Preliminary Estimate Of Impacts of Sea Level Rise on the Regional Water Resources of Southeastern Florida

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ABSTRACT

The Environmental Protection Agency (EPA) estimates that by the year 2050 that global sea level will likely increase by 15 centimeters with a ten percent probability that it may rise as much as 30 centimeters (Titus, 1995). In this precursory analysis, the impact of sea level rise on the ability to meet regional water management objectives is estimated with the application of the South Florida Water Management Model (South Florida Water Management District, 1998). This model is a coarse resolution surface water-groundwater model whose domain extends from Lake Okeechobee in the north to Everglades National Park in the south and includes the highly developed region of the southeastern coast of Florida. The simulated regional hydrologic system performance measures for current and the EPA projected 2050 sea level conditions are compared. Major coastal infrastructure are the same for both model simulations. However, certain operational rules were modified for the developed coastal region in an effort to maintain the hydraulic gradient between the freshwater and the highly saline coastal water.

The results of this analysis indicate that sea level rise of 15 centimeters will cause greater water use cutbacks for the developed regions while the interior regional hydrologic system of south Florida will not be significantly impacted. The additional surface water flow that is required to maintain the coastal canals at higher levels were offset by a reduction in groundwater flow from the interior regions.

Key Words: regional water management, eustatic, hydrologic system performance measures, water use cutbacks

INTRODUCTION

Global sea level rise has been occurring at varying rates since the end of the last major ice age fifteen thousand years ago. For the past three thousand years available geological history indicates that sea level rise averaged about four centimeters per one hundred years. During the most recent years since 1932 sea level rise has been estimated to be at an accelerated rate along the Florida shoreline (Wanless, 1989). Wanless estimates the more recent rates to be in range between twenty to forty centimeters per hundred years. The accelerated rate is more than six times faster than that prior to 1932 but is not unprecedented. Average sea level rise rates as large as one to two meters per century have lasted for periods of thousands years at a time since in the past. It is generally accepted that sea level rise is associated with global warming through several processes including the melting of mountain glaciers and thermal expansion of the ocean waters. Past global warming was likely attributed to such factors as long-term increases in solar energy output and variations of the earth's orbit around the sun.

Scientific evidence suggest that in the future anthropogenic activities may also contribute significantly to global warming. The Environmental Protection Agency (EPA) estimates that the most probable sea level rise that will occur by the year 2050 will be about fifteen centimeters with a ninety percent confidence that the sea level rise will be less than thirty centimeters. The EPA report is chiefly concerned with sea level rise due to increased greenhouse warming. Regardless of the cause for the warming, the potential impacts of sea level rise poses a formidable challenge for water resources planning in the future.

The purpose of this rudimentary analysis is to estimate potential impacts that sea level rise may have on regional water management in south Florida if no major changes are made to the infrastructure to adapt to such eustatic event during the next 50 years.

METHODOLOGY

The South Florida Water Management Model (SFWMM) is a regional scale surface water - groundwater model that simulates the operations of a complex systems of reservoirs and canals that exist in the southern portion of peninsular Florida. It covers an area of 19760 km2 with a mesh of 3.2 kilometers by 3.2 kilometers cells. The model simulates the major components of the hydrologic cycle in south Florida including: evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal-groundwater seepage, levee seepage and large municipal pumpage withdrawals from the groundwater system.Rainfall and parameters to estimate physical processes of evapotranspiration were based on climatic conditions that existed from 1965 through 1995. Figure 1 illustrates the model domain cell mesh.

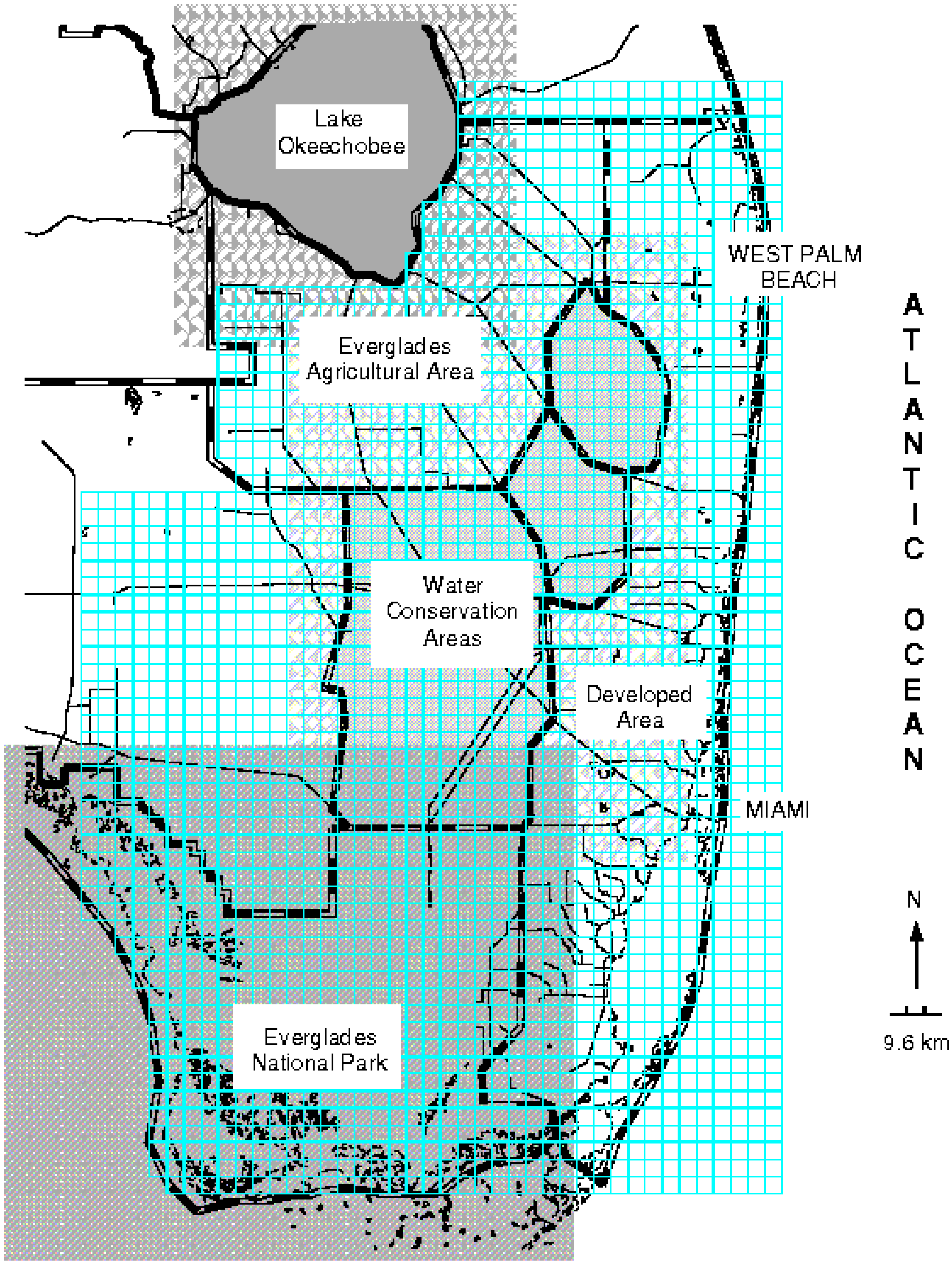

Figure 1. South Florida Water Management Grid Network.

The model estimates overland flow with the two-dimensional diffusion equations while groundwater flow is estimated with a two dimensional, isotropic, transient subsurface flow equation for unconfined aquifers. Canal water levels and discharges are regulated by control structures that exist at various locations within the canal network. A canal reach is generally defined has a stretch of canals that exist between two control structures. Water levels for each reach canal reach are estimated with an iterative mass balance scheme that interacts with the groundwater and surface water system at each cell through which the canal passes.

This model incorporates current or proposed water management control structures and operational rules. The ability to simulate water shortage policies affecting urban, agricultural, and environmental water uses in southern Florida is a major strength of this model. The SFWMM simulates hydrology on a daily basis using climatic data for the period of 1965 through 1995. This period includes dry and wet periods of varying duration and extremities. The model has been calibrated and verified using water level and discharge measurements at hundreds of locations distributed throughout the region within the model boundaries. Technical staffs of many federal/state/local agencies and public/private interest groups have long accepted the SFWMM as the best available tool for analyzing regional-scale structural and/or operational changes to the complex water management system in south Florida. This model was developed in the late 1970s and originally documented by MacVicar (1984).

The primary source of water for the highly developed regions along the southeastern Florida coast is the surficial aquifer. This aquifer is deep, porous and highly transmissive creating a tremendous source of freshwater for the southeastern coastal region. This aquifer is normally recharged from rainfall during the wet periods and from rainfall and groundwater flow from the west during drier periods. Average annual rainfall for the southeastern coast of Florida is more than 1500 millimeters. During extended periods of below normal rainfall large municipal withdrawals from the surficial aquifer along the highly developed coastal regions cause large drawdown of the groundwater table in the coastal aquifer. Supplemental water deliveries must be made from the interior surface water reservoirs including the Water Conservation Areas (WCAs) and Lake Okeechobee to maintain water levels in a dense network of coastal canals. When these canals levels are maintained at the prescribed heights above sea level, the recharge from the coastal canals to groundwater aquifer lessens the opportunity for salt water encroachment during these extended dry periods. This recharge helps maintains the hydraulic gradient that exist between the freshwater aquifer and that of the highly saline coastal waters.

The impact of sea level rise in this analysis is evaluated by making one model run with current sea level conditions and another with sea level being assumed to be 15 centimeters higher. The regional nature and coarse resolution of the SFWMM is not designed to address the full spectrum of issues that are associated with the sea level rise scenario. However, by making some rudimentary assumptions an estimate of the potential impacts that sea level rise may have on regional water management issues such as Everglades hydroperiod restoration and to agricultural and urban areas can be realized. It is with this intention that current analysis is completed. This perfunctory increase in canal maintenance levels is considered the minimal adjustment that would be required to offset the saltwater encroachment that would otherwise occur. Indeed, preliminary analysis with density-dependent groundwater models suggest that the canals may need to be maintained at even higher levels to adequately offset the projected one-half foot rise in sea level.

RESULTS

Figure 2 illustrates a typical comparison of stage-frequency curves of the canals with and without sea level rise scenario. Simulated water levels are in terms of the National Geodetic Vertical Datum developed for the North American coastlines in the year 1929. Sea Level has already risen by at least 15 cm since that period. Canal levels in the future sea level rise alternative were maintained at higher levels than are currently maintained to offset sea level rise. Figure 2 is representative of coastal canals of the developed region which includes Miami and West Palm Beach.

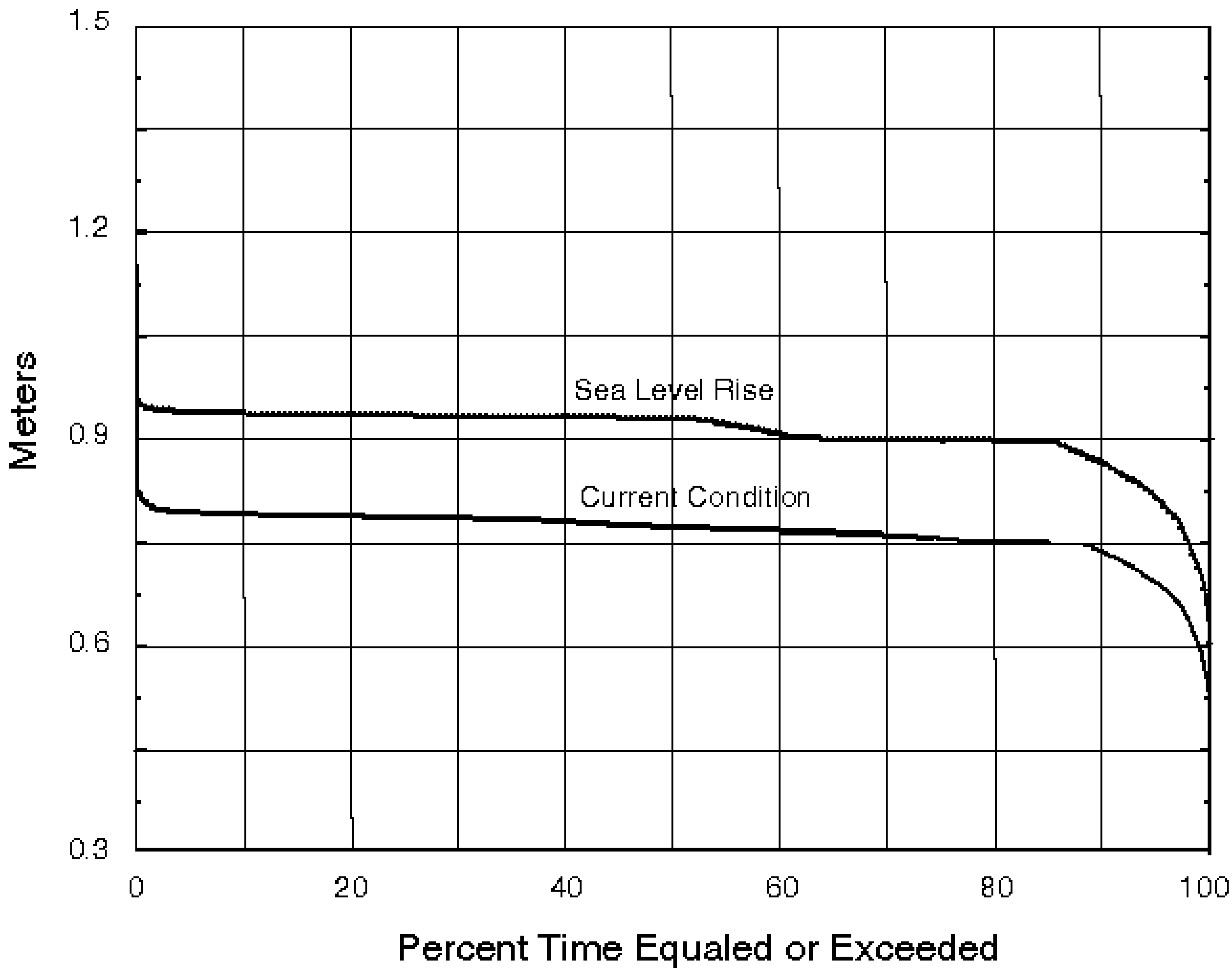

Figure 2. Example Canal Stage-Duration Curve for Developed Coastal Region.

In addition to maintaining higher water levels to offset the effects of sea level rise, water use cutbacks are initiated at groundwater levels that are 15 centimeters higher in the of sea level rise scenario. Table 1 summarizes the months of water use cutbacks for the northern, central and southern regions of the developed areas. As would be expected, the northern region requires the greatest increase in the number of months of cutbacks since the operational rules for maintaining canal water levels were not significantly altered in this region for the sea level rise scenario.

Table 1. Months Of Water Use Cutbacks for Coastal Developed Area

Current Sea Level Conditions			Projected Sea Level Rise		
Northern Coastal Region	Central Coastal Region	Southern Coastal Region	Northern Coastal Region	Central Coastal Region	Southern Coastal Region
68	120	57	124	124	64

The percentage of time that peak annual water levels for the sea level rise scenario exceeded those of the non-sea level rise scenario by at least 8 centimeters for the grid mesh appears in Figure 3. Significant increases in peak annual water levels are an indication that there is increased potential for flooding that may exist with the sea level rise scenario which may require further analysis with finer resolution models. It is important to point out that not only the immediate coastline is influenced by sea rise scenario.

In Everglades National Park at the southern tip of Florida, water levels are simulated to increase. This is a signal that changes are occurring at the boundary of the marine and freshwater interface. It is believed that if sea level rise occurs at a slow enough rate, that natural ecosystems such those of the mangroves would be able to migrate inland as sea level rise occurs. However, according to Wanless and Parkinson (1989), even the current accelerated rate of sea level rise is not favorable for such migration. In more developed areas of the southeastern coast of Florida, the opportunity for migration is limited by the infrastructure that already exists.

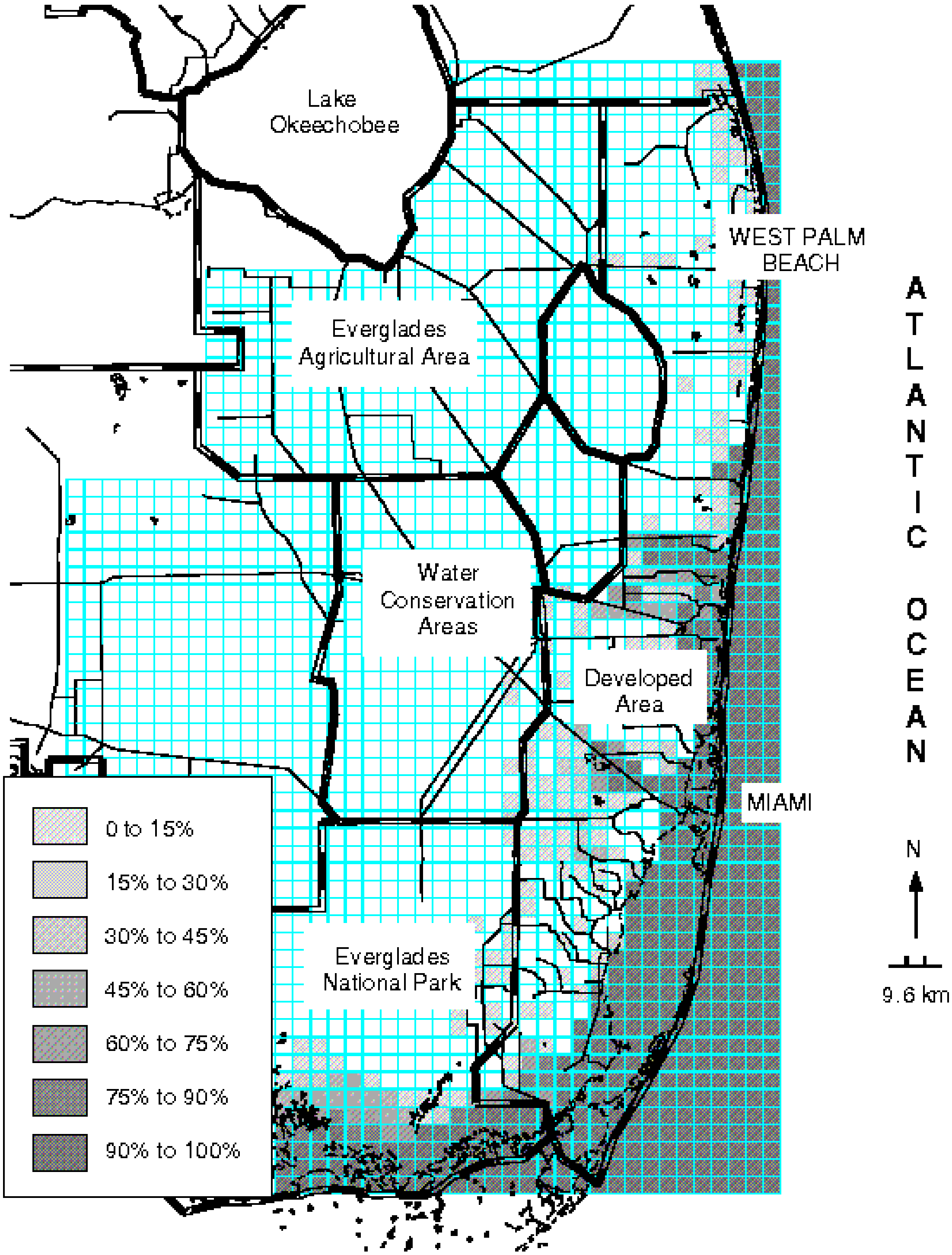

Figure 3. Percentage of Time Sea Rise Scenario at least 8 Centimeters Greater Than That Without Sea Rise.

Estuaries throughout the District may need additional fresh water deliveries to balance increased high saline water trying to enter these valuable habitats. This additional volume, if required, is not known at this time. Therefore it is not included in this sea level rise scenario.

CONCLUSION

Even the current rates of sea level will present formidable challenges for regional water management in southeastern Florida in the next few decades. Without significant infrastructure changes in the future, the results of this analysis indicate that southeastern coastal Florida is likely to experience increased potential for flooding and a greater need for water use cutbacks.It is also significant to note that sea level rise does not appear to significantly impact the hydroperiod of the inland Everglades.

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