8.0 INTEGRATED WATER MODULE

8.1 Overview

The module provides a basis for estimating the impacts of current demands placed on the water-based infrastructure systems in the Florida Keys—water supply, wastewater treatment and effluent disposal systems, and stormwater management facilities—and to estimate the impacts that would be caused by additional growth. The module estimates pollutant loads delivered to the receiving waters from the natural and developed areas of the Florida Keys. The module also provides information to the Fiscal Impacts Module to enable the evaluation of potential fiscal impacts of water-related infrastructure.

The Integrated Water Module calculates pollutant loads entering the nearshore waters in the study area based upon scenario-defined conditions. The module incorporates existing data from the recently adopted Monroe County Stormwater Management Master Plan and Sanitary Wastewater Master Plan. The module includes components for a) predicting potable water demands and gross pollutant loads attributable to wastewater treatment, effluent disposal, and stormwater management; and b) calculating potential reductions due to management strategies and structural interventions.

8.2 Data Collection and Investigation

Data collection and review initially focused on understanding the unique conditions that exist within the study area; then, research focused on providing a sound basis for developing the algorithms that are used within this module. The data search addressed the following types of data:

- **Spatial Framework:** This module uses the Monroe County parcel database as well as the County's stormwater and wastewater master plans. As for other modules, the main unit of analysis was the planning unit. For the FKCCS, efforts were made to define catchment areas or wastesheds, generally defined by surface drainage. Because topographic data at one-foot contour resolution is not generally available within the Keys, catchment delineation followed the existing roadway network and canal systems. Approximately 600 catchments or wastesheds were identified.

- **Potable Water Supplies:** There are no significant water supplies within the Florida Keys. The FKAA supplies virtually all of the potable water used in the study area from a wellfield located in southern Miami-Dade County. Key data reviewed with respect to the potable water system include recent consumption records, permitted capacities, plans for expansion, the cost of delivered water, and the operational capabilities of the primary facilities. The facilities include an existing wellfield, water treatment, pumping and transmission facilities, as well as emergency desalination facilities located within the Keys. The data collected supported the development of viable algorithms to estimate water requirements at the parcel level, aggregate the demand to planning units, assess the adequacy of the existing segments in the transmission pipeline, and assess the capacity of the existing wellfield and water treatment plant.

- **Wastewater Treatment:** With the exception of the Key West Wastewater Treatment Plant (10 Million Gallons per Day (MGD)), there are no large centralized wastewater collection and treatment systems in the Florida Keys. With the exception of the Key West plant, the five largest wastewater treatment plants in the Florida Keys are Key Haven Utility (0.2 MGD), Monroe County Detention Center (0.105 MGD), Key West Resort Utilities (0.499 MGD), U.S. Naval Air Station (0.4 MGD), and Ocean Reef Club (0.55 MGD). Wastewater treatment for existing residential and commercial/industrial wastewater flows is provided by a wide variety of systems ranging from simple cesspits to small on-site package plants. Data that has been collected and reviewed includes current regulations, the type and location of known facilities, the quality of effluents provided by these diverse treatment methods as documented by EPA and FDEP, as well as in the Sanitary Wastewater Master Plan adopted by Monroe County. The data supported the development of viable algorithms to estimate the daily volume and pollutant loads associated with each type of treatment for each wasteshed.

- **Effluent Disposal:** With the recent elimination of the ocean outfall for the Key West Wastewater Treatment Plant, all effluent disposal is accomplished by drainfields or disposal wells. Spatial data collected from the FDEP, based upon permit data, was reviewed and incorporated into this module. This data was sufficient to develop algorithms to estimate daily hydraulic and pollutant loads being input to groundwater.

- **Groundwater Systems:** All of the effluent generated in the Florida Keys enters the groundwater system. Selected driller's information and a variety of hydrogeologic investigation reports documents two highly porous interconnected limestone units underlying the Keys, which preclude the formation of a significant freshwater lens. Additionally, several wastewater fate and transport studies provided limited information on the ability of the subsurface rock to attenuate soluble phosphorous, but did not examine any other pollutants. The highly porous rock that underlies the Keys, combined with the lack of specific subsurface physical conditions data and undocumented water levels throughout the Keys, prevented the development of viable algorithms to accurately simulate subsurface flows and detailed pollutant transport calculations.

- **Weather:** A significant amount of information is available for weather in the Keys (Appendix A). The data collected supported the development of viable algorithms to generate suitable rainfall values for each month for wet, normal, and dry years.

- **Rainfall Runoff:** Due to the historic lack of flooding in the Florida Keys related to rainfall, little quantitative data exists on the relationship between rainfall and runoff. While some data documents nuisance flooding due to the lack of local drainage facilities, no data were found that could be used to establish runoff coefficients or infiltration rates. The data collected for the watersheds supported the development of viable algorithms to estimate daily rainfall runoff volumes for the selected weather conditions by using values that were derived from the literature for mainland Florida. This is the same approach that was used in the recent Stormwater Management Master Plan adopted by Monroe County.

- **Runoff Management:** Given the highly porous soils and the general proximity to open water, few engineered drainage systems have been developed in the Keys. Similarly, until recent years, there were virtually no stormwater treatment systems in the Keys and stormwater pollutant loads were generally discharged directly to receiving waters. Data collection efforts focused upon the identification and location of stormwater treatment facilities, the Event Mean Concentration (EMC) values for pollutants discharged in runoff, and the documented treatment efficiencies/benefits associated with existing stormwater BMPs. The lack of treatment systems and lack of Keys-specific data precluded the development of a viable event-based simulation model. However, the data collected for the watersheds supported the development of viable algorithms to estimate daily runoff pollutant loads for the selected weather conditions, using EMC values that were derived from the literature for mainland Florida. This is the same approach that was used in the recent Stormwater Management Master Plan adopted by Monroe County due to the absence of any local EMC or BMP efficiency data.

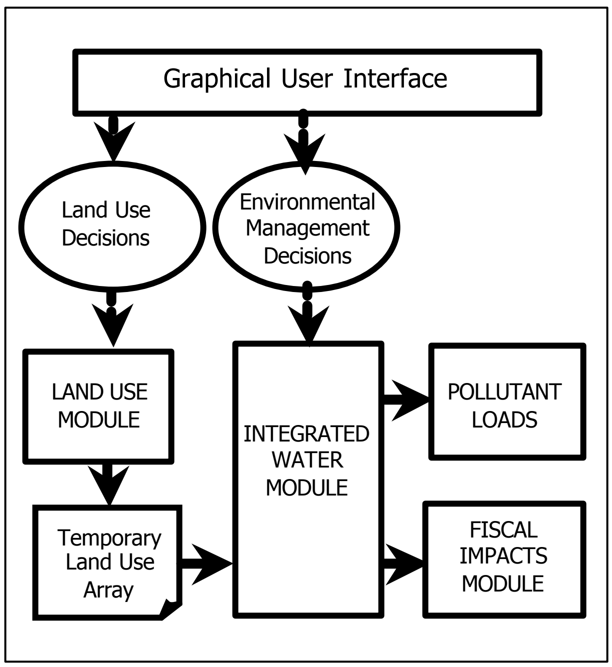
- **Marinas, Boats, and Live-Aboards:** Early input from stakeholders suggested that discharges from marinas, boats, and live-aboard boats, as well as their related boat repair and servicing/maintenance activities, might generate a significant pollutant load to receiving waters. To investigate this possibility, data was collected and reviewed for the number and location of existing marinas, boating registrations, wastewater pump-out facilities and the disposal of the pumped-out wastes, live-aboard boats, metals discharged from hull paints, and fueling practices. EPA estimates that live-aboards contribute 2.8 percent of the total nitrogen load in the Florida Keys (Kruczynski and McManus 2002). This is the only quantitative estimate available regarding pollution from boat discharges in the marine environment. Therefore, this paucity of information precluded the development of a viable algorithm for estimating pollutant loads attributable to marinas or boating activities.

8.3 Assumptions and Module Components

The Integrated Water Module has been developed upon the following principles:

- **Connection to Other CCIAM Modules**. The Integrated Water Module relies upon, and interacts with, other components of the CCIAM (Figure 8.1). Some of the CCIAM components provide inputs to the Integrated Water Module (e.g., land use and socioeconomics modules); other CCIAM components receive inputs from the Integrated Water Module (e.g., fiscal module).

FIGURE 8.1
RELATIONSHIP BETWEEN THE INTEGRATED WATER MODULE AND OTHER CARRYING CAPACITY ANALYSIS MODEL MODULES



- **Modular Architecture.** The module was designed to react to changes in regulatory mandates, and accept the future incorporation of new analytical tools and more current data. It is divided into analytical components and datasets, which facilitate the revision of individual components without affecting the entire component.

Three upstream CCAIM components provide input for the Integrated Water Module:

- **Scenario Decisions.** Scenario input decisions affect pollutant characteristics, management strategies, intervention concepts, and timing considerations.
- **Background Data.** Several temporal and spatial datasets contained in the CCIAM database are used by the components of the Integrated Water Module to generate intra-component outputs as well as the outputs required by other CCIAM modules.
- **Parcel Attributes.** Output arrays from the Land Use Module provide parcel based information regarding parcel size and location, land use, wastewater EDUs, treatment/disposal methods, stormwater BMPs, and similar parcel based data, which is required by the Integrated Water Module's components.

The Integrated Water Module calculates total pollutant loads per watershed throughout the study area and applies a modeling approach under the following guidelines:

- **Assumption of Worst Pollutant Form.** For Total Nitrogen (TN) and Total Phosphorus (TP) loads, for which data is lacking on the speciation of the total loads, it has been assumed that the entire pollutant mass is in the soluble form.
- **Use of Central Values.** In cases where a range of values have been reported in studies or otherwise used in regulatory processes, the value selected for use in the Integrated Water Module is the value in the middle or the normal range of values.
- **Conservative Pollutant Characteristics.** The modules assumes that pollutants are conservative, so that they are neutral buoyant and well mixed, do not settle out of suspension, are non-reactive with other soluble constituents in the flow process, and do not volatilize.
- **No Sediment/Benthos Interactions.** The liquid volumes involved in the transport process do not allow re-suspension of settled solids, do not interact with the sediments or benthos to allow settled forms of pollutants to convert to soluble forms, and do not otherwise cause stripping/de-adsorption of constituents that have been removed by passing through the limestone matrix underlying the Florida Keys.
- **Assumption of No Treatment.** In the case of pollutant movement through the unsaturated and saturated subsurface limestone matrix that underlies the Florida Keys, where no treatment or pollutant removal rate has been documented in the literature, the Integrated Water Module assumes that no reduction of the pollutant load occurs.

In many cases, the treatment process has been simply modeled with loading and treatment values selected for the input constants of the different components that reflect the preceding conservative approach. Conservative assumptions have been adopted in the absence of specific data. In the future, the CCIAM can be refined by simply modifying the input constants when acceptable data becomes available.

The Integrated Water Module includes five components, which address each of the following processes that define pollutant generation, conversion and transport (Figure 8.2 and Table 8.1):

- **Weather Characteristics.** The weather component provides the precipitation, antecedent conditions, and wetfall/dryfall pollutant loading values that are used in the stormwater component.

- **Potable Water Demand.** This component utilizes permanent and temporary (seasonal and transient) populations, and documented local water consumption rates to estimate potable water demand. It then compares the demand to the capacity of the existing potable water supply and primary distribution system. Also, the FKAA is contracted with the U.S. Navy to provide up to 2.4 MGD. Currently, the U.S. Navy utilizes less than half the contracted amount (average 1.1 MGD). However, if the U.S. Navy needs the full contracted amount, the FKAA is obligated to meet this water demand.

- **Stormwater.** This component utilizes land use from the contributing drainage areas and associated pollutant loading rates to estimate pollutant loads generated within each watershed. It also calculates pollutant load reductions attributable to stormwater BMPs, and calculates the net pollutant loads discharged to the receiving surface water and groundwater systems.

- **Wastewater.** This component utilizes permanent and functional populations, local wastewater generation rates, local wastewater characteristics, and point source discharge data from the contributing wastesheds to estimate pollutant loads generated within each wasteshed. It also calculates the levels of load reduction attributable to treatment systems, and calculates the net pollutant loads of the effluent discharged to the receiving groundwater systems.

- **Groundwater.** This component simulates groundwater system interactions, including groundwater flows and pollutant transport in the subsurface environment underlying each of the modeled islands in the Florida Keys and estimates groundwater discharges to the nearshore waters.

All of these components, with the exception of weather component, utilize computational algorithms that have been developed and generally accepted in other modeling studies. These have been subsequently modified for use in the CCIAM through the selection and/or development of suitable input variables, input constants, and management variables.

FIGURE 8.2
RELATIONSHIP BETWEEN THE FIVE COMPONENTS OF THE INTEGRATED WATER MODULE

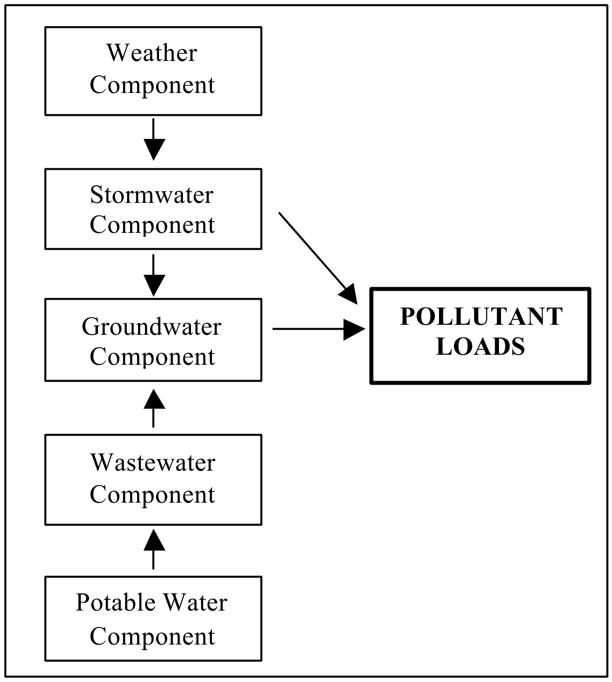


TABLE 8.1
COMPONENTS AND ELEMENTS OF THE INTEGRATED WATER MODULE

Component	Elements
Weather	Rainfall Evaporation Atmospheric Deposition
Potable Water	Estimation of Water Demand Adequacy of the Permitted Supply Adequacy of the Existing Conveyance Facilities
Stormwater	Computation of EMC Values Runoff Volumes Runoff Pollutant Loads Pollutant Load Reductions due to BMPs Allocation of Discharged Pollutant Loads
Wastewater	Estimation of Wastewater Volumes by Treatment Method Estimation of Pollutant Loads Associated with Each Treatment Method Aggregation of Effluent Volumes and Pollutant Loads by Disposal Method Seasonal Adjustment of Flows
Groundwater	Gross Pollutant Loads Pollutant Treatment Volumetric and Pollutant Transport Discharge Location

8.3.1 Weather Component

The Weather Component provides look-up tables with pre-processed parametric weather data that is required for evaluating the stormwater flows. Existing weather data for the study area was identified, acquired where possible, analyzed and assimilated into look-up tables. Primary data of interest included rainfall and atmospheric loading rates for the pollutants of concern.

Rainfall. Six of 14 rainfall stations identified in the study area were determined to have suitable data for use in CCIAM. Daily rainfall data from the selected stations were compiled and summarized into monthly and annual records. Annual rainfall summaries were developed to determine the average, wet and dry annual rainfall, with dry and wet year values developed by assuming a normal distribution and selecting the 10 percent non-exceedance and 90 percent non-exceedance annual rainfall. Monthly totals were computed for the selected stations from the daily rainfall data. Monthly rainfall totals were evaluated for each rainfall station to identify the average, wet, and dry rainfall amounts for each month of the year. The same method used to select the wet and dry year was used to identify the wet and dry months.

Atmospheric Deposition. No viable data sets were identified. A brief summary of average data values for a 5-month period was collected at a meteorological station at the Florida Keys Marine Laboratory at Long Key, which was not deemed sufficient for purposes of this study. Therefore, no atmospheric deposition data were included.

The Weather Component provides look-up tables with monthly values for rainfall and evaporation for average conditions, as well as hydrologically wet and dry years.

Assumptions and Uncertainties

- The module assumes that the periods of available record for the rainfall data were adequate to estimate rainfall for specific months for the expected weather conditions in the Keys.
- Virtually no Keys-specific data has been identified for aerial deposition, which may represent a load factor for other modules. However, because aerial deposition is not expected to change significantly with the projected changes in land use in the Florida Keys, it is treated as a constant subsumed within baseline conditions.
- Rainfall varies spatially across the study area, and the rainfall record at the selected six rainfall stations adequately represents the spatial variability.
- Temporal rainfall variations are adequately represented in terms of monthly average values and in the definition of wet, normal, and dry year values.

8.3.2 Potable Water Component

The Potable Water Component develops an estimate of daily potable water demand for each given scenario and then compares the estimate against the allowable groundwater withdrawal of FKAA's current consumptive water use permit and the currently constructed potable water infrastructure. The comparison determines whether the existing water system has adequate supply and treatment capacity to meet the required water demand. The Potable Water Component addresses the following four elements:

Allocation of Current Potable Water Demands to Existing Equivalent Dwelling Units. Efforts initiated by the Monroe County Sanitary Wastewater Master Plan to allocate the existing total number of EDUs to specific developed land parcels were completed in this study in order to spatially assess existing and future potable water demands. Additionally, representative daily demands were calculated based upon FKAA water use records for each planning unit.

Estimation of Potable Water Demand. Daily potable water demand is calculated for each scenario using land use categories, converted to EDUs, and current specific water consumption rates computed for each planning unit. The calculated demand includes the demands of permanent and seasonal residents, tourists, and day-trippers. Computations are aggregated to the level of the 28 wastewater planning units (including Key West), adjusted at the planning unit level for functional populations, and then summed to produce the estimated total potable water requirement for the entire study area.

Adequacy of the Permitted Supply. The component compares the controlling constraints, such as the permitted groundwater withdrawal rate established for the water supply source and the treatment facility capacity, against the estimated potable water demand of a scenario. While the FKAA maintains two small desalination facilities within the Keys for emergency services in the event of a pipeline problem, these units are not used for daily supply and are not considered when determining the adequacy of existing potable water supplies versus the demands for a specific scenario.

Adequacy of the Existing Conveyance Facilities. Transmission pipeline throughput requirements are calculated based upon the potable water demand of a scenario and an assumed maximum average daily velocity of 7 feet per second in the transmission main segments. The component compares the capacity constraints established for each FKAA aqueduct segment against the estimated cumulative potable water demands calculated for each of the planning scenarios. It then generates advisories/warning messages when conveyance throughput demands exceed the established capacity of the pipe segment passing through any planning unit.

Assumptions

- The availability of fresh water on the mainland, pumped through the pipeline to customers, will continue to be a controlling aspect of development and a critical component in the carrying capacity of the Florida Keys particularly given the high cost of producing water by desalination processes.

- The existing secondary source of water supply, consisting of the two reverse osmosis water plants, will not be used as a primary supply of water but will be reserved exclusively for emergency use purposes.
- The existence of irrigated lawns is limited in the Keys. The degree to which potable water is used for lawn irrigation is largely undocumented, but assumed to be zero in the model. The FKAA estimates lawn irrigation at 15 percent (letter from Roger Braun, FKAA, to Debbie Peterson, USACE, dated August 15, 2002; in lit.). Therefore, the model is conservative and may estimate larger wastewater volumes and pollutant loads.
- Water reuse is not expected to significantly affect future development costs and water use.
- While the primary source of potable water to the Keys is direct withdrawals from the Authority's Florida City wellfield, future resources may include seasonal water banking using Aquifer Storage and Recovery (ASR), or construction of a 2–5 MGD operational reverse osmosis plant. This would substantially increase the monthly supply rate.
- Water use may be reduced through ongoing FKAA regulatory initiatives (e.g., the FKAA recently adopted a formal Resolution requesting all municipalities and unincorporated Monroe County to adopt mandatory water conservation and irrigation ordinances in accordance with SFWMD's permit allocation manual). Draft ordinances are being provided (FKAA letter to Ann Lazar, DCA, February 27, 2002).

8.3.3 Stormwater Component

The Stormwater Component calculates gross pollutant loads and BMP-based reductions, and then routes the resulting net pollutant load discharges to either the groundwater system or the nearshore waters. The Stormwater Component, as the entire CCIAM, is a steady-state model; therefore, it uses average or central values to address stormwater flows. No episodic events are considered. The component includes the following elements:

Delineation of Watersheds. Watersheds, smaller drainage areas within each planning unit, were developed to relate the non-point source discharge loads generated within specific portions of each planning unit to a specific discharge point on the shoreline. Watershed delineation was based primarily upon the network of local roadways and canals, due to the lack of suitable topographic information, and then digitized to form a watershed overlay.

Computation of EMC Values. The EPA has designated a number of Florida communities as Municipal Separate Storm Sewer Systems (MS4s), and subsequently required them to collect stormwater discharge characterization data. Because of the absence of stormwater discharge monitoring data in the Florida Keys, EMC data from representative Florida communities were used to calculate the pollutant and nutrient loads in the study area. Constituents incorporated into the Stormwater Component include TN, TP, 5-day biochemical oxygen demand (BOD) and Total Suspended Solids (TSS).

The resulting database uses much of the data that were incorporated in the Stormwater Management Master Plan adopted by Monroe County, but differs in that it does not include data from non-Florida stormwater discharge characterization sites. EMC values were computed for the average, 10-percentile, and 90-percentile values for the development of uncertainty analysis using a lognormal distribution. The percentiles provide guidance for values to be used in sensitivity analyses.

Runoff Volumes. The Stormwater Component develops an area-weighted runoff coefficient for each delineated watershed (drainage catchment) using the aggregated land use data computed by GIS for the watershed, a look-up table that maps specific land uses into generalized classes of land use, and a data table of runoff characteristics for generalized land use classes. Runoff volumes are computed for each watershed using the area-weighted runoff coefficient from the aggregate land use data, and the rainfall volume provided by the Weather Component.

Runoff Pollutant Loads. Pollutant loads are calculated with a simple washoff model, commonly used in most Florida MS4s, that utilizes the EMC database for generalized land uses in the study area. Pollutant loads are computed for selected pollutants for each watershed using the watershed's computed runoff volume and area-weighted EMC values from a data table of land-use specific EMC values for the selected pollutants.

Stormwater BMPs. Few structural BMPs exist in the Florida Keys and virtually no performance data has been collected on existing BMPs. The array of current stormwater BMPs was evaluated based upon their potential suitability in the study area, and a look-up table of treatment performance by specific BMP was developed based upon literature values and the published values from the Stormwater Management Master Plan adopted by Monroe County.

Pollutant Load Reductions due to BMPs. Stormwater BMPs, selected by the user, form the basis for calculating the reduction of discharged pollutant loads. Pollutant load reductions are calculated for each catchment on the basis of the user-specified extent of BMP coverage (drainage areas served) and the default removal rate from a data table of potential BMPs.

Allocation of Discharged Pollutant Loads. The final step involves allocating the net discharged pollutant volumes and loads by receiving waters. Significant portions of stormwater runoff percolate into the surficial region of the localized groundwater systems due to the highly porous soils in the Keys. Allocation of the discharged stormwater volumes and pollutants is based upon the governing transport mechanism. Initial loss to the Groundwater Component due to percolation/infiltration is based upon the nature of the soils and the treatment mechanisms of the implemented BMPs. The remainder of the discharge, occurring due to direct runoff, is allocated to the nearshore waters.

The outputs of the stormwater component are:

- Estimated stormwater runoff volume generated by each catchment.
- Estimated pollutant load in the stormwater runoff from each catchment.
- Estimated pollutant load removed from stormwater runoff in each catchment attributable to the implemented BMPs.
- Estimated net runoff volume discharged into the Groundwater Component via percolation/infiltration from each catchment.
- Estimated pollutant load discharged into the Groundwater Component via percolation/infiltration from each catchment attributable to the implemented BMPs.
- Estimated net runoff volume discharged into the nearshore via surface runoff from each catchment.
- Estimated pollutant load discharged into the nearshore waters via surface runoff from each catchment attributable to the implemented BMPs.

Assumptions

- Runoff coefficients based on similar land uses in other Florida communities, rather than on custom measurements made in the Florida Keys, will be sufficient for predicting generated stormwater volumes.
- Stormwater discharge characterization data for similar generalized land uses collected in other Florida communities will be representative of the discharge generated by similar land uses in the study area.
- The land use classification used in the CCIAM will adequately characterize variations in EMCs and will be suitable for estimating gross stormwater pollutant loads.
- Stormwater pollutant removal rates for future structural BMP installations in the Keys, which incorporate soils processes as part of their overall treatment effectiveness, will be similar to the existing documented performance of these types of BMPs at non-Keys BMP installations.
- Stormwater pollutant removal rates for future structural BMP installations in the Keys, which do not incorporate soils processes as part of their overall treatment effectiveness, will be similar to the existing documented performance of these types of BMPs at non-Keys BMP installations.
- Stormwater pollutant removal rates for future non-structural BMP installations and implemented pollution prevention practices in the Keys will be similar to the existing documented performance of these BMPs and pollution prevention practices at non-Keys BMP installations.

Uncertainties

- Due to the highly porous soils and high transmissivity of the limestone units underlying the Keys, the runoff and infiltration fractions that are being used in this component may be somewhat different than the documented rainfall-runoff rates in other Florida locations. However, the algorithms can be readily adjusted in the future when Keys-specific rainfall-runoff data is available.
- EMC data developed from other Florida MS4s was used in this component. EMC values will be readily updated in the CCIAM should Keys-specific data be developed.
- Due to the lack of soil in the Keys, the documented stormwater pollutant removal rates for future BMP installations in the Keys that incorporate soils processes as part of their overall treatment effectiveness may be different than documented performance of the same BMPs at other locations due to the lack of organic fractions and lack of finer, less porous, grain sizes.

8.3.4 Wastewater Component

The Wastewater Component utilizes the water use estimates from the Potable Water Component, parcel ownerships, GIS mapping and datasets, raw wastewater characteristics, treated wastewater effluent characteristics per treatment method, and discharge/disposal method data from the contributing wastesheds. These data are used to estimate pollutant loads discharged to groundwater systems and then discharged to the nearshore water.

Wastewater loads are calculated using standard algorithms that relate, for each effective dwelling unit (EDU), the volume of wastewater generated per unit time, the concentration of the target pollutant, and the treatment type. The loads generated per EDU are summed for the entire wasteshed.

The Wastewater Component operates in an extensive parcel-based geo-spatial data set that locates and characterizes the existing onsite systems and wastewater treatment facilities within the Study Area. Of the five elements of this component, the first two involve defining the database and the watershed boundaries. The next three computation elements address wastewater volumes to be treated by specific treatment methods, pollutant loads associated with each treatment method, and aggregation of the effluent volume and pollutant loads for each wasteshed by disposal method.

Completion of the Wastewater Database. The GIS coverages provided from the Monroe County Sanitary Wastewater Master Plan (CH2M HILL 2000) were supplemented to complete the GIS coverage and linked database. The fully developed database includes the following information for each parcel:

- Parcel identification number
- Potable water demand estimates

- Allocated number of EDUs
- Method of wastewater treatment
- Method of wastewater effluent disposal

Delineation of Watershed Areas. The watershed areas developed for each planning area as part of the Stormwater Component were used in the Wastewater Component and are referred to as wastesheds. Wastewater flows by treatment type are aggregated at the wasteshed level.

Estimation of Wastewater Volumes by Treatment Method. For each scenario, the Wastewater Component calculates the daily wastewater volumes at the parcel level given each parcel's number of EDUs, existing wastewater generation rates, and the specified treatment method associated with each parcel. Computations of wastewater volumes are initially executed at the parcel level, and then aggregated at the wasteshed level by specific treatment types. This analysis uses the revised database from the Monroe County Sanitary Wastewater Master Plan. These wasteshed characteristics are further aggregated to the level of the 28 Wastewater Planning Areas, and then summed to produce the estimated total wastewater generated, by specific treatment type, for the entire Study Area for the given scenario.

Estimation of Pollutant Loads Associated with Each Treatment Method. Pollutant loads are estimated at the wasteshed level for the aggregated flows being treated by either onsite wastewater technology or wastewater treatment plants. Computations of wastewater pollutant loads are executed at the wasteshed level for each treatment technology, then aggregated to the level of the 28 planning areas, and then summed to produce the estimated total wastewater pollutant load for the entire Study Area for each scenario. The CCIAM applies effluent characteristics established by the DEP during the Monroe County nutrient credit evaluation undertaken by DCA, Department of Health, and DEP in April 1999 (Table 8.2). These characteristics are the default in the CCIAM pursuant to DEP and EPA recommendations.

TABLE 8.2
EFFLUENT CHARACTERISTICS BY TREATMENT METHOD, PER FDEP AND EPA

Treatment Method	BOD (mg/l)	TSS (mg/l)	Total N (mg/l)	Total P (mg/l)
None (Raw Sewage) and Cesspits	200	200	35	6
Substandard (Unpermitted) On-Site Treatment and Disposal Systems	140	85	32	6
Approved On-Site Treatment and Disposal Systems	10	10	25	5
Secondary Treatment	20	20	25	5
Best Available Technology, Including On-Site Treatment and Disposal Systems with Nutrient Removal	10	10	10	1
Advance Waste Treatment	5	5	3	1

Aggregation of Effluent Volumes and Pollutant Loads by Disposal Method. Effluent pollutant loads from each onsite wastewater treatment system and wastewater treatment plant are aggregated by respective disposal methods. Computations of effluent pollutant loads are executed at the wasteshed level by specific treatment technologies and then accumulated at the planning unit level by disposal method.

The wastewater module produces the following outputs:

- Total daily pollutant load of specific modeled pollutants, discharged to the groundwater system in a given wasteshed.
- Total daily wastewater effluent volume discharged to the groundwater system in a given wasteshed.
- Total daily pollutant load of specific modeled pollutants, discharged to the deep well disposal systems, in a given wasteshed.
- Total daily wastewater effluent volume of wastewater discharged to deep well disposal systems, in a given wasteshed.

Assumptions

In order to complete the dataset for use in the Wastewater Component, the following assumptions were made based on the information provided in the Monroe County Sanitary Wastewater Master Plan (CH2M HILL 2000):

- The number of treatment system types per study area presented in the master plan was held constant.
- Older buildings such as those constructed before 1970 were more likely to have cesspits as their onsite system.

Other assumptions include:

- To determine the estimated number of EDUs served by the wastewater treatment plant, the average daily flow of the wastewater treatment was divided by the wastewater generation value for the respective wastewater planning area to calculate an equivalent number of EDUs.
- As in the Monroe County Sanitary Wastewater Master Plan, it was assumed that 100 percent of the potable water provided was converted into the wastewater flows.
- Inflow/infiltration in existing central collection systems is insignificant.

- In the past, the Key West Wastewater Treatment Plant has had wastewater treatment flows on the order of 7+ MGD, due to the high inflow/infiltration rates in the City of Key West central wastewater collection system. In recent years, the City of Key West has undertaken and completed a significant rehabilitation program for its central wastewater collection system, which has significantly reduced inflow/infiltration and lowered the peak flow rates at the Key West Wastewater Treatment Plant to approximately 4 MGD. This component assumes that the effluent flow rate will continue to be 4 MGD for existing conditions.

Uncertainties

- Data from the Sanitary Wastewater Master Plan was used and supplemented for this study. Should future studies provide revised information regarding parameters used in the CCIAM, the new data can be easily updated in the model.

8.3.5 Groundwater Component

The Groundwater Component calculates the discharged groundwater volumes and pollutant loads generated by infiltrated stormwaters and wastewater treatment system effluents. The calculation assumes additional treatment is provided by flow through the limestone underlying the Florida Keys. The four elements of this component calculate the gross loads to the groundwater system: the in-aquifer treatment, the transport through the aquifer, and the eventual discharge load and location at the shoreline.

The aquifer system underlying the Study Area consists of two well-defined units, the Key Largo Limestone, and the Miami Limestone that overlies the Key Largo Limestone in the lower Keys. Surface contact between the two units occurs at the southern tip of Big Pine Key. Due to the high transmissivity of the limestone, the freshwater lens is very thin brackish, and quickly conveys and discharges percolated stormwaters and wastewater effluents to the shoreline. The module assumes steady-state conditions with idealized hydraulic transport of groundwater along the path of least resistance.

Gross Pollutant Loads. The watersheds and wastesheds previously discussed in the Wastewater and Stormwater Components are also used for volume and load accounting in this component. The shallow groundwater pollutant mass loadings are allocated to specific wastesheds depending on the point of origin for Total Nitrogen, Total Phosphorous, BOD, and TSS. Pollutant loads and volumes entering each wasteshed in the Groundwater Component are passed as aggregated values for effluents from on-site disposal systems and wastewater treatment plants from the Wastewater Component. Similarly, stormwater volumes and loads from percolated stormwater runoff are also passed as aggregated values from the Stormwater Component.

Pollutant Treatment. Existing literature and data indicate that pollutant load reductions due to in-aquifer treatment mechanisms are not time-dependent for pollutants that have been studied. Rather, pollutant mass introduced to the groundwater will be reduced by a constant percentage at a fixed distance from the source and then remain relatively unchanged thereafter. Pollutant reductions in the groundwater system for the simulation period, based upon the conceptual construct of the groundwater aquifer, are calculated as one-time, fixed percentage reductions that are pulled from a look-up table containing groundwater system reductions values based upon reported literature values for the Keys.

Volumetric and Pollutant Transport. Hydraulic transport rates are not calculated in the Groundwater Component since pollutant treatment is not dependent upon time. Hydraulic transport rates reported in the literature and field observations indicate that effluents from on-site disposal systems and percolated stormwater runoff are very quickly transported to the surface waters. Therefore, given the conceptual construct of the groundwater aquifer system, pollutant transport to the nearshore waters is treated as an instantaneous, steady state process without any time-phased delays or storage of flows.

Discharge Location. The volumes and net pollutant loads calculated for each wasteshed are transported to the shoreline based upon the idealized hydraulic transport of groundwater along the path of least resistance. The shallow groundwater loads simulated in the Groundwater Component for each wasteshed are totaled and assumed to enter the marine environment.

The outputs of this component are:

- Total daily groundwater volume discharged from a given catchment to nearshore waters.
- Total daily pollutant load of specific modeled pollutants, discharged from a given catchment to nearshore waters.

Assumptions

- Regardless of the transport time, pollutant mass introduced to the groundwater in a particular simulation period will either be reduced or remain unchanged, based on the treatment reduction, and then transferred to the nearshore within the same time step.
- "Steady-state" groundwater flow conditions occur, which implies that ambient conditions do not change with respect to time.
- No biological production or reduction of nutrients occurs in the saturated portion of the aquifer system.
- All groundwater discharges arrive in proximity of the shoreline and can be idealized as being transferred to the nearshore element closest to the shoreline.

- In the absence of literature documenting treatment for specific pollutants, a "no treatment" condition will be assumed to exist in which no pollutant reduction occurs as the stormwater and wastewater effluents moves through the aquifer system to the nearshore elements.

- TN is assumed to remain conservative in the groundwater system; thus no treatment reduction will be employed.

- Based on the literature review, phosphate can either form a precipitate or sorb onto the limestone very easily. Thus, based on a removal rate calculated by Corbett et. al (2000) of 95 percent within the 15 feet of the source, a conservative removal percentage estimate of 50 percent is utilized to predict the total phosphate reduction within the groundwater system.

- BOD loads will not be reduced as they are transported to the nearshore water due to the rapid groundwater transport reported in field studies.

- Copper, cadmium, lead, zinc pollutant mass loads will not be reduced as they are transported to the nearshore due to the lack of any soil development in the Florida Keys, the corresponding lack of significant organic carbon sources, and the reported rapid transport of on-site disposal system leachate to surface waters. This is a conservative approach. However, all binding sites may be occupied along preferred pathways and, therefore, additional input would result in replacement of sorbed phosphate. More research is needed to explore this possibility. Should this be found to be true, this input parameter may be updated.

- Due to the depth of the existing deep well in Key West (approximately 3,000 feet) and the porosity of the limestone aquifers underlying the Study Area, it has been assumed that any wastewater effluent discharged to a deep well is functionally lost to the system.

- Sea level rise will have no impact during the 20-year planning period of the scenario simulations (see page 146).

<u>Uncertainties</u>

- Nitrogen, BOD, and TSS pollutant loads reductions are not documented at this time. These potential reductions were set at zero in the Integrated Water Module.

- Canals were not explicitly modeled in the CCIAM due to lack of suitable information on canal configurations, depths, widths, exchange rates, connectivity, and other critical data. Pollutants generated in wastesheds with internal canals have been idealized as a single point of discharge with the pollutant loads being expressed at the canal's connection to the receiving water body (Section 10). Additional effort is being made to address canals based on existing data.

- Due to lack of data regarding the groundwater flows in the deeper portion of the limestone formations underlying the Keys at depths of 2,000+ feet, it is possible that wastewater effluent discharged to deep wells may not be uniformly dispersed, but might flow through cracks, fissures or ancient solution channels and appear as minor “freshwater springs/marine discharges” in the nearshore waters.