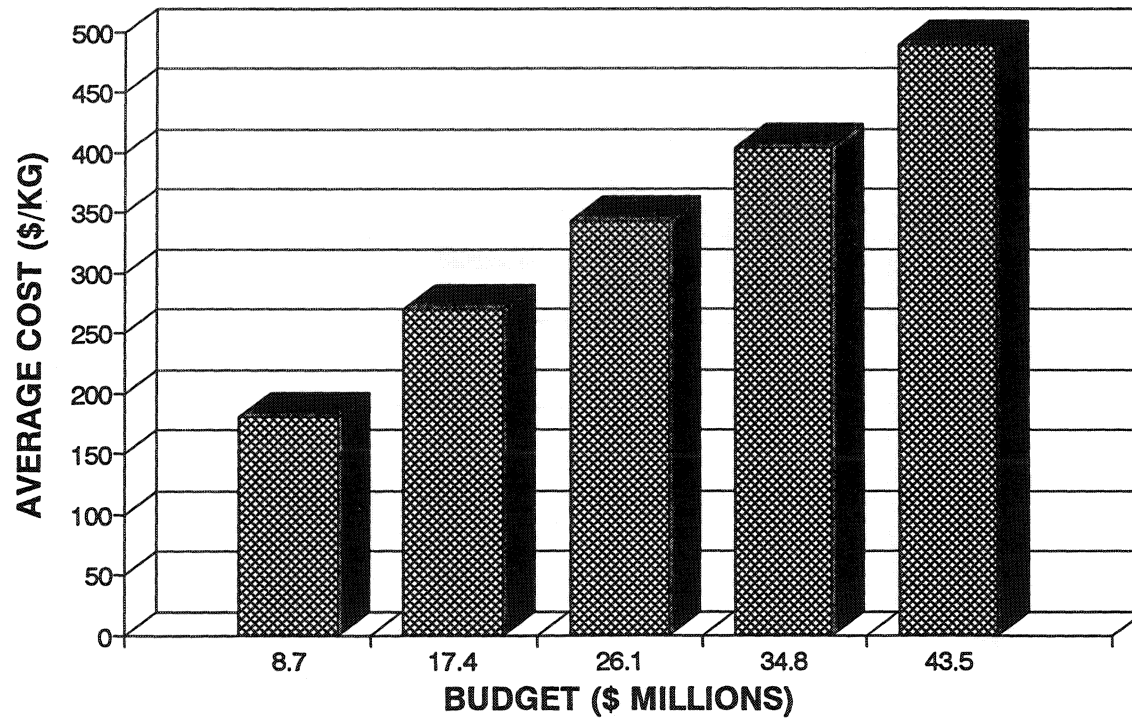


Figure 8.3 Average cost of nitrogen removal, Old Tampa Bay.

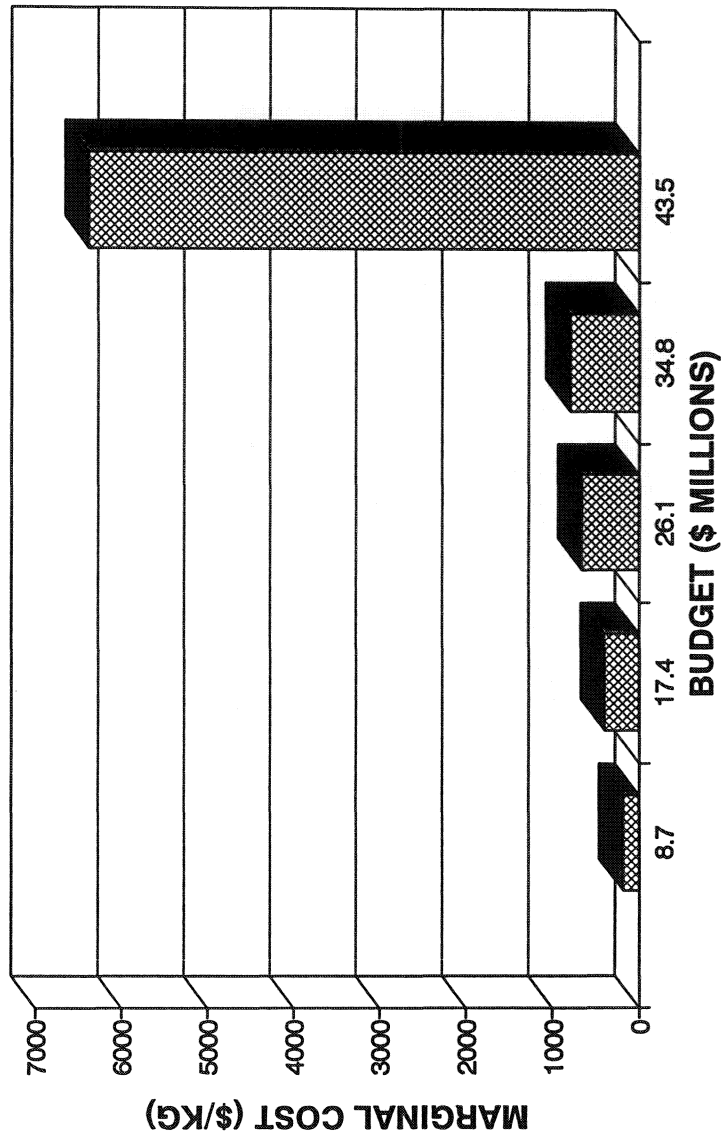


Figure 8.4 Marginal cost of nitrogen removal, Old Tampa Bay.

## Abbreviations used in Tables and Figures

BMPNBR	Best Management Practice number
TN_MIN	minimum removal efficiency for Total Nitrogen
TN_MAX	maximum removal efficiency for Total Nitrogen
TN_AVG	average removal efficiency for Total Nitrogen
TP_MIN	minimum removal efficiency for Total Phosphorus
TP_MAX	maximum removal efficiency for Total Phosphorus
TP_AVG	average removal efficiency for Total Phosphorus
LUDESC	land use description
DAMIN	minimum drainage area
DAMAX	maximum drainage area
SOILINFMIN	minimum soil infiltration rate
DEPTHWT	depth to water table
SLOPE_MAX	maximum slope of terrain
SLOPE_MIN	minimum slope of terrain
STORMMAX	maximum storm frequency
CONSTR_COST	construction cost
O&M, CONSTR	
COST UNIT	units for construction and operational and maintenance costs
WR	wet retention
CM	cover and green manure crop
IB	infiltration basin
DR	dry retention
FS	filter strip
VF	vegetative filter
NM	nutrient management
OG	oil and grit separator
SB	sedimentation basin
WW	wetland and wet retention

## References

EPA (1993), Guidance Specifying Management Measures for Sources of Non-Point Source Pollution in Coastal Waters. USEPA Office of Water Report No. 840-B-92-002. c500pp.

Kehoe, M. J. (1992), Water Quality Survey of Twenty-four Stormwater Wet-Detention Ponds, Southwest Florida Water Management District.

National RCWP Symposium (1992), Ten Years of Controlling Agricultural Non-Point Source Pollution: The RCWP Experience.

NCSU (1991), Water Quality Monitoring Report for Agricultural Non-Point Source Pollution Control Projects, North Carolina State University.

Park, W.M. and Shabman, L.A. (1991), Consideration in Choosing the Appropriate Mix of Urban and Agricultural Non-Point Pollution Control, Water Resources Bulletin.

Richardson, R. J. and Davis, J.A. (1987), Natural and Artificial Wetland Ecosystems: Ecological Opportunities, Duke University.

Rushton, Betty, and Dye, C.W. (1993), An In-Depth Analysis of a Wet Detention Stormwater System, Southwest Florida Water Management District. 54pp.

Schiffer, D.M. (1989), Water Quality Variability in a Central Florida Wetland Receiving Highway Runoff, AWRA, Water: Laws & Management.

Schueler, Thomas R. et al (1992), A Current Assessment of Urban Best Management Practices, Techniques for Reducing Non-Point Source Pollution in the Coastal Zone, Metropolitan Washington Council of Governments.

Spooner, J., and Humenik, F.J. (1992), Evaluation of the Experimental RCWP, North Carolina State University.

Weigand, C., and Schueler, T., (1986), Cost of Urban Runoff Quality Controls, ASCE.

Wilde and Beightler (1992), Foundations of Optimization, Prentice-Hall, 1967. 480pp.

*Editor's note: Because the sources for the above references are incomplete, we suggest you contact the chapter authors for further information.*