



STORMWATER MANAGEMENT

A GUIDE FOR FLORIDIANS

FLORIDA GUIDEBOOK



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Cover Photograph:

DER's commitment to stormwater management is demonstrated by its new wet detention system which replaced a traditional drainage system.

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CONTENTS

STORMWATER MANAGEMENT: A GUIDE FOR FLORIDIANS

INTRODUCTION	5
ONE - BACKGROUND	7
A. Hydrologic Cycle	7
B. The Watershed	8
C. The River (Lake) System	9
D. The Estuarine System	9
E. The Groundwater System	11
F. The Groundwater-Surface Water-Land Connection	13
TWO - THE STORMWATER PROBLEM	15
A. Effects of Urbanization on Stormwater Quantity ..	16
B. Effects of Urbanization on Stormwater Quality	17
C. The First Flush	19
THREE - STORMWATER AND WATERSHED MANAGEMENT	21
A. Stormwater Management	21
B. Watershed Management: The Challenge of the Future	22
FOUR - PRINCIPLES OF STORMWATER MANAGEMENT	29
FIVE - STORMWATER MANAGEMENT PRACTICES	33
A. BMP Treatment Train	34
B. On-Line vs. Off-Line BMPs	35
C. The Importance of Vegetation	37
D. Infiltration (Retention) Practices	38
Dry Retention Basins or Areas	39
Grassed Swales	41
Infiltration Trenches	44

E. Detention Practices	47
F. Wetland Stormwater Systems	53
G. Detention with Filtration	54
H. Parking Lots	55
I. Alum Treatment	57
J. Maintenance of Stormwater Systems	59
SIX - STORMWATER REGULATORY PROGRAMS	61
A. Federal NPDES Stormwater Permitting	61
B. State Stormwater Permitting	62
C. Local Government Stormwater Permitting	63
SEVEN - WHAT LOCAL GOVERNMENTS CAN DO	65
A. Develop a Watershed Management Plan	65
B. Implementation of the Watershed Plan	66
Local Ordinance	66
Public Education	66
Funding - Stormwater Utilities	68
C. Operation and Maintenance of the Stormwater System	70
D. Intergovernmental Coordination	70
CONCLUSION	71
INFORMATION SOURCES	72
ACKNOWLEDGMENTS	72



INTRODUCTION

Water flowing over the land during and immediately following a rainstorm is called **stormwater runoff**.

Stormwater runoff from agricultural lands, from lands that are undergoing urban development and from lands which already are developed causes significant problems for landowners in its path, for local governments, and for the waterbodies which ultimately receive it.

As a result of stormwater, sediment fills drainage ditches and channels, causing flooding. The sediment fills rivers, lakes and estuaries, destroying wildlife habitat, degrading water quality, and requiring extensive restoration. High stream velocity causes bank erosion (and more sedimentation downstream) and loss of valuable habitat and property. Areas that once seldom flooded now flood with regularity. Eroded sites must be regraded. Often, new soil must be brought in to replace the soil which has washed away. Sediment must be removed – at great cost – from

culverts, storm sewers and navigable waters to restore their capacity. In addition to sediments, stormwater carries nutrients, heavy metals, oils, greases, pathogens and any other materials that accumulate on the land between rains.

This guidebook has been prepared as a source of general information on urban stormwater management. It is intended for the use of local government officials and others interested in sound planning and design of stormwater management systems. It presents general information on the stormwater problem and how to manage it. Sound planning and good design can create stormwater management systems that are attractive, safe, and efficient, and which provide many different uses and benefits to the community. **It is much easier, and much less expensive, to prevent stormwater problems through proper planning than it is to restore water bodies and rebuild flooded properties.**

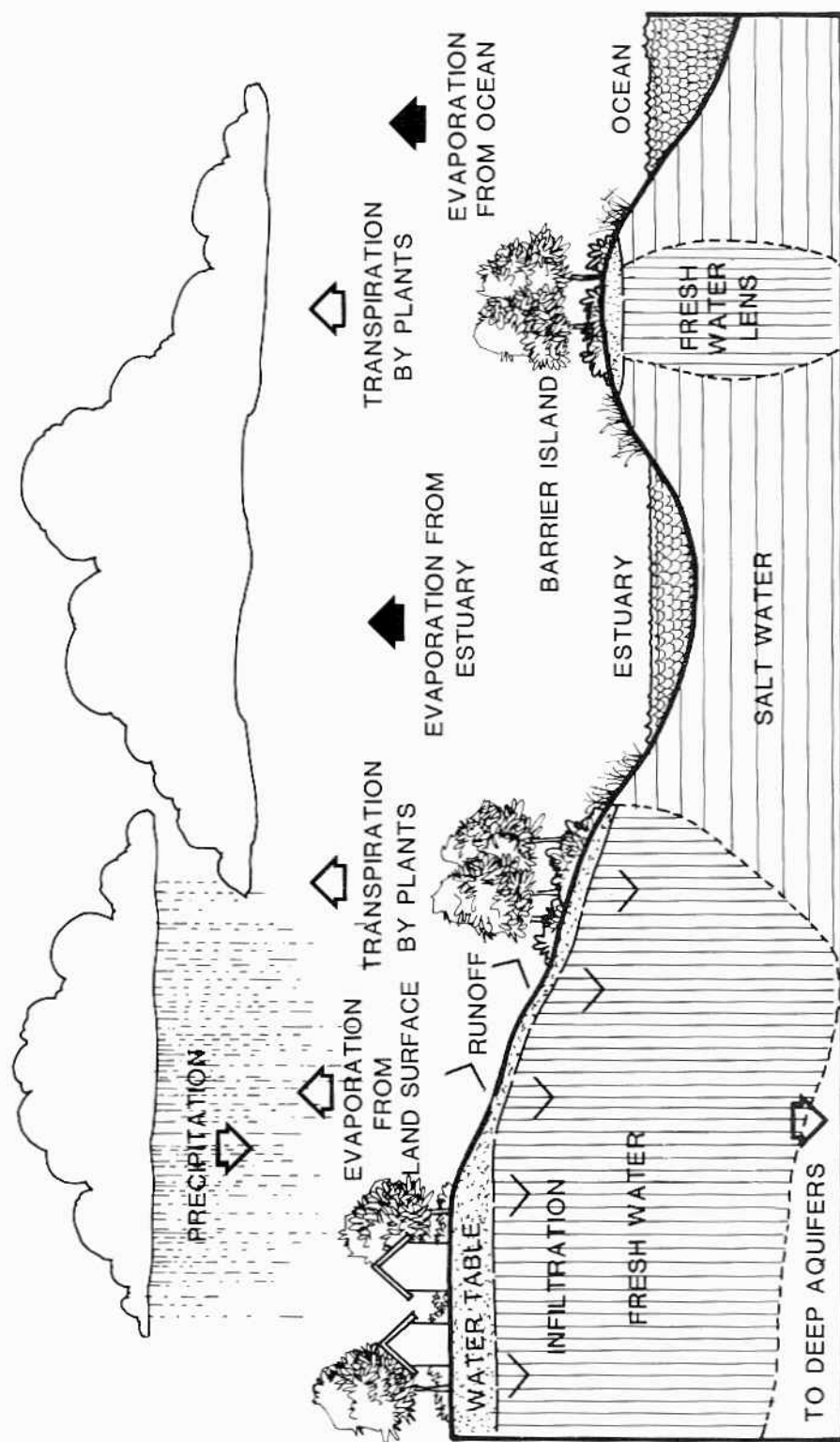


Figure 1: HYDROLOGIC CYCLE

CHAPTER ONE

BACKGROUND

THE IMPORTANCE OF WATER

Water is Florida's lifeblood. Whether it is used for agriculture, industry, recreation, or for drinking, an abundance of clean water is essential for Florida's economy and our quality of life. Florida's rapid growth, and the vulnerability of its surface and ground waters, makes it imperative that its water resources are managed wisely. Fortunately, the Sunshine State receives an abundance of rainfall - 50 to 65 inches from about 120 storms a year. The resulting stormwater, just like treated wastewater, represents a valuable component of our water resources to be recovered and reused.

A. The Hydrologic Cycle

In undeveloped areas, stormwater management is part of the natural environment. The movement of water through the environment, from the clouds to the earth, and back again, is called the **Hydrologic Cycle** (*Figure 1*).

The cycle begins with the sun's energy warming surface waters, causing evaporation. It continues when water vapor rises into the atmosphere, condenses to form clouds, then falls to earth as rain or snow.

When water reaches the ground, it can take three main paths: it can run off the land and collect in

the wetlands, lakes and rivers that eventually flow to the sea; it can infiltrate through the soil, recharging the ground water, or it may be absorbed into the topsoil to be used by plants and eventually returned to the atmosphere through evapotranspiration, which is the evaporation of water from land surfaces plus transpiration, the water given off by the roots and leaves of plants.

Of course, this is a simplified explanation of a very complex natural system - a system that in undeveloped areas maintains a dynamic balance. Natural stormwater systems are in constant change: streams change course, natural erosion occurs, and vegetation and soil permeability change with the seasons. The natural system is thrown out of balance by man-made changes to the land.

The effect of water moving through Florida's diverse water system can differ greatly depending on whether the receiving water is a river, lake, estuary or ground water system. Additionally, Florida's water systems often are interconnected—surface waters become ground waters which can eventually flow back to surface waters. A brief discussion of Florida's various water systems follows to provide a basic introduction to these complex, interrelated systems.

B. The Watershed

A watershed (or drainage basin) is the geographic area from which water in a particular stream, lake or estuary originates (*Figure 2*). All lands in the watershed drain toward the stream, lake or bay and contribute pollutants to these waters. It is important to recognize the connection between our activities on the land within a watershed and the ground water and surface water that flows through it. Everything we do on the land within the watershed ultimately will have an effect on the

water resources of that watershed. It is for this reason that we must begin to manage our land and water resources in a comprehensive, coordinated manner through **Watershed Management**. Watershed management is the integration of land use, infrastructure and water resources throughout an entire watershed.

Watershed boundaries rarely correspond to local government boundaries. As a result, coord-

ination and cooperation among local and regional governments, state government and the private sector is essential for effective water management. If one community limits pollutants or manages its stormwater but others within the watershed do not, then flooding and water quality problems can still result. Those who join the **Watershed Management Team** can work together and effectively solve problems and manage the resources within a watershed.

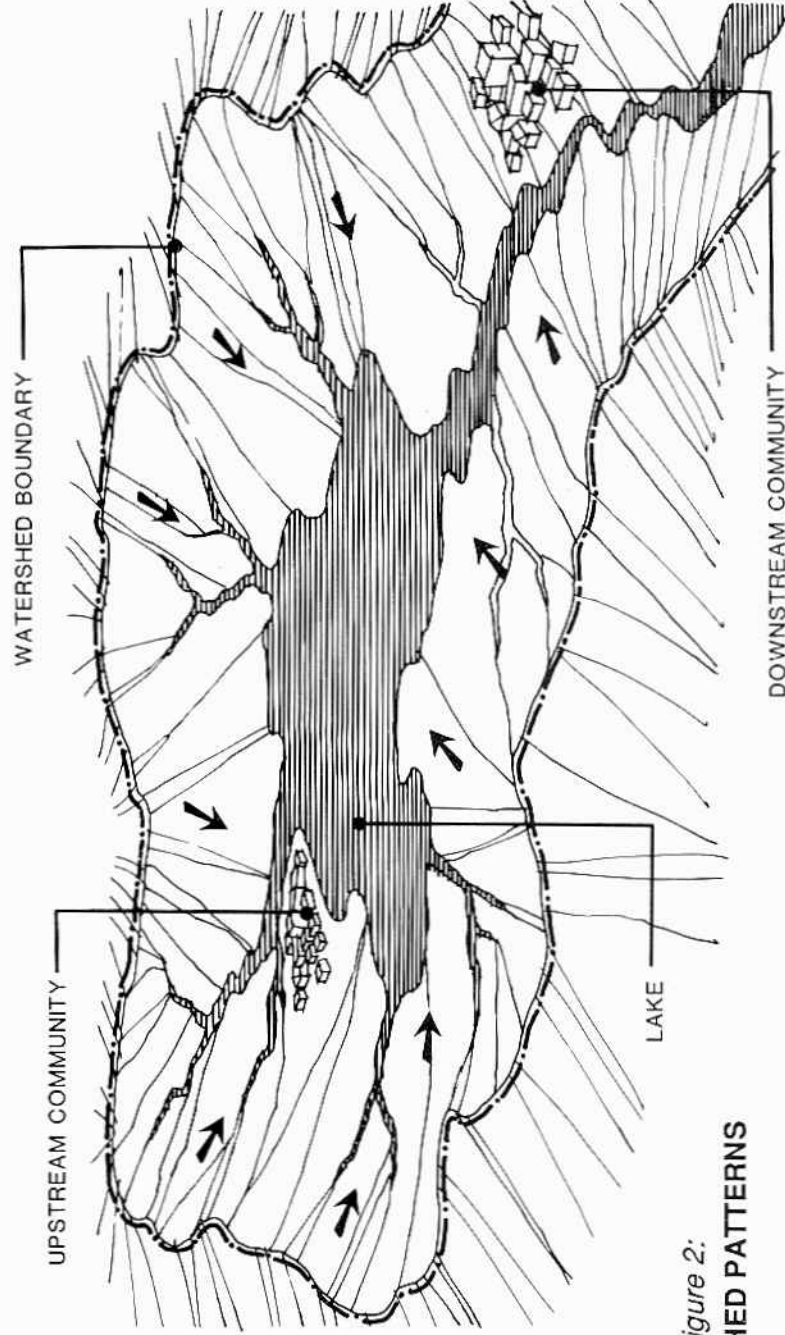


Figure 2:
WATERSHED PATTERNS

C. The River (Lake) System

The characteristics of water and its effects on daily life can be best understood by studying the river or lake basin in which a community is located.

For instance, a small creek running through a neighborhood may appear to be unrelated to the stream that crosses another part of town, but they can be connected. Creeks join to create larger streams, which in turn form still larger ones in a natural drainage network that carries rainwater off backyards, fields, and streets and into rivers or lakes or estuaries. Without this natural stormwater system, land would stay wet or flooded.

As water circulates through a river system it can carry pollutants to downstream parts of the watershed. This is why lakefront or coastal residents may be concerned about the activities of people living some distance upstream from them. Although many miles apart, they all live

within the same watershed, and so can affect one another through their various uses of land and water.

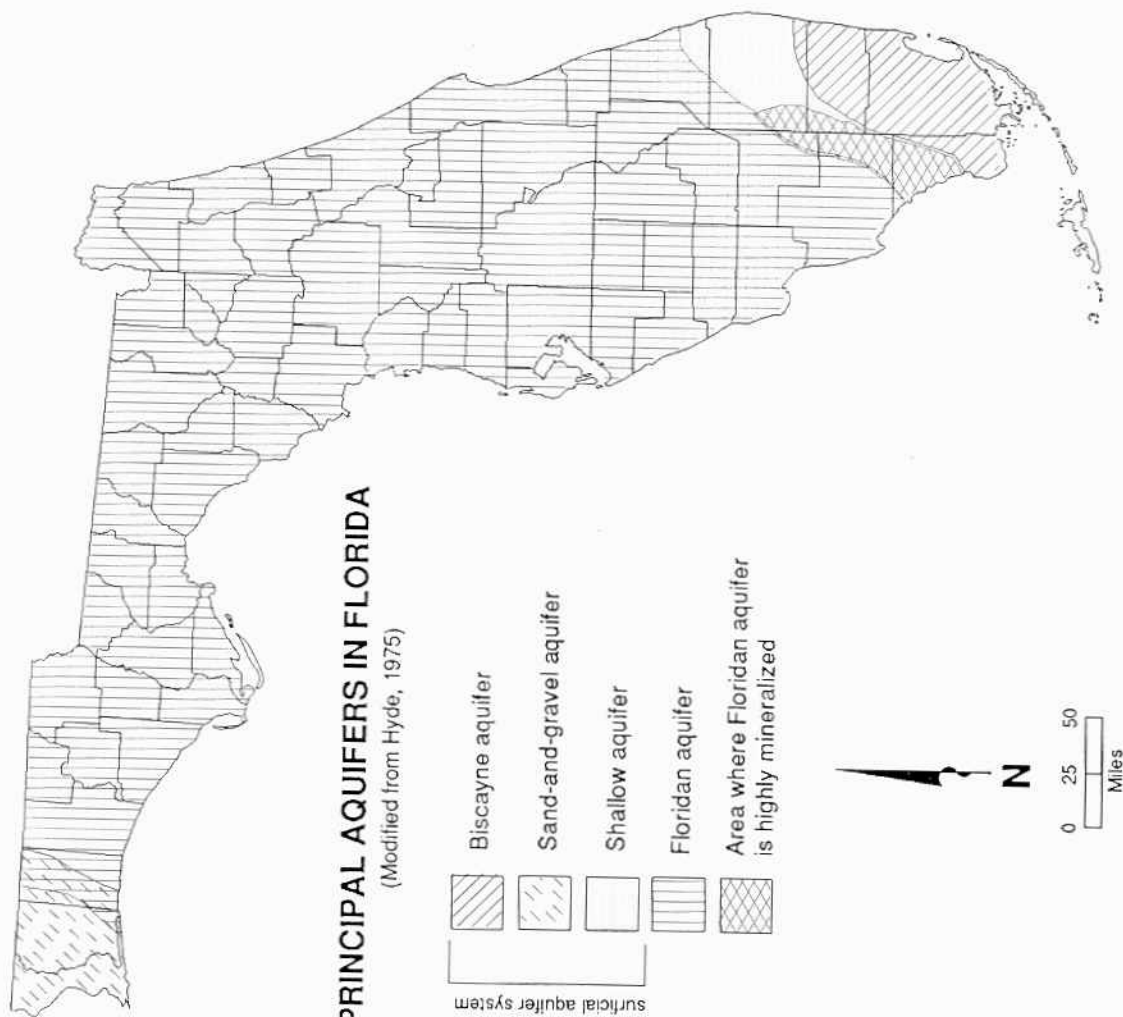
D. The Estuarine System

Coastal estuaries have been called the cradle of life. They are the bodies of water where fresh and salty waters mix, producing a nutrient-rich habitat for plants, animals and fish. Florida's estuarine system, the largest in the United States, encompasses three million acres of tidal streams, wetlands, bays and lagoons. Estuaries are one of the most productive natural systems on earth. In Florida, they account for more than seventy percent of the recreational and important commercial fish and shellfish.

Florida has a wide variety of estuaries, ranging from tidal rivers like the St. Johns River, secluded lagoons like the Indian River lagoon, tropical bays like Florida and Biscayne Bays, and shallow basins

behind barrier islands like Apalachicola Bay and Santa Rosa Sound. All of these estuaries have different salinity patterns, tides, marine life, sediment types and shorelines. The conditions within estuaries are continually changing so the organisms that live in them must be adaptable. The combination of changing salinity, temperatures, and tides, together with shallow water and marsh grasses, provides physical protection and abundant food for juvenile fish and shellfish that use estuaries as nursery areas.

The very functions that make estuaries productive also make them vulnerable to pollutants in stormwater. Just as estuaries efficiently trap and recycle the nutrients that support the estuarine food web, they can also trap and concentrate pollutants. Estuaries can be hurt by too much fresh water, the possible result of urbanization and the increase in stormwater runoff in the estuarine watershed.



E. The Ground Water System

When water seeps into the ground it is either absorbed by the plants and soil or passes through the soil to become part of the ground water supply. More than 90% of Florida's residents depend on ground water for their drinking water. The sand, gravel and rocks that allow water to collect and move through them are called **aquifers**.

The water level in an unconfined or "water table" aquifer will rise and fall depending upon the amount of water stored in the ground. The recharge of this aquifer occurs by seepage through porous soils when it rains. Although this type of aquifer will recharge relatively easily, pollutants can seep into it just as easily.

A second type of aquifer is called a confined aquifer. It consists of layers of various types of rock (generally limestone in Florida) and clay.

The water in this aquifer moves through the earth under pressure rather than simply by gravity. Recharge to the confined aquifer takes place only in certain areas (recharge zones), so it is less likely to get polluted, unless pollution sources are located in the recharge zones.

The dynamics of ground water movement are complicated. In essence, ground water moves downward, following the slope of the water table (not the land surface) from its highest level to its lowest. The water slowly filters between the rocks and soil of an aquifer, usually at a rate of a few inches a day. This slow movement keeps pollutants from being quickly diluted. Therefore, a well located down-slope from a source of pollution could be contaminated by the ground water flow that still contains concentrated pollutants.

The permeability of soil overlaying an aquifer can also affect pollution. For example, the siting of septic tanks or retention ponds in areas where the water table lies just below very sandy soil can create problems. The porous sand does not retain pollutants as long as other soils do, and it lacks the organic material and microbes that can trap and degrade some pollutants. Areas of Florida with karst geology—land with numerous sinkholes and with underground flow through large cavities in the limestone—are also highly susceptible to ground water contamination, even from stormwater management systems.

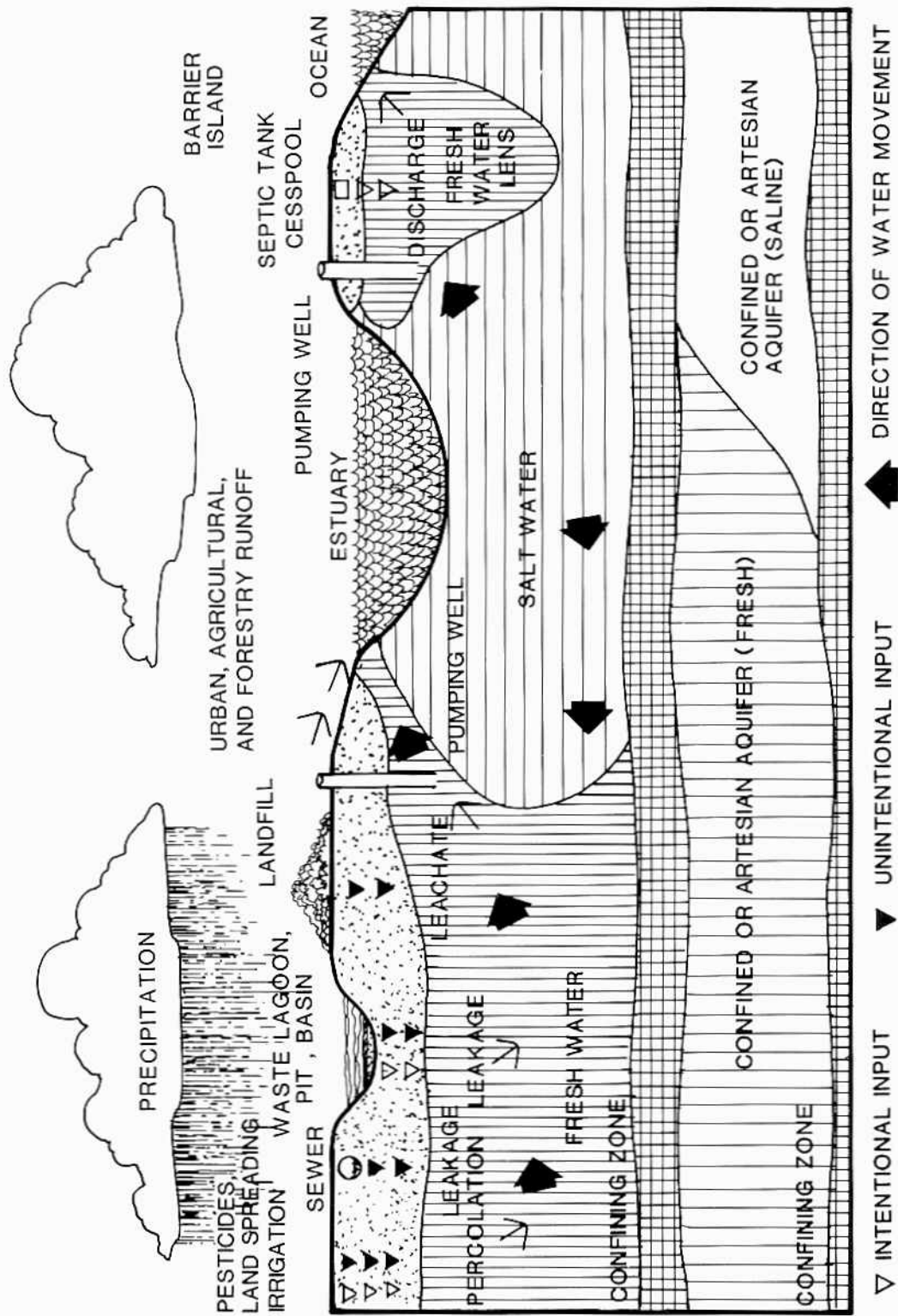


Figure 3:
GROUNDWATER ESTUARINE CONNECTION

F. The Ground Water-Surface Water-Land Connection

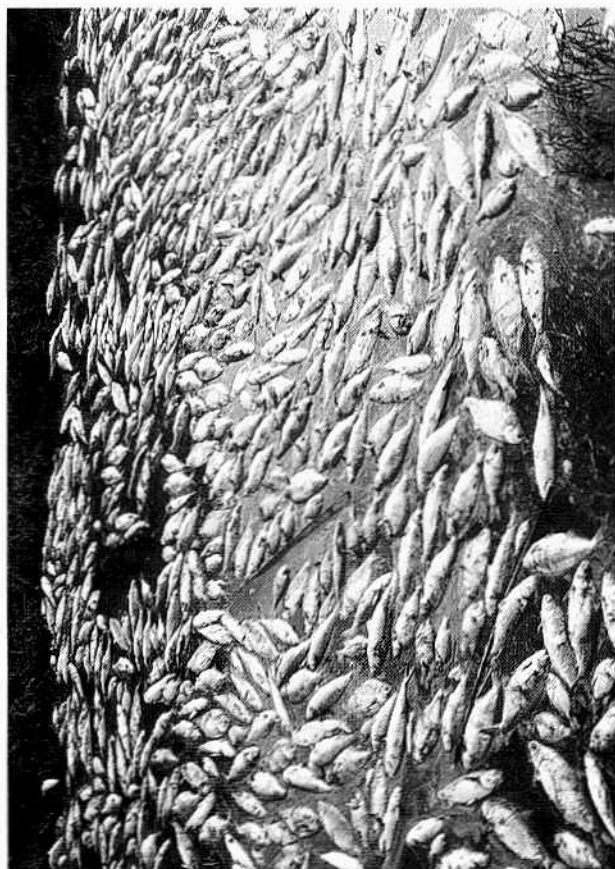
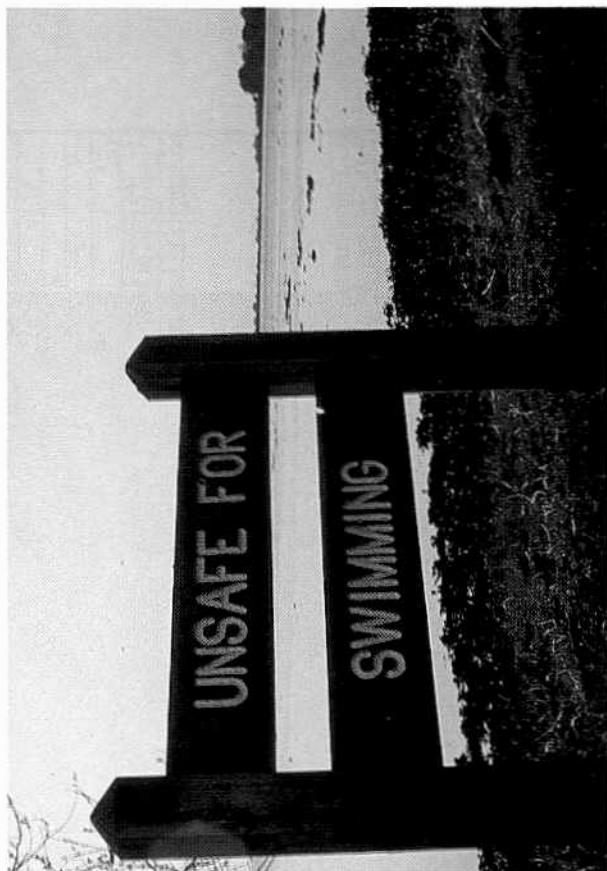
To maintain the quality of our lakes, rivers and estuaries, we must recognize the connection between ground waters and surface waters. In many cases, ground water eventually flows into a river, lake or estuary (*Figure 3*) or even becomes surface water such as a spring. Although some of the pollutants in degraded ground water may be dispersed as the water flows through the

aquifer, some pollutants still reach surface water bodies. Movement of contaminated surface water to ground water can also occur by percolation of pollutants from surface impoundments (e.g., pits, ponds, lagoons) into the aquifer underneath. Not only can ground water contamination affect lakes, rivers and estuaries but it is also possible for estuarine waters to flow back

into the underlying aquifer. An example of this is salt water intrusion such as has occurred in Dade County where uncontrolled canal drainage caused declines in fresh water levels allowing salt water to gradually migrate inland.



Little River Spring creates a stream which flows into the Suwannee River and on to the Gulf.



THE STORMWATER PROBLEM

The volume of stormwater generated by a rain storm depends upon the total amount of rainfall, except that lost by infiltration, transpiration, evaporation, and surface storage. The amount of these losses is a function of climate, soils, geology, topography, vegetative cover and, most importantly, land use.

Changes in land use affect the hydrology of an area in four ways: changes in peak flow charac-

teristics of runoff, changes in runoff volume, changes in water quality, and changes in the hydrologic amenities. The hydrologic amenities are what might be called the appearance or the impression a water body and its adjacent lands leave with the observer. Of all the land use changes that affect an area's hydrology, urbanization is the most important.

A. Effects of Urbanization on Stormwater Quantity

As an area urbanizes, streets, sidewalks, parking lots and buildings cover the soil. In addition, the process removes natural vegetation and compacts the soil. The land's surface becomes more impervious. Rainfall no longer soaks into the ground as readily as before. This causes an increase in runoff and accelerates the speed at which runoff flows (the peak discharge rate) as seen in Figure 4.

Historically, the primary concern about stormwater was to remove it from a developed area as quickly as possible after a storm for flood protection. Unfortunately, this led to drainage systems that maximize local convenience and protection, without considering other important factors such as off-site damage from accelerated flow, water pollution, or even the loss of a water resource. Other problems include increased channel erosion and flooding, deposition of sediment, flood plain and channel erosion with a resulting loss of property, wildlife habitat and natural vegetation.

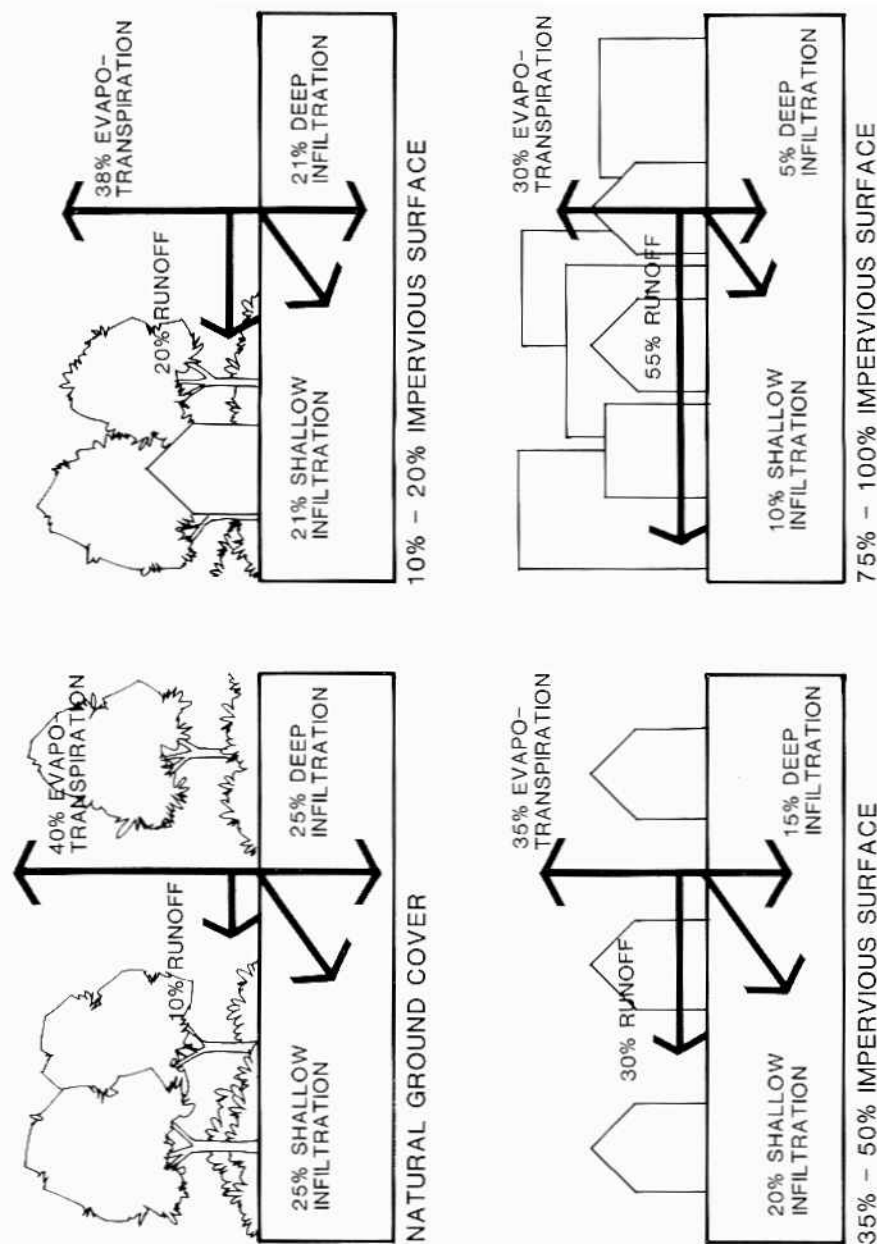


Figure 4:

CHANGES IN RUNOFF FLOWS RESULTING FROM PAVED SURFACES

In an undeveloped area, a natural stream normally adjusts so that its cross section and slope are in approximate equilibrium. Increased volumes and peak discharge rates of stormwater produce drastic changes in the natural stream channel. Eroded banks and frequent flooding are not only unsightly but cause damage to adjacent property and homes. Structures are undermined, homes are damaged, recreational areas are threatened and aesthetic values are destroyed.

Accelerated channel erosion also creates downstream damages by the deposition of eroded sediment. Lakes and reservoirs fill, storm sewers and culverts become clogged causing flooding and areas adjacent to streams and lakes may become covered with mud and debris left after the flood.

Increased stream volumes and velocities associated with the stormwater from urbanized areas produce more frequent floods. Areas that previously flooded only once every five years may flood every year, or several times each year. Flood plain erosion and damage to structures and vegetation increase.

B. Effects of Urbanization on Stormwater Quality

Land use directly affects water quality. In an undeveloped area, natural, physical, chemical, and biological processes interact to recycle most of the materials found in stormwater. As human land use intensifies, these processes are disrupted and everyday activities add materials to the landscape. Leaves, litter, animal wastes, oil, greases, heavy metals, fertilizers, and pesticides are washed off by rainfall and are carried by stormwater to our lakes, rivers and bays. These materials can create high pollutant loadings of:

Sediment which clogs waterways, smothers bottom living aquatic organisms and increases turbidity.

Oxygen demanding substrates which consume the oxygen in water, sometimes creating an oxygen deficit that leads to fish kills.

Nutrients (nitrogen, phosphorus) which cause unwanted and uncontrolled growth of algae and aquatic weeds like hydrilla or hyacinths.

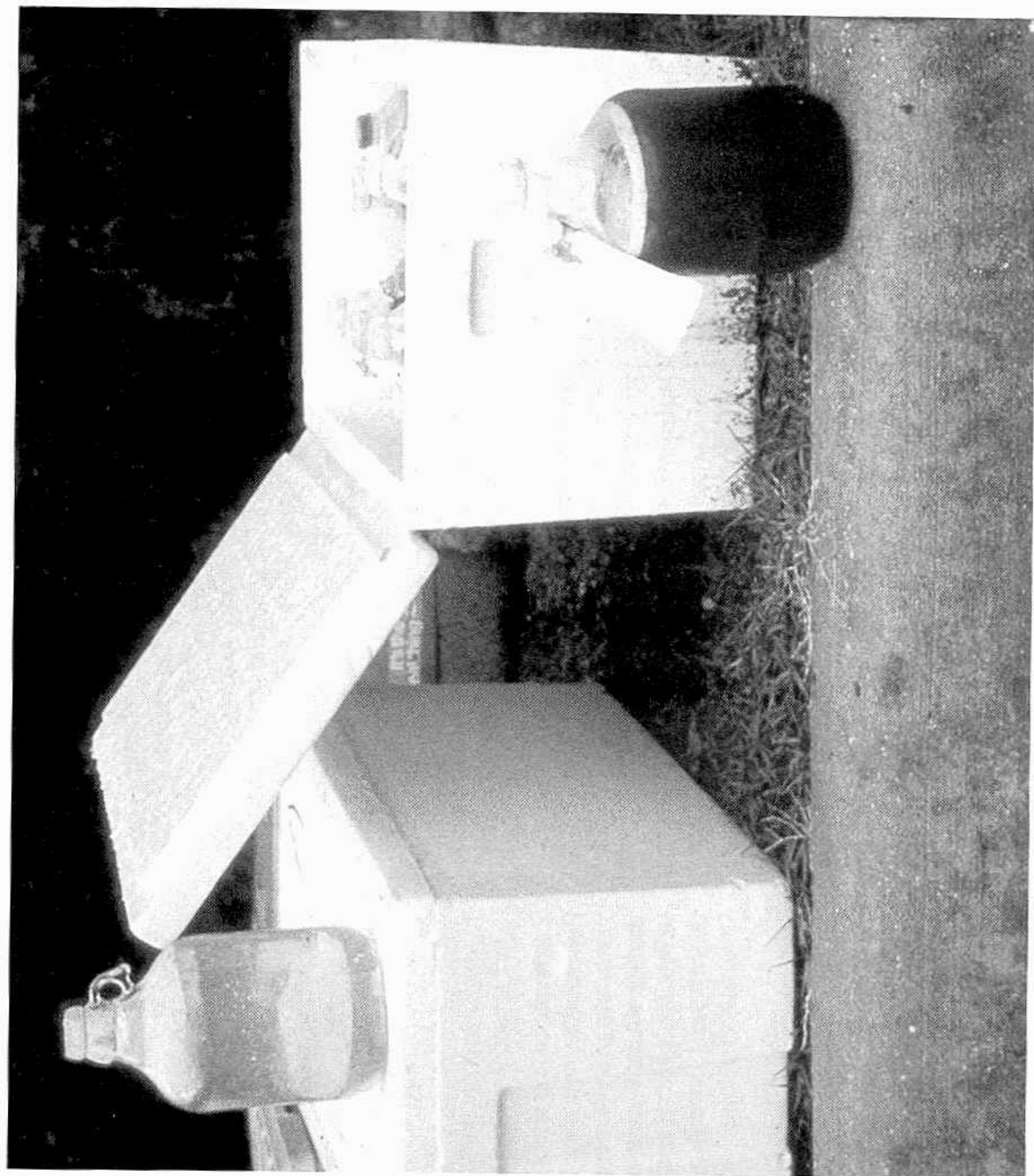
Heavy metals (lead, cadmium, chromium, copper, zinc) which can disrupt the reproduction of fish and shellfish and accumulate in fish tissues.

Petroleum hydrocarbons (oils, greases) which are toxic to many aquatic organisms.

Coliform bacteria and viruses which contaminate lakes and shellfish waters and prevent swimming and harvesting.

Excessive fresh water which changes the salinity of estuaries, alters the types of organisms which live in estuaries, and disrupts this important nursery area.

Stormwater is the major source of pollutants to Florida's lakes, estuaries and streams. Improved stormwater management will reduce pollution loads from new developments and from old stormwater systems that were built primarily for drainage.



"First Flush" sample (right bottle) contains most pollutants. Later samples (left bottle) are cleaner.

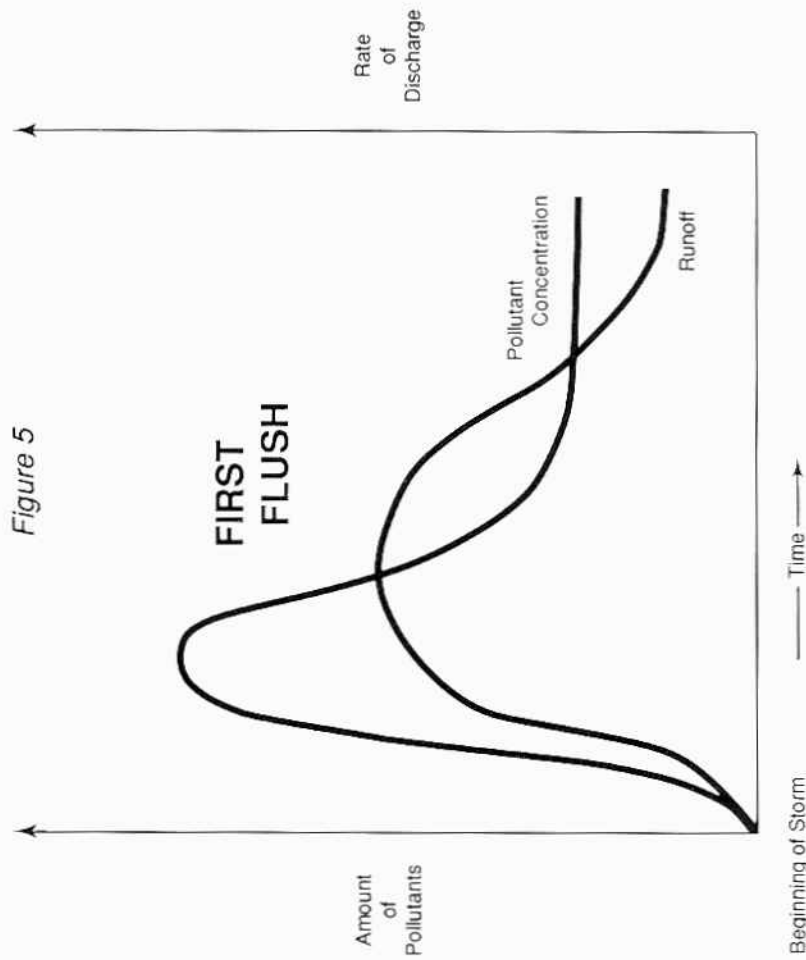
C. The First Flush

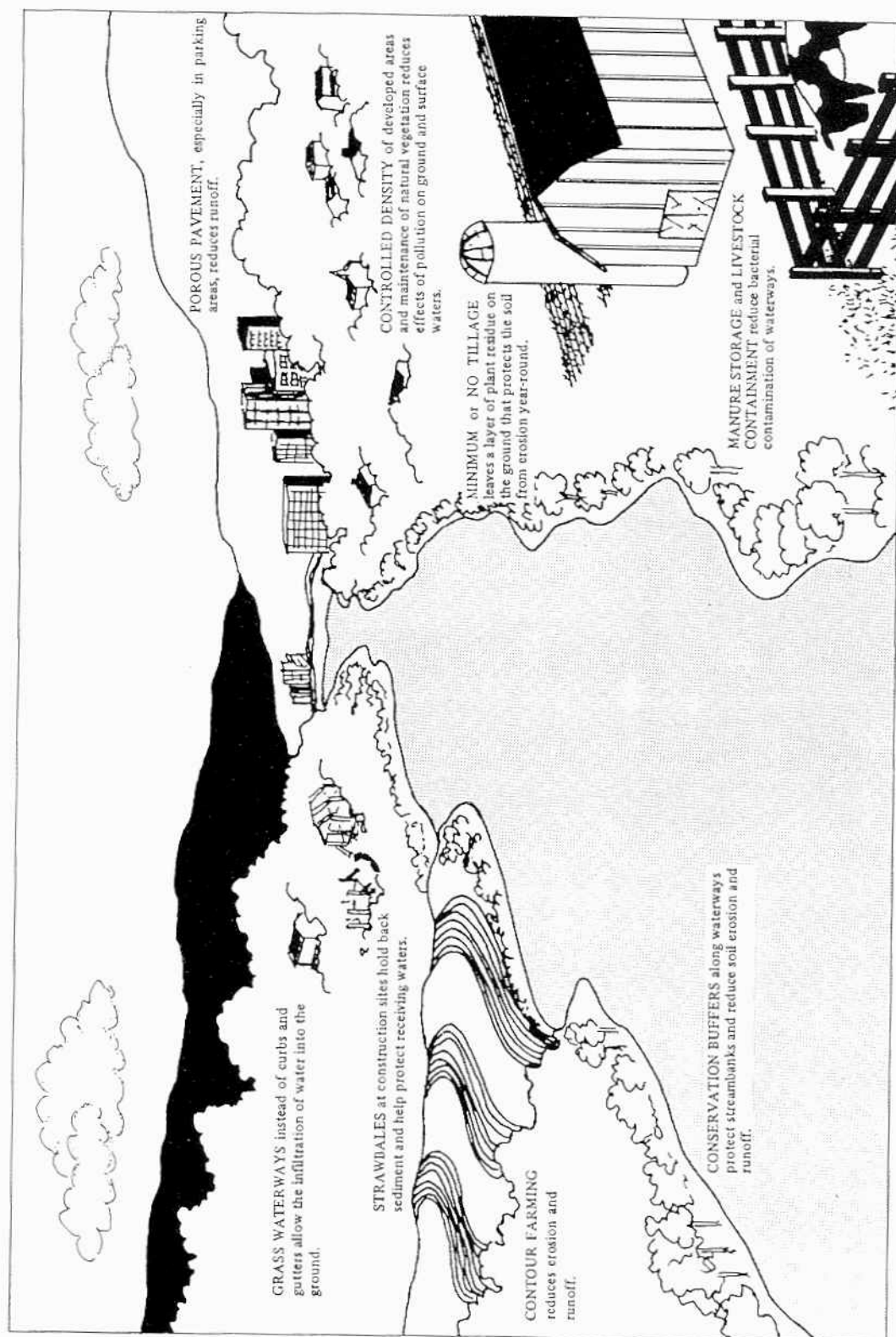
Of primary importance to minimizing the effects of stormwater on water quality is the **FIRST FLUSH** (Figure 5). This term describes the washing action that stormwater has on accumulated pollutants in a watershed. In the early stages of runoff the land surfaces, especially the impervious surfaces like streets and parking areas, are flushed clean by the stormwater. This creates a shock loading of pollutants. Studies in Florida have determined that the first one inch of runoff generally carries 90% of the pollution from a storm.

Treatment of the first flush is the key to proper stormwater management, and treatment of the first one inch of runoff from new development is the minimum needed to achieve the desired water quality benefits. In some cases, more than the first inch may need treatment depending on the

size of the drainage basin, the amount of impervious surface, the type of land use, the type of stormwater management system and, most importantly, the type of receiving water and the desired water quality.

Figure 5





Best Management Practices must be applied throughout a watershed.

STORMWATER AND WATERSHED MANAGEMENT

A. Stormwater Management

Stormwater must be managed to abate the alterations of the hydrologic cycle caused by changes in land use, especially urbanization. An effective **Stormwater Management Program** requires actions to control stormwater to provide:

- Reduction of stormwater pollutants
- Surface drainage and flood protection
- Erosion and sedimentation control
- Enhanced aesthetics and recreational opportunities
- Reuse of this valuable water resource

To achieve these objectives, new developments (or redevelopment projects) should include a stormwater management system which assures that the **Peak Discharge Rate, Volume, and the Pollution Load** of stormwater leaving a site after development are no greater than before development. Chapters Four and Five present addi-

tional information on how a stormwater management system is designed. In addition, new developments must have an erosion and sediment control plan using suitable techniques to retain sediment onsite and minimize the tremendous adverse effects that can occur from improperly managed construction sites.

However, one of the major water quality problems facing Florida is how to reduce the pollution load from old drainage systems that were built solely for flood protection. These systems had one purpose: to convey stormwater away from improved properties as quickly as possible. There was little regard for any environmental effects. It is extremely difficult, and expensive, to correct problems caused by old systems. The solution will take years. Innovative technology, and close coordination with planned infrastructure improvements and urban re-development will be required to solve our stormwater problems.

B. Watershed Management: The Challenge of the Future

We must re-evaluate regulatory approaches to stormwater management to shift the emphasis toward more comprehensive, prevention oriented strategies such as **"Watershed Planning"**. Stormwater management is a very important element in watershed planning.

The following comparison illustrates the differences between the usual approach to stormwater management and a comprehensive watershed approach.

1) Usual Approach:

For existing urban development, the usual approach would **address local stormwater problems without evaluating the potential for the runoff control measure to cause adverse effects in downstream areas**. In the case of new urban development, we would delegate stormwater management responsibilities to local land developers and each would be responsible for constructing stormwater management facilities on the development site to maintain post-development

peak runoff and pollution loads from the site at predevelopment levels. There would be little or no consideration of the cumulative effects of the developments with their individual stormwater systems on either the local government stormwater infrastructure or downstream lands and waters.

2) Comprehensive Approach:

This option involves **developing a comprehensive watershed plan**, known as the "master plan", **to identify the most appropriate control measures and the optimum locations to control watershed-wide activities**. The watershed approach typically involves combinations of the following:

- overall review of the watershed and its characteristics to assess problems and potential solutions;
- strategically locating a single stormwater detention facility (a regional system) to control post-development runoff from several land development projects;

- providing stream channel improvements (e.g., removal of obstructions to flow, properly vegetating) where necessary upstream from the stormwater detention facility; and
- nonstructural measures throughout the watershed, such as acquisition of parkland and floodproofing to supplement structural control measures.

Watershed management also allows coordination of infrastructure improvements with point and nonpoint source management programs and provides a vital link between land use and water resources management.

While the normal approach to urban stormwater management is relatively easy to administer, it offers several disadvantages. There is greater risk of negative effects, particularly in watersheds that cover several jurisdictions. Insignificant flood protection benefits result from emphasis on the effects of minor flooding. Ineffective runoff

control throughout the watershed is caused by the failure to evaluate locational differences in the benefits of stormwater management facilities. Relatively high local costs for facility maintenance are incurred, as are unnecessary costs associated with the use of small-scale structural solutions rather than large-scale nonstructural solutions which are much cheaper.

Included among the possible negative effects of this piecemeal approach to stormwater management are the following:

- It may only partially solve the major flooding problem(s);
- It may solve flooding problems in the upstream jurisdiction, but create flooding problem in downstream jurisdictions;
- Randomly located detention basins may increase downstream peak flows;
- The program may result in overall prohibitively high maintenance costs for a significant number of runoff control facilities;

- Significant capital and operation/maintenance expenditures may be wasted; and
- The costs of remedial structural solutions likely will be much greater than the costs of a proper management program if it had been implemented in the first place.

The watershed master plan approach offers significant advantages over the piecemeal approach. It promises reductions in capital and operation/maintenance costs and reductions in the risk of downstream flooding and erosion, particularly in multi-jurisdictional watersheds. It offers better opportunities to manage existing stormwater problems and the ability to consider nonstructural measures. Other benefits include an increase in land development opportunities, increased opportunities for recreational uses of runoff controls, potential contributions to local land use planning, enhanced reuse of stormwater, and popularity among land developers. The major **disadvantages** of the **master plan approach** include:

- Local governments must conduct, in advance, studies to locate, and develop preliminary designs for, regional stormwater management facilities;
- Local governments must finance, design, and construct the regional stormwater management facilities before most development occurs and provide for reimbursement by developers over a build-out period that can be many years long.
- In some cases, local governments may have to conduct extraordinary maintenance activities for regional stormwater management facilities the public feels are primarily recreational facilities that merit protection for water quality.

WATER PLANNING

(Proposed)

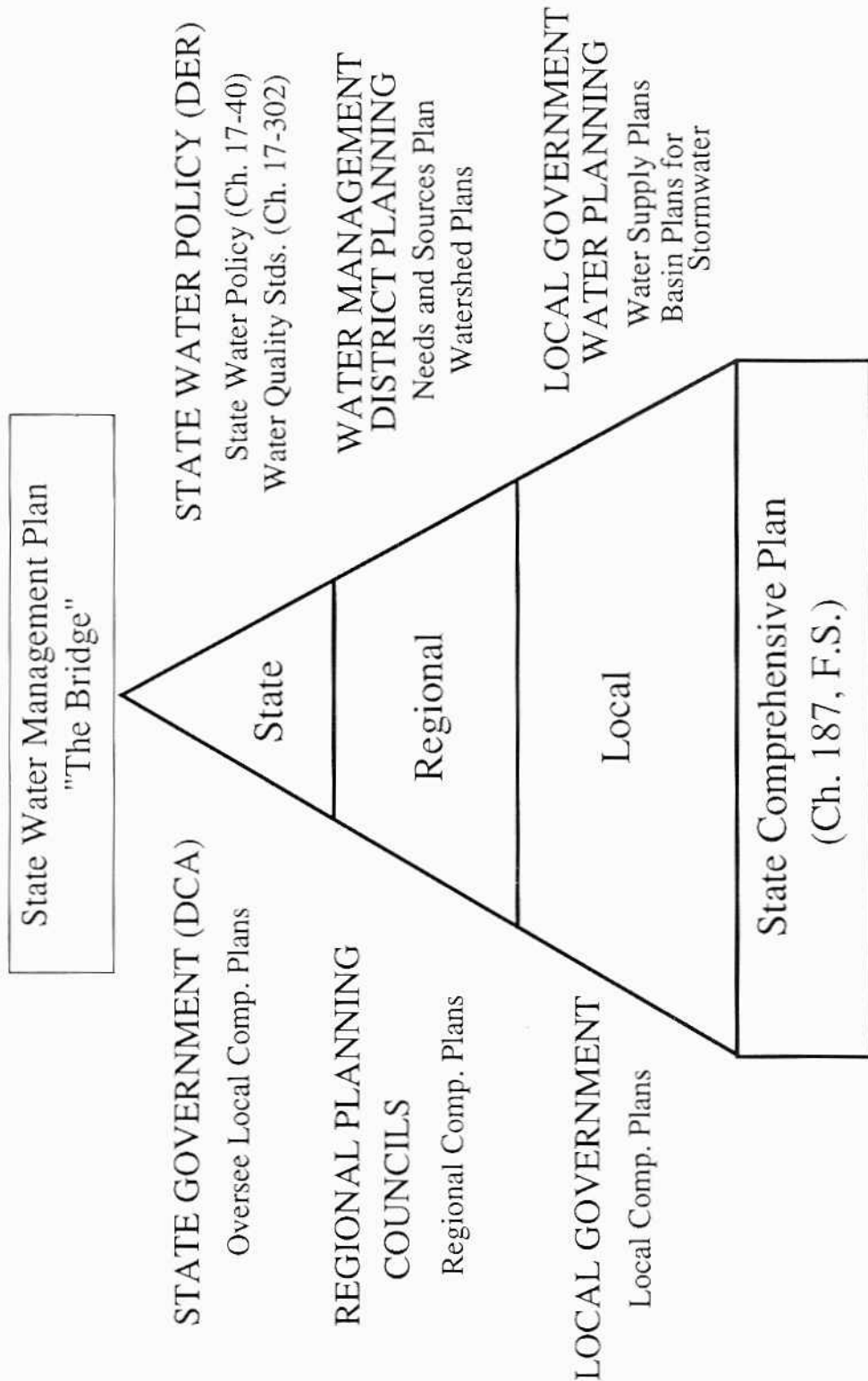


Figure 6: Florida's Water Planning Triangle

C. Florida's Evolving Watershed Management Program

The 1989 STORMWATER LEGISLATION establishes a statewide watershed management framework that relies upon a cooperative effort between the Department of Environmental Regulation, water management districts and local governments. The framework is built upon the integration of the Local Government Comprehensive Planning Act, the State Comprehensive Plan and the Surface Water Improvement and Management Act (SWIM) into a comprehensive watershed management program (Figure 6). The framework is set forth in the State Water Policy, Chapter 17-40, F.A.C.

The legislation designates the Department as the overall lead agency for the watershed management program with specific responsibilities of establishing water quality standards and stormwater treatment requirements and of overseeing the program's implementation by the Water Management Districts and local governments. The Districts will be the chief administrators of the state stormwater regulatory program and will establish watershed specific goals such as the allowable stormwater pollutant loading to a receiving water. As part of the SWIM Program, the Districts have identified priority waters (Table 1) and are developing watershed management goals and plans for these waters.

Table 1

Approved Priority Lists and Plans of the Surface Water Improvement and Management Program (SWIM)

July 1, 1991

NORTHWEST FLORIDA WMD		
1. Apalachicola River		
2. Apalachicola Bay/St. George Sound		
3. Lake Jackson		
4. Deerpoint Lake		
5. Pensacola Bay Area		
6. St. Marks River		
7. Choctawhatchee Bay		
8. Choctawhatchee River		
9. Santa Rosa Sound		
10. St. Joseph Bay		
11. Chipola River		
12. St. Andrews Bay		
13. Escambia River		
14. Lake Munson		
15. Merritts Mill Pond		
16. Upper Ochlockonee River/Lake Talquin		
17. Lake Iamonia		
18. Blackwater River		
19. Lake Lafayette		
20. Shoal River		
21. Yellow River		
22. Lower Ochlockonee River/Lake Talquin		
23. Lake Miccosukee		
24. Sand Hill Lakes		
SUNWANNEE RIVER WMD		
1. Suwannee River (Withlacoochee River/Falling Cr)		
2. Santa Fe River System		
3. Coastal Rivers Basin (Steinhatchee River)		
4. Alligator Lake (Columbia Co.)		
5. Aucilla River (Wacissa River)		
6. Waccasassa River		
SOUTHWEST FLORIDA WMD		
1. Tampa Bay		
2. Blue Run (Rainbow River)		
3. Banana Lake		
4. Crystal River/Kings Bay		
5. Lake Panasoffkee		
6. Charlotte/Placida Harbor		
7. Lake Tarpon		
8. Lake Thonotosassa		
9. Winter Haven Chain of Lakes		
ST. JOHNS RIVER WMD		
1. Lower St. Johns Basin		
2. Indian River Lagoon System		
3. Lake Apopka Basin		
4. Upper Ocklawaha River Basin		
5. Lake George Basin		
SOUTH FLORIDA WMD		
1. Lake Okeechobee/Kissimmee River		
1. Biscayne Bay		
1. Indian River Lagoon		
4. Everglades National Park/Florida Bay		
5. Everglades Water Conservation Areas		
6. Lake Tohopekaliga		
7. East Lake Tohopekaliga		
8. Lake Weohyakapka		
9. Caloosahatchee River Estuary		
10. Big Cypress National Preserve		
11. Lake Kissimmee		
12. Everglades East		
13. Lake Arbuckle		
SOUTH FLORIDA continued		
14. Corkscrew Swamp		
15. Naples Bay/Gordon River		
16. Estero Bay		
17. Lake Butler		
18. Alligator Lake		
19. Florida Keys		
20. Pine Island Sound/Matlacha/Ding Darling		
21. Lake Jackson (Osceola Co.)		
22. Lake Rosalie		
23. Cypress Lake (Osceola Co.)		
24. Lake Hatchineha		
25. Lake Istokpoga		
26. Lake Worth		
27. Everglades Holey Land/Rotenberger Tract		
28. Loxahatchee River		
29. Rookery Bay/Marco		
30. Lake Pierce		
31. Lake Marian		
32. Lake Trafford		
33. Corbett Wildlife Management Area		
34. Savannas State Reserve		
35. Three Lakes Ranch		
36. Fish Lake (Osceola Co.)		
Bold = Approved Plans		