Lecture 4: Editing the RSM

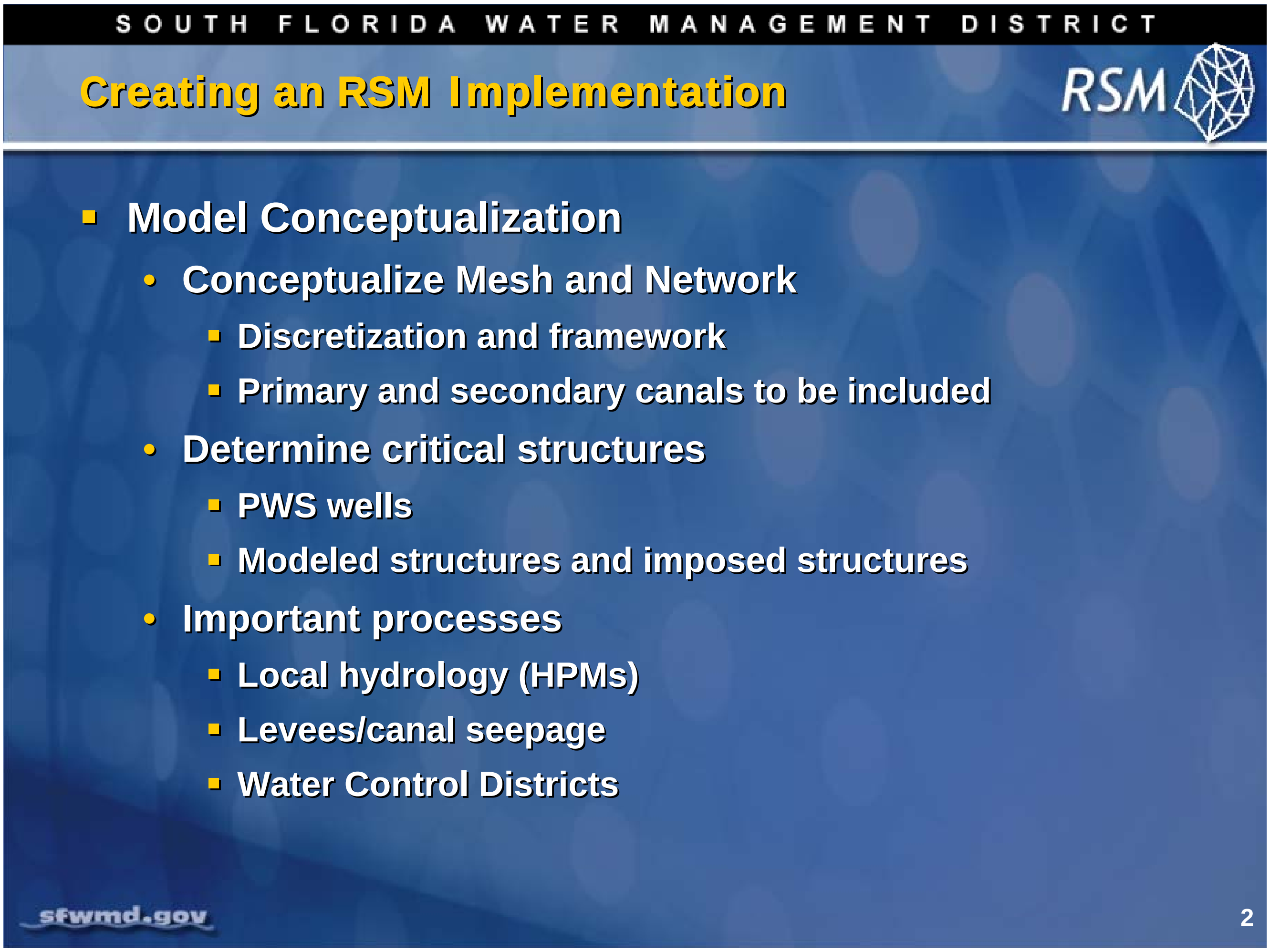
This lecture reviews the components of a complete RSM. Several features will be discussed in detail in subsequent lectures.

NOTE:

Additional Resources

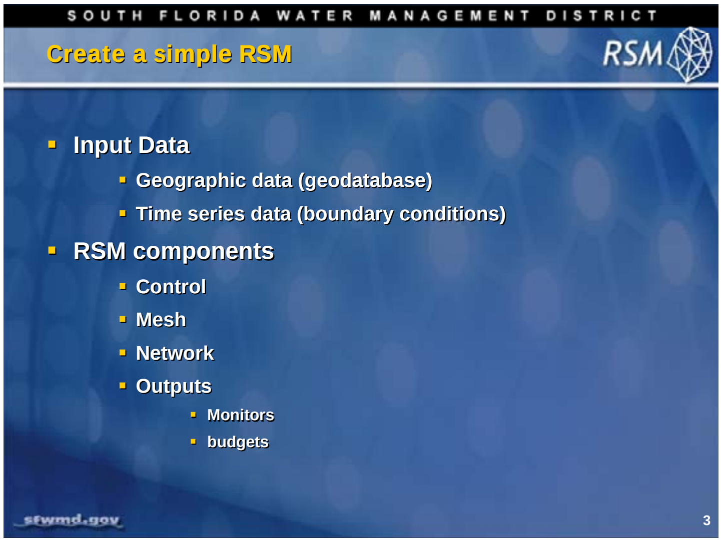
The HSE User Manual can be found in the `labs/lab4_complete_RSM` **directory.**

The AFSIRS documentation can be found in the `labs/lab11_hpm` **directory: Smajstrla, A.G. (1990).** ***Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) Model.*** **Technical Manual Version 5.5. Agricultural Engineering Dept., University of Florida.**



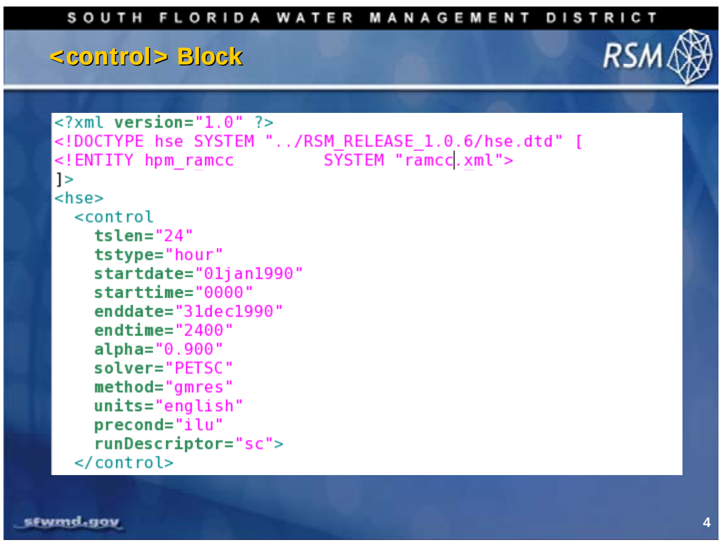
The construction of a complete RSM model will lead to the development of the complete XML run file, or set of XML files.

1. Construct the appropriate mesh and network. In the previous lecture we discussed the development of the appropriate mesh and network based on the characteristics of your model domain and model objectives. These decisions include the choice of whether to include all canals or only the primary canals.
2. Select the structures that you want included in the model. These include all water flow structures. They can be simulated as watermovers or imposed as boundary conditions. Wells are imposed as stresses on the aquifer using an input flow time series. Structure flow may be simulated or imposed. An important process in hydrologic simulation model implementation in south Florida is the process of calibrating the canal/aquifer and stream bank interaction terms because of the high degree of interaction of the canal with the aquifer. As such, the historical structure flows have been imposed on the canal junctions (flows at the downstream segment and heads on the upstream segment). These models have used the Parameter Estimation program (PEST) to calibrate the model. Calibration will be covered in lectures 13 and 14.
3. Select the other important features that affect the regional hydrology. These may include local hydrology, levees and Water Control Districts. There is a standard set of HPMs that is currently being used with small variations in the individual subregional models (refer to the model files located in $RSM/data/[model], where [model] is one of: C111, Biscayne Bay Coastal Wetlands (BBCW), Glades_LECSA. The levees are modeled using the <leveeSeepage> watermover function. Water Control Districts are special features that are implemented through a set of specific elements.



Input data for parameter values, and time series data for boundary conditions, are required to create a complete RSM implementation.

Although an RSM can be created with only a mesh or only a network for checking model connectivity, the minimum model structural information should include the 2D mesh and the canal network. The control block provides the model control functions and the output block defines the output from the model.

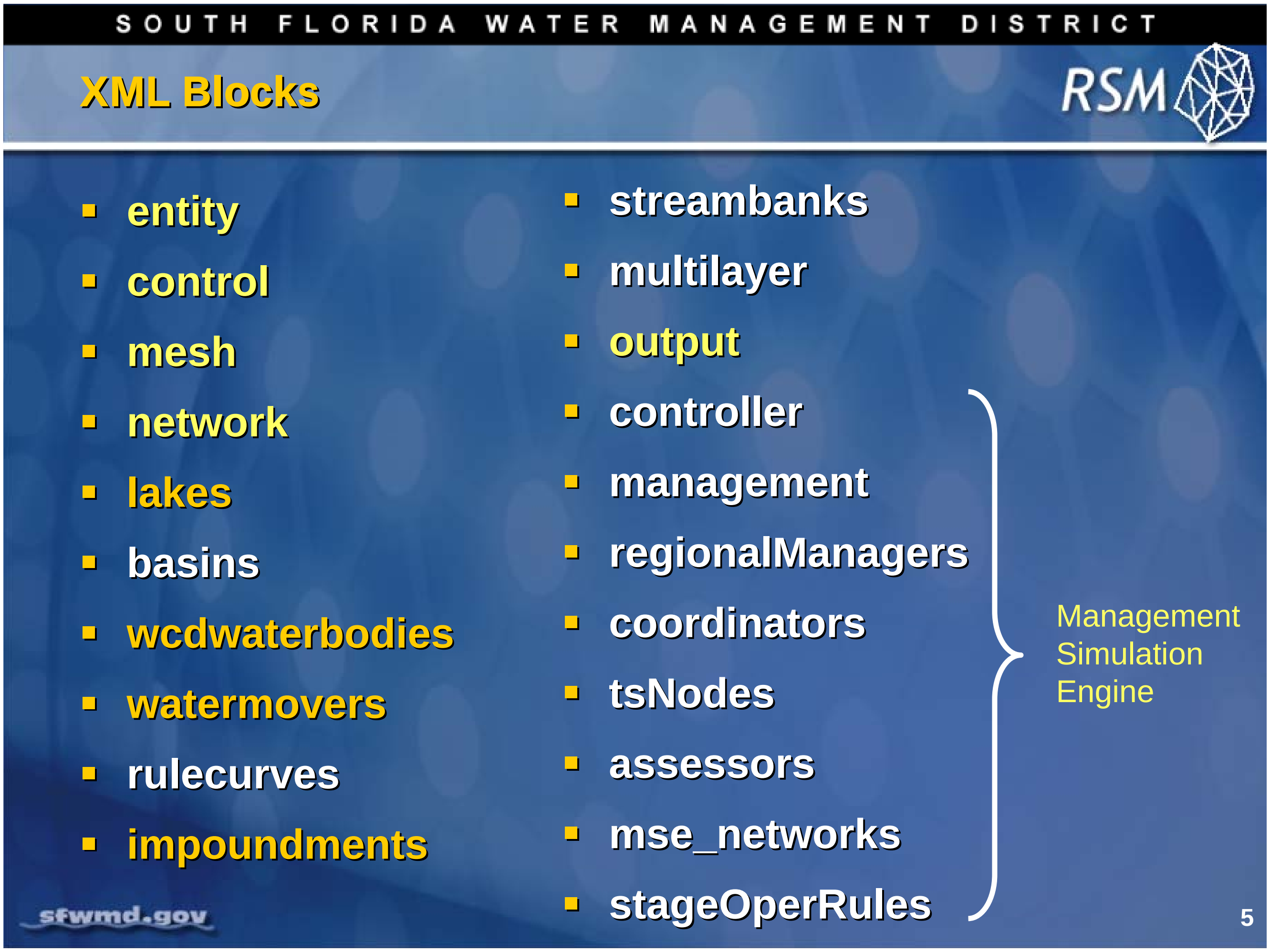


The Header determines which version of the XML software we are using and the location of the hse.dtd that is used to parse the input files.

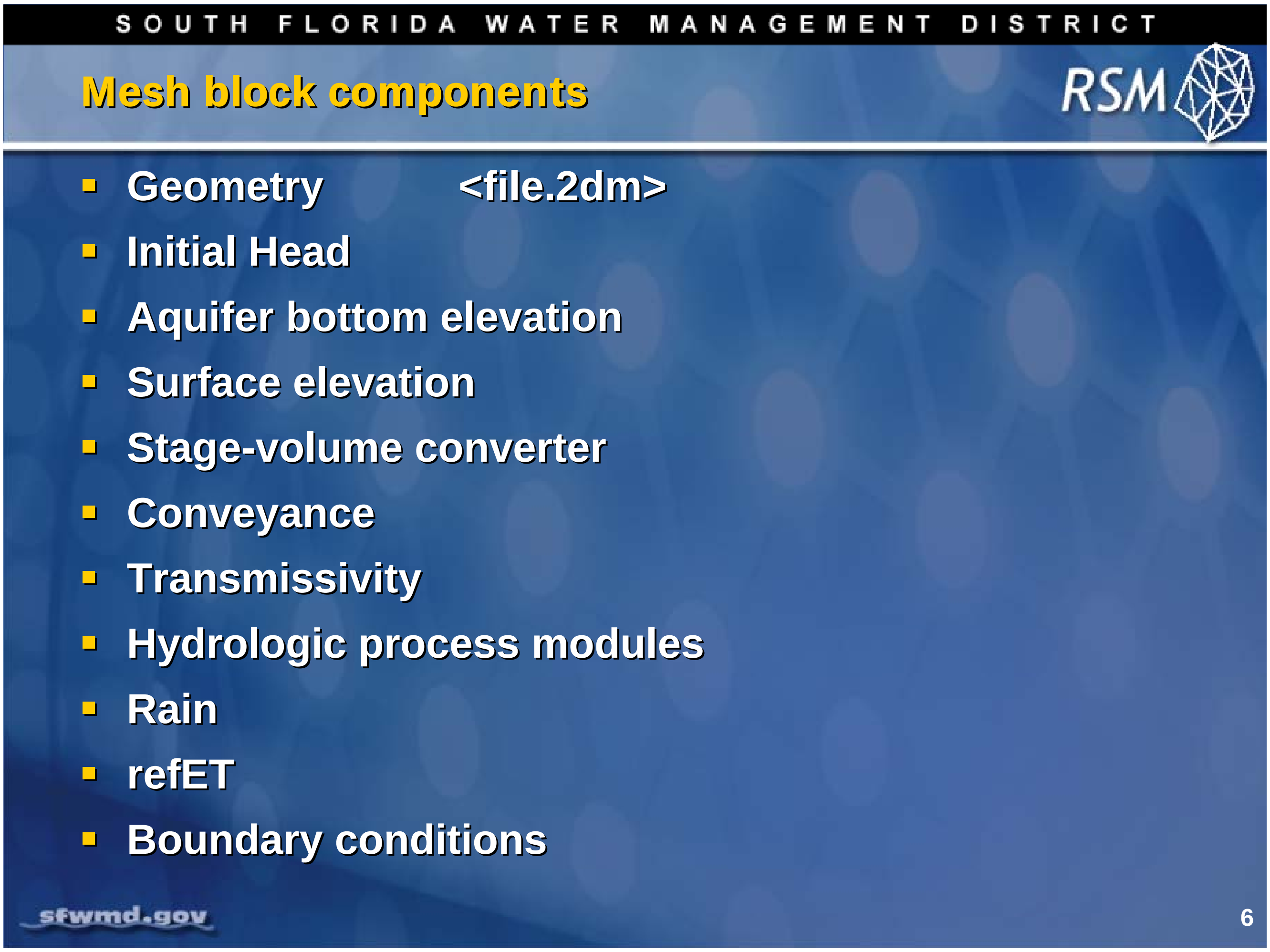
The Entity element provides the option for including other XML files. This is useful when the model input becomes very long and can be broken into pieces for ease of viewing and editing.

The Control Section specifies the start and end times for the simulation, the timestep, units and the control parameters for PETSc solver.

The details of the control block are found in Chapter 2 and Section 3.1 of the HSE User Manual.



A complete RSM model can have several blocks of XML input code. The yellow highlighted blocks are the essential components of an RSM-HSE implementation. Other commonly used waterbodies are highlighted in orange. If the Management Simulation Engine (MSE) is implemented, than several additional blocks of code will be necessary. Some blocks such as <streambanks> are no longer used.



The mesh block requires the following components:

- The geometry of the mesh is provided in the *.2dm file, which is an ASCII file that follows the Groundwater Modeling System (GMS) file format.
- The aquifer bottom elevation and the surface elevation complete the description of the waterbodies.
- A stage-volume converter provides the specific yield or drainable porosity of the soil and underlying aquifer.
- The conveyance and the transmissivity elements provide the parameters for surface resistance terms (Manning) and groundwater resistance terms (Darcy).
- The Hydrologic Process Modules (HPM) process the rain and refET, and produce runoff and recharge.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Minimum elements of <mesh> Block

RSM

```
<mesh>
  <geometry file="eaamc.2dm"> </geometry>                        // mesh nodes and connections
  <shead>  <gms file="shead_eaamc.dat"></gms></shead>             // initial head
  <bottom> <const value="-24.0">   </const> </bottom>             // aquifer bottom
  <surface> <const value="12.0"> </const> </surface>              // land surface

  <conveyance>
     <mannings a="0.0500" detent="0.001"></mannings>               // surface resistance term
  </conveyance>

  <transmissivity>
      <unconfined k = "0.002"> </unconfined>                       // subsurface resistance term
  </transmissivity>

  <svconverter>
      <constsv sc="0.2"> </constsv>                                // Storage-Volume converter
   </svconverter>
</mesh>
```

sfwmd.gov

7

This is an example of the syntax used to describe the necessary elements of the mesh block. In each element the simplest input is provided as a constant value.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

<mesh> block details

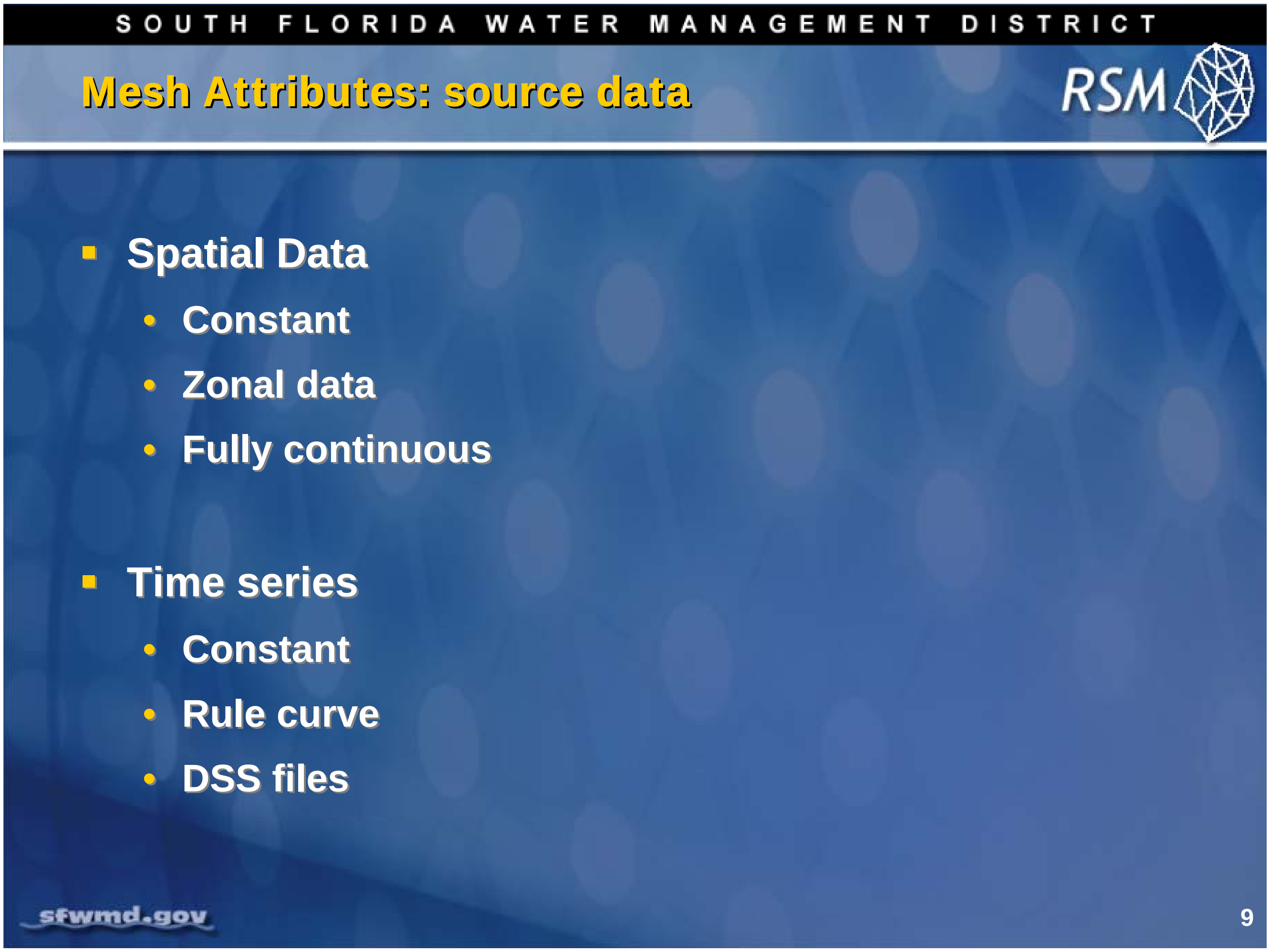
RSM

```
<!-- Rainfall & ET in GRIDIO -->
     <rain>
       <gridio file="$RSM/data/rain+et/rain_v2.0_global.bin"
          xorig="237027" yorig="286611" mult=".0833" dbintl="1440">
       </gridio>
     </rain>
     <refet>
       <gridio file="$RSM/data/rain+et/ETp_recomputed_tin.bin"
          xorig="237027" yorig="286611" mult=".0833" dbintl="1440">
       </gridio>
 </refet>

<!-- Top of layer 1 or land surface -->
 <surface> <gms file="eaamcL_topo.xml" mult="1.0"> </gms> </surface>

<!-- Bottom of layer 1 -->
 <bottom>  <gms file="eaamcL_botelev.xml" mult="1.0"> </gms>  </bottom>
```

sfwmd.gov 8

Typically, the standard daily rainfall and reference vegetation evapotranspiration are provided to the model in the GRIDIO binary file format.

The spatial distribution of topography and aquifer bottom elevations is provided as ASCII cell index-ordered GMS input files.



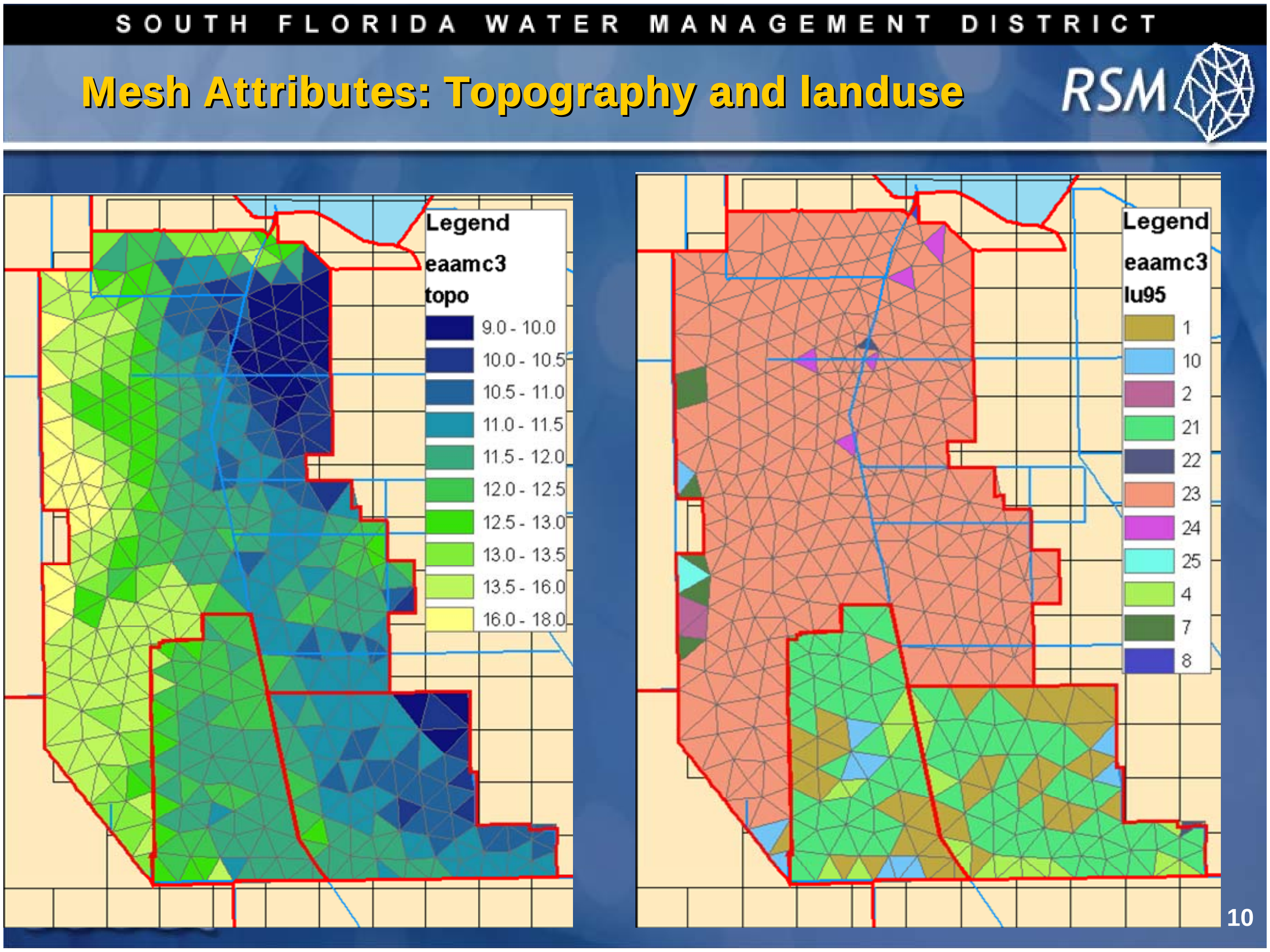
The source data for the mesh attributes may be provided to the model as:

- constant values for simple RSM models (e.g. testbeds)
- fully continuous data with a unique value for each cell
- zonal data with fixed values for a group of cells

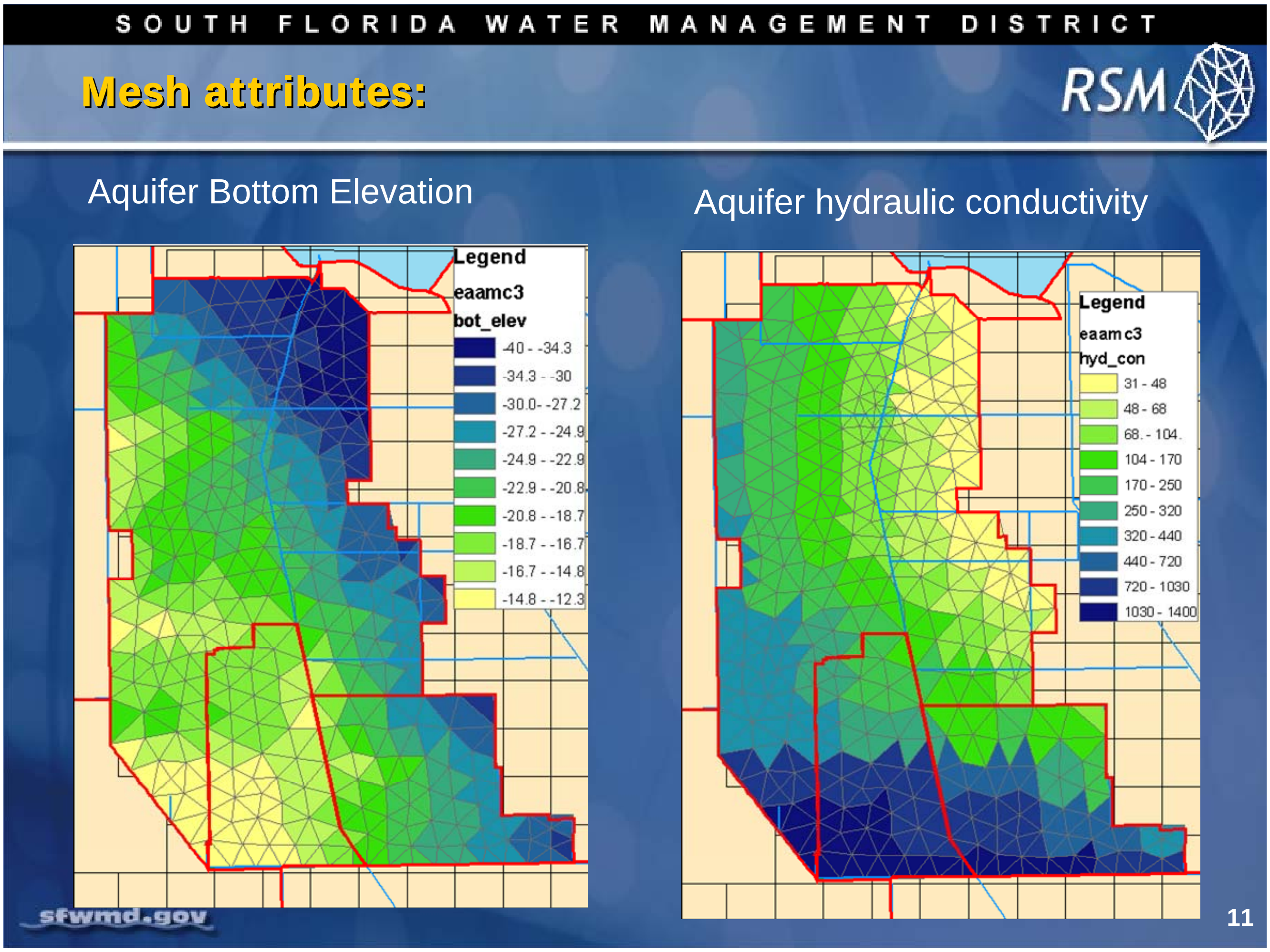
We use the functionality of GIS to create the spatial input files. Times series data can be provided as:

- constant values
- rulecurves
- times series data in the US Army Corps of Engineers Data Storage System (DSS) format

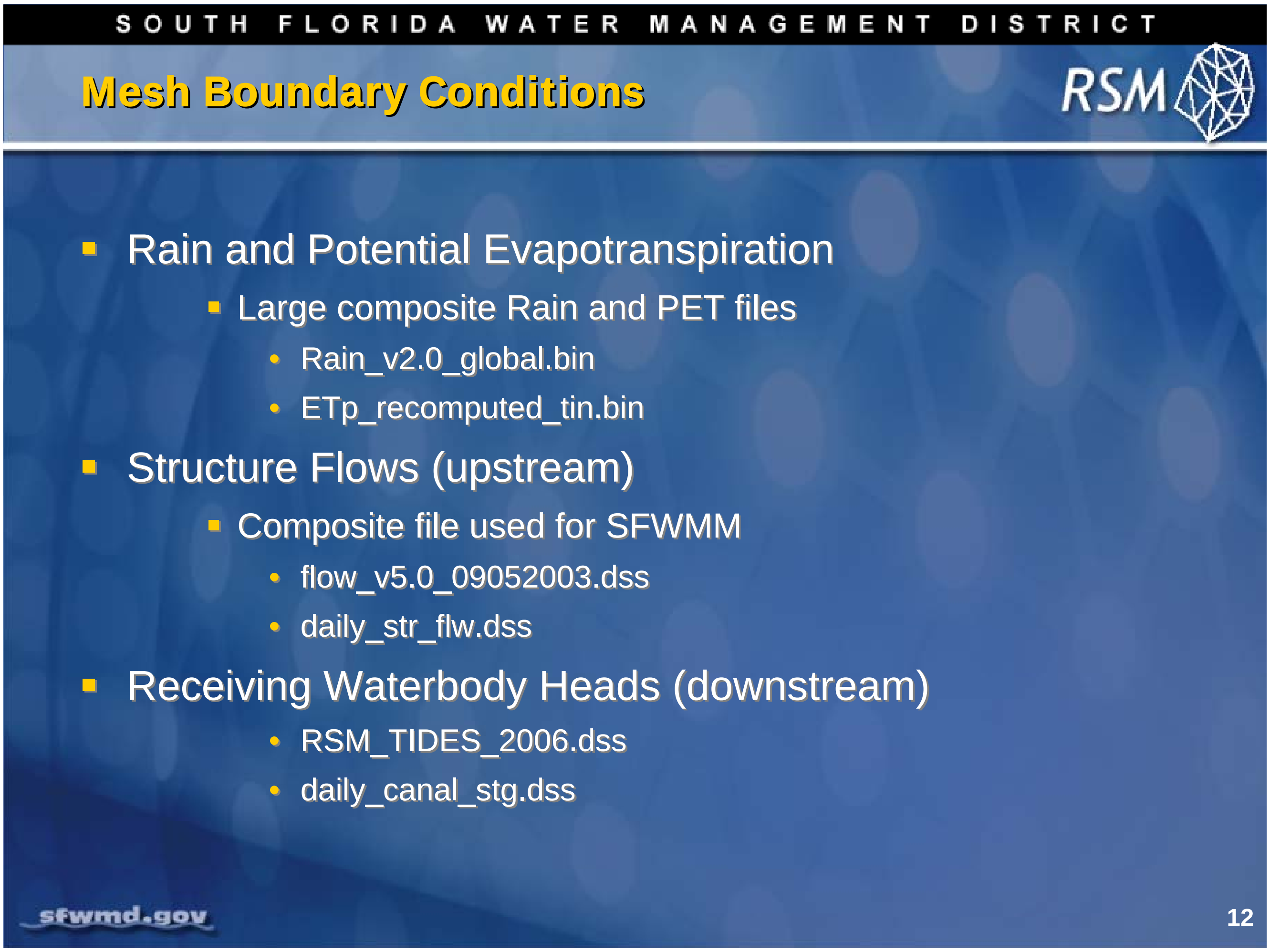
The rulecurves are useful for inputting management schedules as boundary conditions.



This is the typical distributed data for topography and landuse type (SFWMM landuse classes) used by the RSM. The data are sampled from a more detailed geographic database and single values are assigned to each cell.



Aquifer bottom elevation and aquifer conductivity are necessary attributes. These attributes can be input as individual values for each cell or a single value for several cells. These values are based on interpolated values from well core data. These data will be used in the lab exercises.



For the mesh boundary conditions there are commonly used data time series which have been created and verified for modeling. These will be discussed in Lecture 9.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Mesh Boundary conditions

RSM

- Complete <mesh_bc> XML

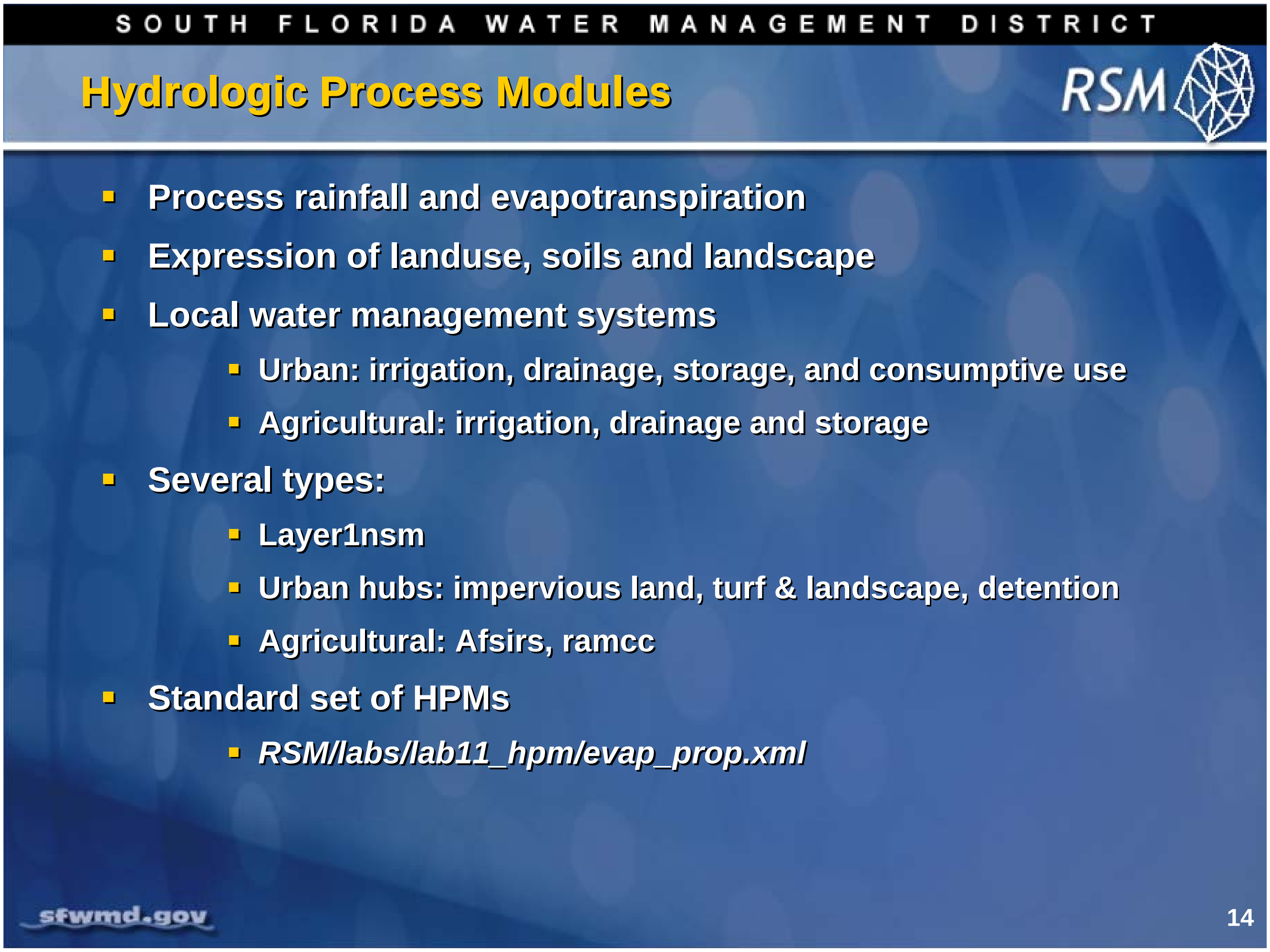
```
<mesh_bc>
<!--  Use  Tidal stage record from   -->
  <wallghb  value=0.001" label = "Flamingo tide record" >
    <nodelist>
      850 793 738 677 614 555 496 495 424 363 307 255
      214 213 212 178 152 125 124 99 76 57 38 37 36
      56 75 55 54 35 21 20
    </nodelist>
    <uniform>
       <dss
         file="../input/RSM_TIDES_2006.dss"
         pn="/NSRSM/FLAMINGO/TIDE/01JAN1983/1DAY/SIMULATED/"
         units="ft">
       </dss>
     </uniform>
   </wallghb>

<!-- western and northern mesh BC from 2x2 stages -->
  <cellghb id="6" value="1.0" label="WMM54-221">
    <dss
         file="../input/WMM_V54_stage_for_BCs.dss"
       pn="/WMM_V54/221/STAGE//1DAY/SIMULATED/">
    </dss>
  </cellghb>
</mesh_bc>
```

sfwmd.gov

13

A complete boundary condition may be specified as a general head boundary condition on a wall by a list of nodes <nodelist> that defines the wall. It may also be specified as a general head boundary condition for a cell and the time series of head values applied to the wall or cell.

In the first case, the time series of tidal stages are applied to the coast. In the second case, the simulated stage values from the SFWMM are applied to a selected boundary cell.



Hydrologic Process Modules (HPMs) are used to model the local hydrology. In the simplest HPMs, rainfall and refET are processed to calculate recharge and runoff. More complex HPMs simulate urban and agricultural water management systems. There are several types of HPMs available for implementation. A standard set of HPMs are used that reflect the land use/land cover types common to south Florida.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Standard land use types simulated in RSM

HPM	SFWMM	Land use	HPM	SFWMM	Land use
1	CAT	Cattails	14	MLP	Open Land
2	CIT	Citrus	15	ROW	Row crops
3	FUP	Forested Upland	16	RS1	Ridge & Slough 1
4	FWT	Freshwater wetlands	17	RS2	Ridge & Slough 2
5	GLF	Golf courses	18	RS3	Ridge & Slough 3
6	HDU	High Density Urban	19	RS4	Ridge & Slough 4
7	IRR	Irrigated Pasture	20	RS5	Ridge & Slough 5
8	LDU	Low density Urban	21	SAW	Sawgrass
9	MAN	Mangrove	22	SHR	Shrubland
10	MAR	Marsh	23	SUG	Sugar cane
11	MDU	Medium Density Urban	24	WAT	Open Water
12	MEL	Melaluca	25	WET	Wet Prairie
13	MIX	Mixed cattail/sawgrass			

sfwmd.gov 15

These standard landuse/landcover types are simulated in the RSM and used in the SFWMM.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Standard HPMs simulated in RSM

RSM

HPM	SFWMM	Land use	HPM	SFWMM	Land use
1	CAT	layer1nsm	14	MLP	Open Land
2	CIT	afsirs	15	ROW	afsirs
3	FUP	layer1nsm	16	RS1	layer1nsm
4	FWT	layer1nsm	17	RS2	layer1nsm
5	GLF	afsirs	18	RS3	layer1nsm
6	HDU	Urban hub	19	RS4	layer1nsm
7	IRR	afsirs	20	RS5	layer1nsm
8	LDU	Urban hub	21	SAW	layer1nsm
9	MAN	layer1nsm	22	SHR	layer1nsm
10	MAR	layer1nsm	23	SUG	afsirs
11	MDU	Urban hub	24	WAT	layer1nsm
12	MEL	layer1nsm	25	WET	layer1nsm
13	MIX	layer1nsm			

sfwmd.gov

16

These HPM types are used to simulate different landuse types. There are different parameter sets for each implementation of AFSIRS, layer1nsm and urban hub reflecting the different landscapes. Although the evap_prop.xml file contains detailed descriptions for each of these HPMs, only a small number are typically referenced in any subregional HPM implementation.

The HPMs will be described in detail in Lecture 11.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Hpm.xml

RSM

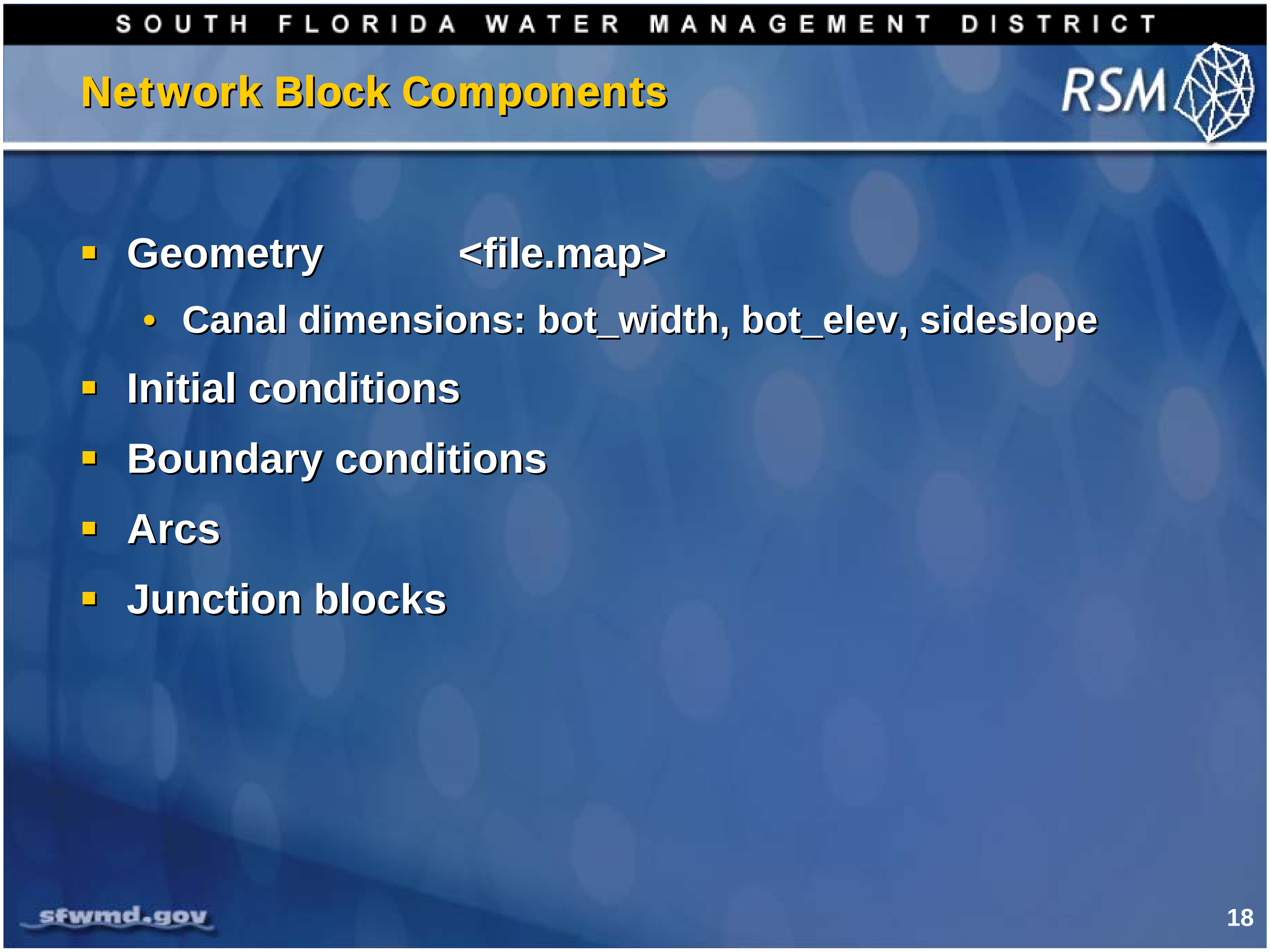
```
<hpModules>
  <indexed file="lu.index">
<!-- Sugar Cane -->
    <hpmEntry id="6" label="sugar - subirrigation">
      <afsirs>
        <afcrop label="sugar" id="15" j1="01-01" jn="12-31" depth1="18" depth2="36">
          <kctbl>
            0.61 0.57 0.51 0.59 0.88 0.98
            1.07 0.90 1.00 1.00 0.80 0.72
          </kctbl>
          <awdtbl>
            0.65 0.65 0.35 0.35 0.35 0.50
            0.65 0.65 0.65 0.65 0.65 0.65
          </awdtbl>
        </afcrop>
        <afirr label="SEEPAGE, SUBIRRIGATION" wtd="8.0">
          <irrmeth id="7" eff="0.5" arzi="1.0" exir="1.0"></irrmeth>
          <irrmgmt trigcode="0"></irrmgmt>
        </afirr>
        <afsoil label="MUCK SOIL" depth="96" minwc=".20" maxwc=".50" cond="1"> </afsoil>
      </afsirs>
   </hpmEntry>
 <!-- Marsh -->
   <hpmEntry id="10" label="marsh">
      <layer1nsm kw="1.0" rd="0.0" xd="1.2" pd="4.0" kveg="0.0" imax="0.0">
    </layer1nsm>
   </hpmEntry>
  </indexed>
</hpModules>
```

sfwmd.gov 17

The simplest HPM assignments are based on the <afsirs> and <layer1nsm> types. The <afsirs> is an implementation of the Agricultural Field Scale Irrigation Requirements System FORTRAN program (Smajstrla, 1990). It was created by the University of Florida to estimate optimal irrigation for many common Florida crops, soil types and irrigation management types. The parameters for the AFSIRS model are provided in the AFSIRS documentation (in the labs/lab11_hpm directory). The AFSIRS model tracks soil moisture based on rain and crop evapotranspiration (ET) and calculates drainage and irrigation requirements which are passed to the mesh cells. The AFSIRS HPM assumes that the water table is maintained below the root zone by the RSM.

The layer1nsm HPM was adapted from the SFWMM to represent shallow wetlands where the water table is always in the root zone or only slightly ponded. This HPM calculates ET based on the location of the water table relative to the rooting depth (rd), extinction depth (xd), below which ET ceases; and the ponding depth (pd) above which the HPM assumes the ET rate of shallow lake.

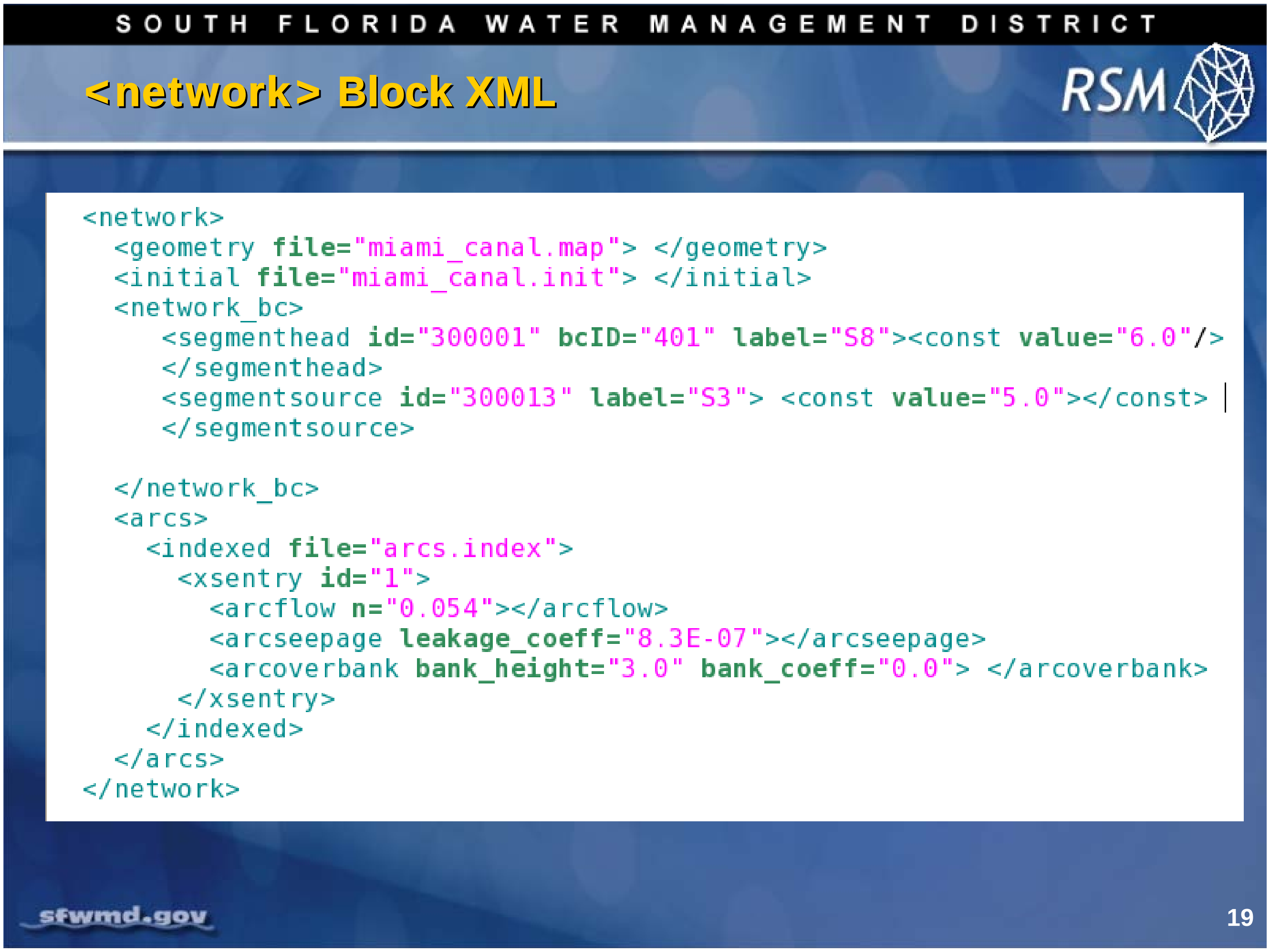
As each cell has an HPM assigned to it, the HPMs are assigned to each cell based on the “lu.index” file. The lu.index file provides a list of hpmEntry id values, one row for each cell. In this instance, the lu.index file would be a list of 23s and 10s for sugar cane and marsh cells respectively.



The Network Block consists of the following information:

- A geometry file that includes the canal dimensions and connectivity
- Location, length, type of cross-section, width, depth and side slope
- A file that defines the initial heads for each segment
- Boundary conditions for each segment
- Junctions, which are blocks between segments where structures are located.

When the RSM initiated, watermovers are constructed between each segment. A junction is necessary to break the default watermover between the segments so that a user-defined watermover can be implemented.



This is a typical XML input block for the network component of a simple RSM model. The network block contains four elements, as described in the previous slide. The elements are as follows:

- <geometry> describes the geometry of the network
- <initial> represents initial heads in the segments
- <arcs> provides the parameters for each segment in the network. These include: the Manning roughness coefficient, leakage coefficient which characterizes exchange with the aquifer, bank height and bank coefficient which characterizes overbank flow.
- <network_bc> contains the specification of the boundary conditions (BCs) for all of the reach end-segments. Typical network BCs include a flow BCs for the upper end of a canal reach and a head BC for the downstream end of a canal reach in order to form a well posed model. Other internal BCs may be applied as appropriate.

The <arcs> attributes are applied to single segments, reaches (groups of segments between structures), or entire canals. The attributes are applied to the segments using an indexed file, “arcs.index” that provides one set of arc attributes to each segment by placing the xentry id in the appropriate row for each segment. For example, if there are 192 segments in the network, there will be a list of 192 rows each containing one value. A separate <xsentry> is required for each different set of attributes.

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

Network Boundary Conditions

RSM

- **Simple**

```
<network_bc>
   <segmenthead id="300001" bcID="401" label="S8"><const value="6.0"/>
   </segmenthead>
   <segmentsource id="300013" label="S3"> <const value="5.0"></const>
   </segmentsource>
</network_bc>
```

- **Complete**

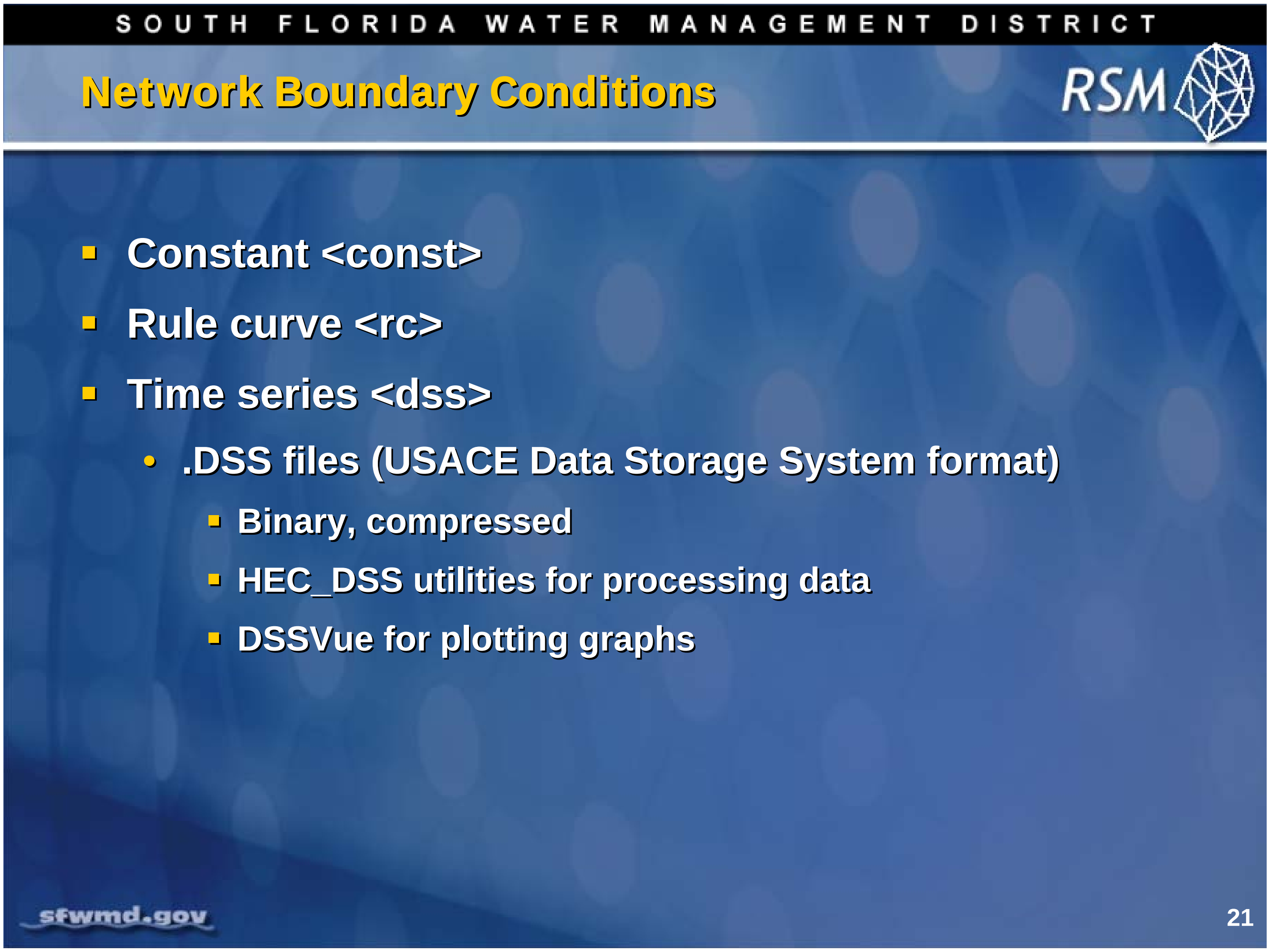
```
<network_bc>
    <segmentghb id="300007" bcID="1" kcoef="1.0e5" label="S8(GHB)">
         <dss file="./input/eaa_obs_canal_stage.dss"
              pn="/SFRSM/S8H/STAGE//1DAY/OBS/"
              units="FT" type="PER-AVER" mult="1.0">
         </dss>
      </segmentghb>
   <segmentsource id="300001" bcID="2" label="S3">
        <dss file="./input/flow_v5.0_09292003.dss"
             pn="/SFWMM/S3/FLOW//1DAY/HISTORICAL/"
             units="cfs" type="PER-AVER" mult="1.0">
        </dss>
   </segmentsource>
</network_bc>
```

sfwmd.gov 20

The BCs for the canal reaches are specified in the <network_bc> element. Typical BCs are <segmentsource> for the upstream end of a reach and <segmenthead> for the downstream end of a reach. In the simple case, a constant small flow may be applied to the upper end of the reach to avoid drying out the canal reach and causing model instability. A constant downstream head, such as a mean lake stage may be applied to the downstream segment as a fixed head in the canal.

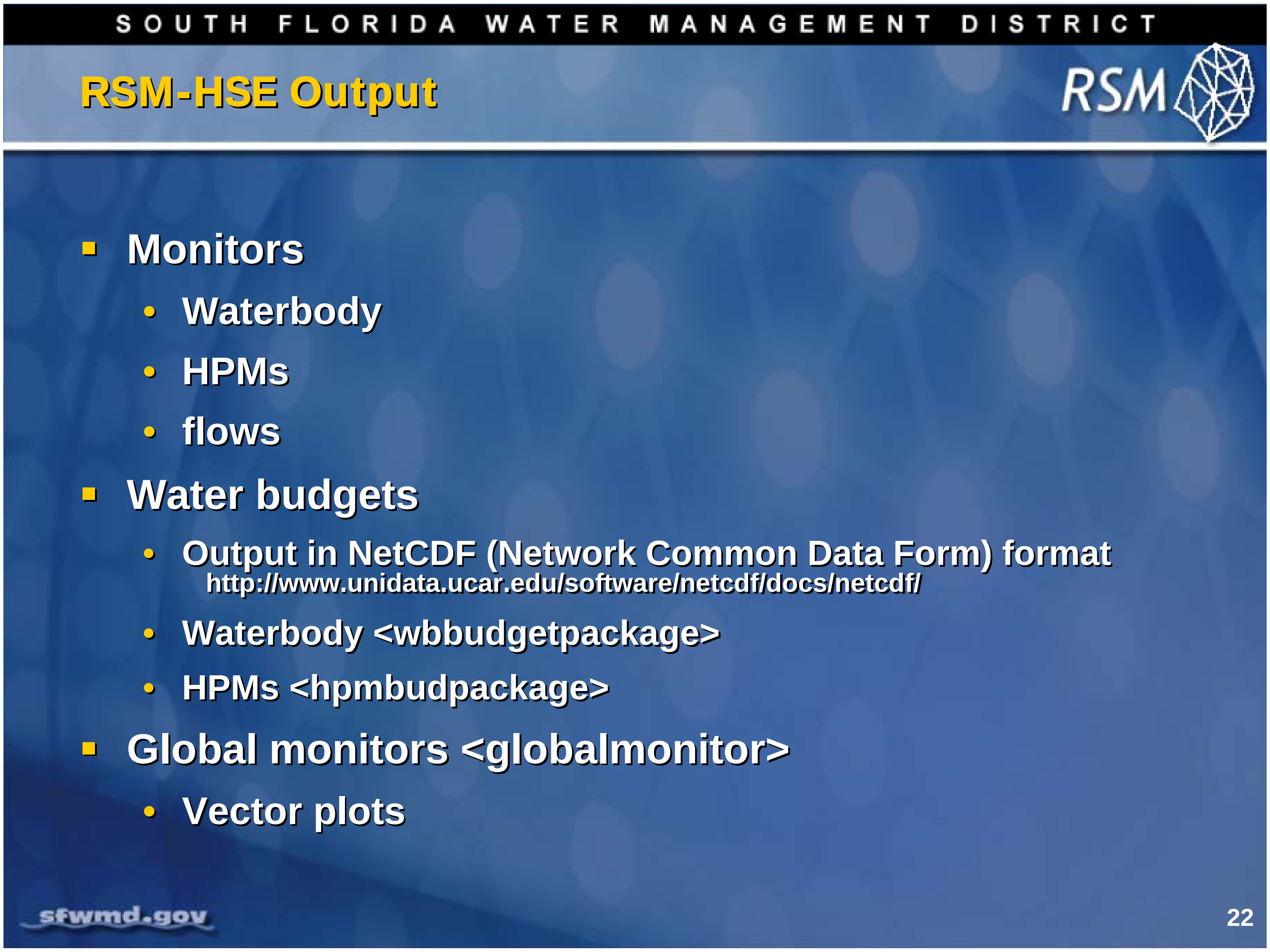
In a more complete case, the upstream source boundary condition may be the historical flow that occurred at the upstream structure. The “flow_v5.0_09292003.dss’ file is an archived set of time series of flows for structures from the SFWMM and represents the South Florida Water Management District’ s best set of flow data for hydrologic modeling. The downstream head boundary condition for each canal may be set as a general head boundary condition with the external head described by a time series of daily head values. In this case the mean daily tide values are used.

The labels indicate the source data and the IDs indicate the segments. Note that the segments in the complete case are numbered 300000+. These numbers are assigned so that the segment IDs do not overlap with the numbering for other waterbodies (cells, lakes, impoundments, wcdwaterbodies and basins).



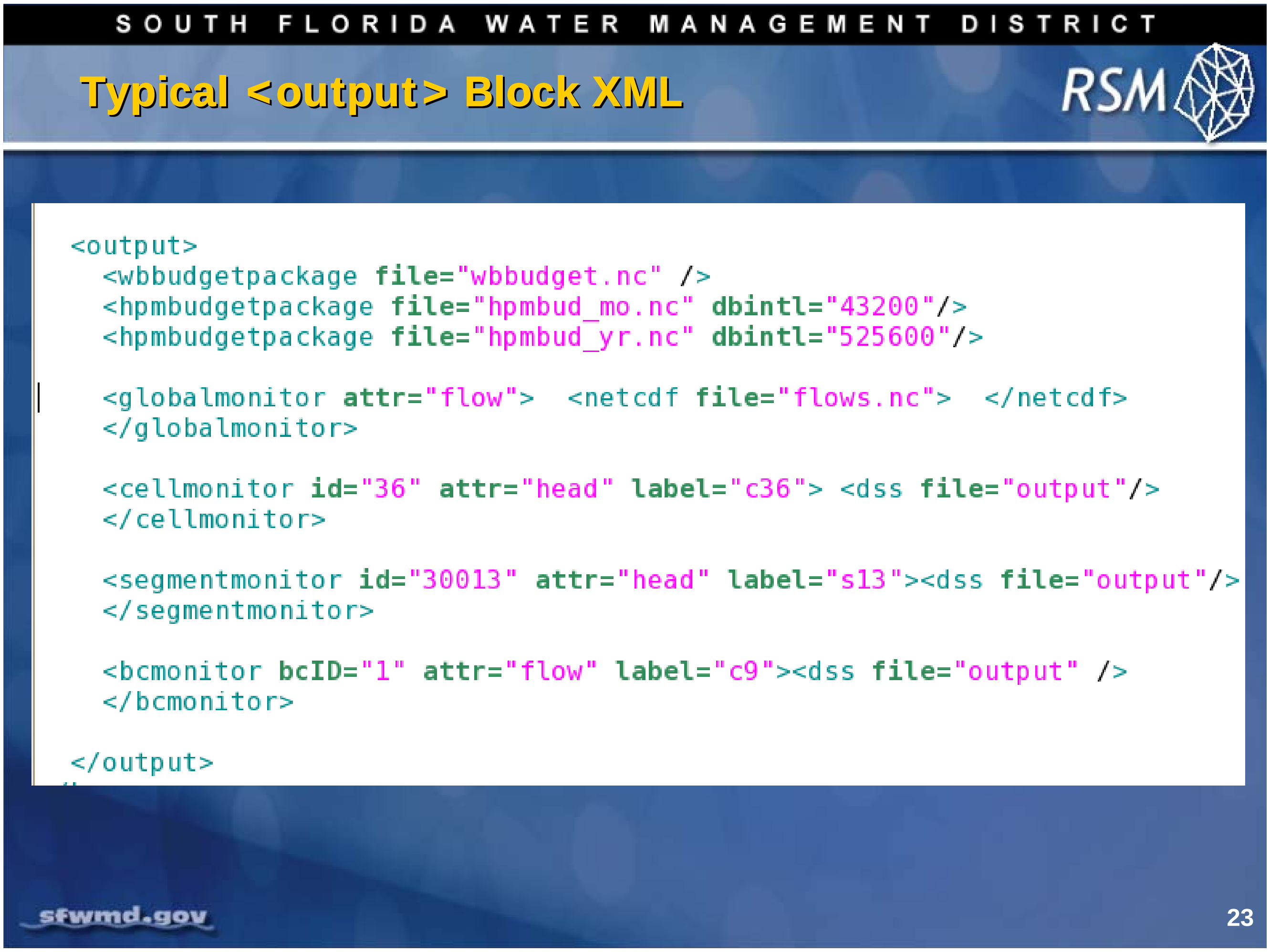
The specification of the values for the boundary conditions can be one of the following data types:

- Constant: Data that does not change.
- Rulecurve: A table of paired values (date, value). The model linearly interpolates between adjacent values.
- Time Series: Can be applied in a .DSS (Data Storage System) file format. The DSS format is a binary format that was developed by the United States Army Corps of Engineers (USACE) for the storage of large volumes of time series data. We use DSSVue for rapid plotting of formatted graphs.



There are three output types for the RSM: Monitors, water budgets and global monitors.

- Monitors provide a time series of values of any attribute for any waterbody or watermovers for each timestep or multiples of timesteps (measured in minutes). These data are used for evaluating hydrographs or hydroperiods. The data are typically stored in .DSS format, comma delimited, or fixed column format.
- For water budget calculations the time series data for all of the inflows and outflows for waterbodies and HPMs are written to output files as Network Common Data Form (NetCDF). The netCDF approach was developed to provide a means for sharing array-oriented data that is self-describing and portable. It is freeware promulgated by Unidata, an organization sponsored by the National Science Foundation, with associated libraries for writing interfaces. Simple water budgets can be created using “hpmbud” and “wbbud” utilities. The wbbud utility can be accessed through the RSM Graphical User Interface (RSM GUI) post-processing tool.
- Global Monitors provide a method for displaying spatial data such as heads, flows and topography; and include vector plots for flows. Time varying data can be developed into animated “movies” using the RSM GUI. The RSM GUI is presented in Module 8.

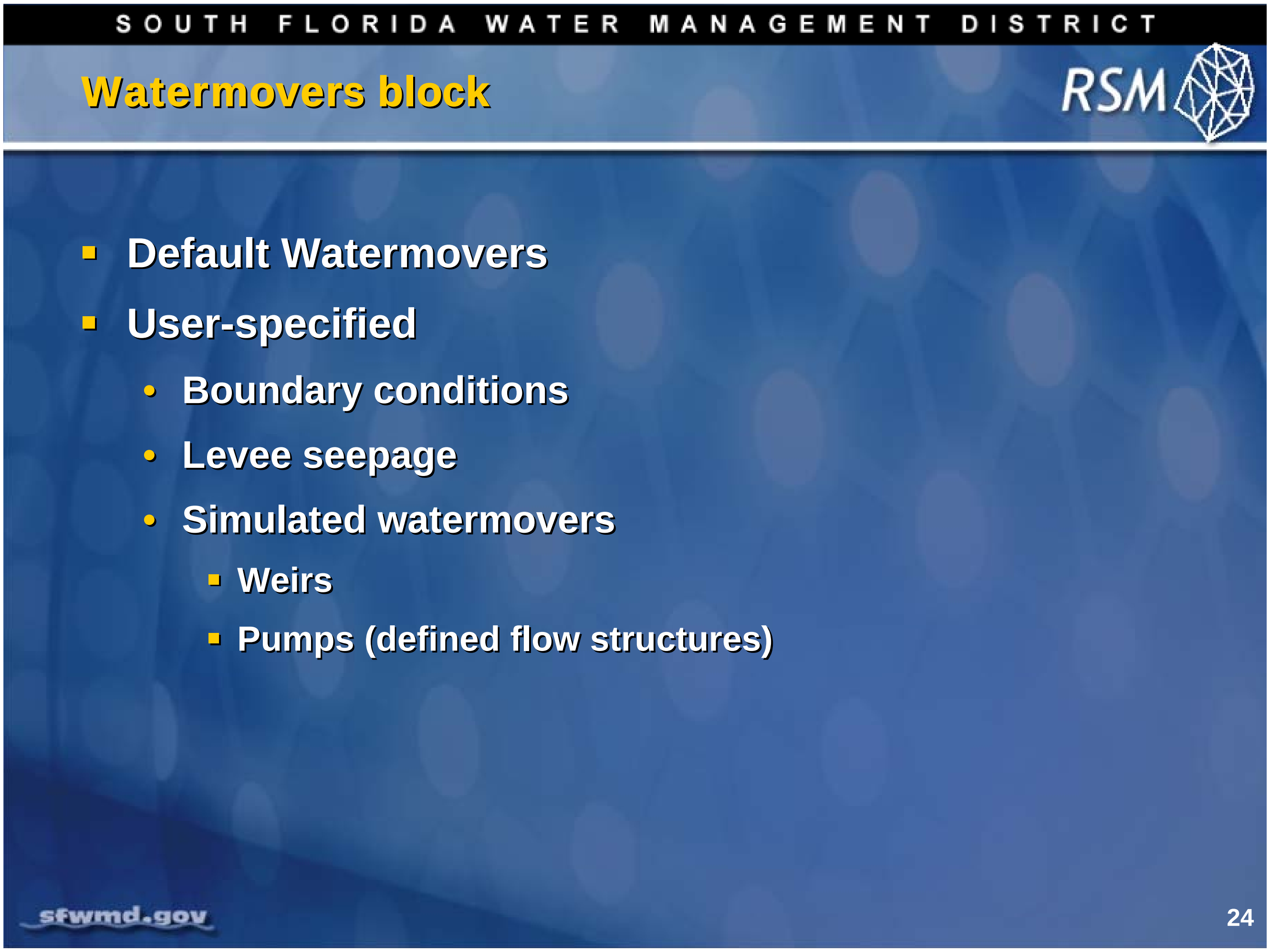


The typical <output> block will include several elements, primarily:

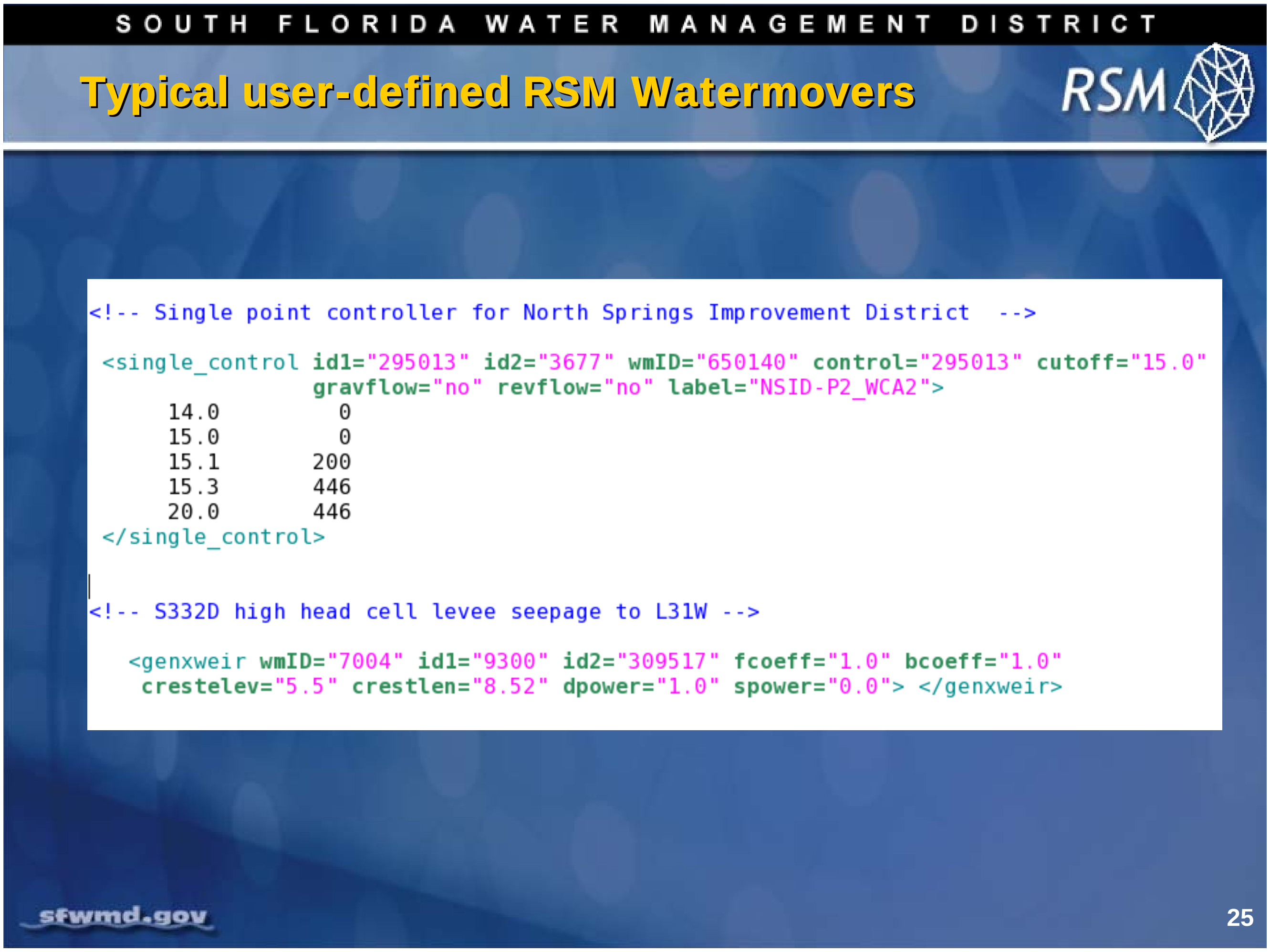
- the budgetpackages for waterbodies and HPMs
- global monitors and many monitors for the waterbodies and watermovers

The output to the budgetpackages includes the database interval “dbintl” in minutes, which specifies the timestep for writing the output data. Typical intervals are daily (1440), monthly (43200) and annual (525600).

There are monitors available for each waterbody and watermover type to report any of the variables used in the model, e.g.: head, flow.



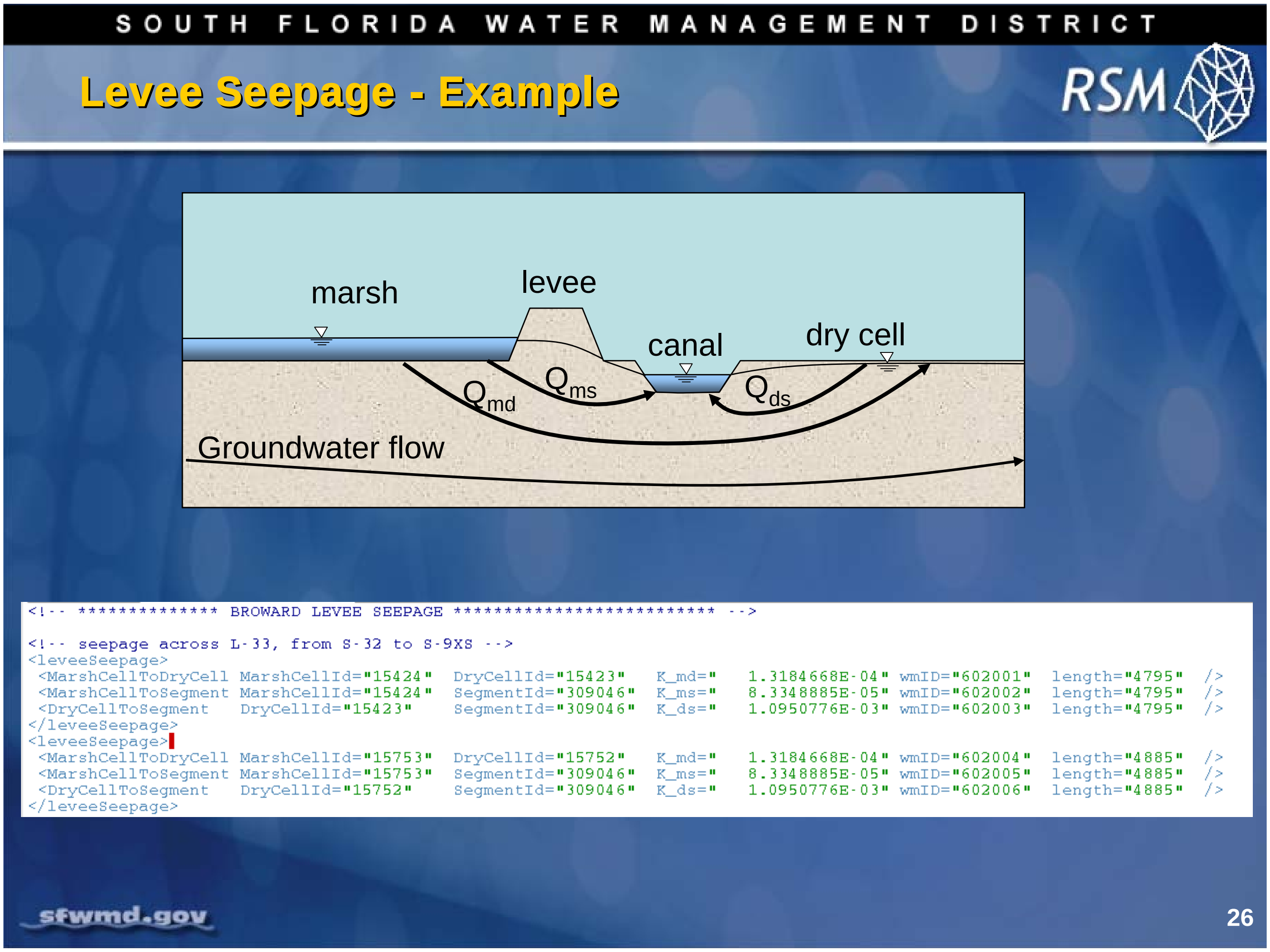
Watermovers are necessary to represent structures in the RSM. There are default watermovers that connect all of the mesh cells and network segments. Other user-specified watermovers are necessary to represent simulated and imposed flow at structures. The watermovers also are used to represent levee seepage.



Two common user-defined watermovers include the <single_control> watermover and the <genxweir>.

The first case is a pump that is defined by the upstream stage in waterbody 295013 and the discharge rate. For this simple case it is assumed that the downstream stage is not important. The <single_control> watermover does not allow gravity flow through the structure or reverse flow.

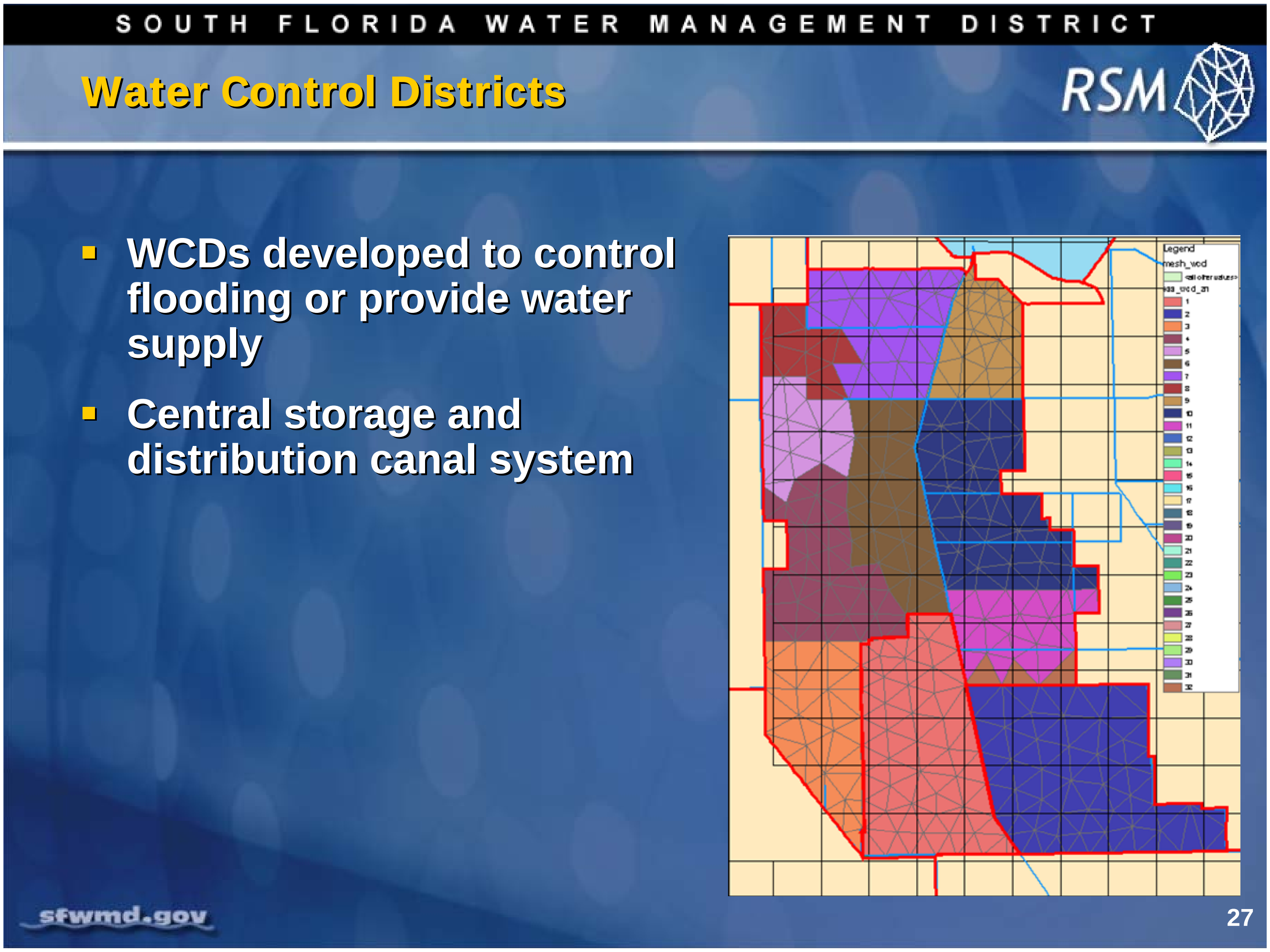
The second common structure is the <genxweir>. This watermover is described in more detail in Lecture 10.



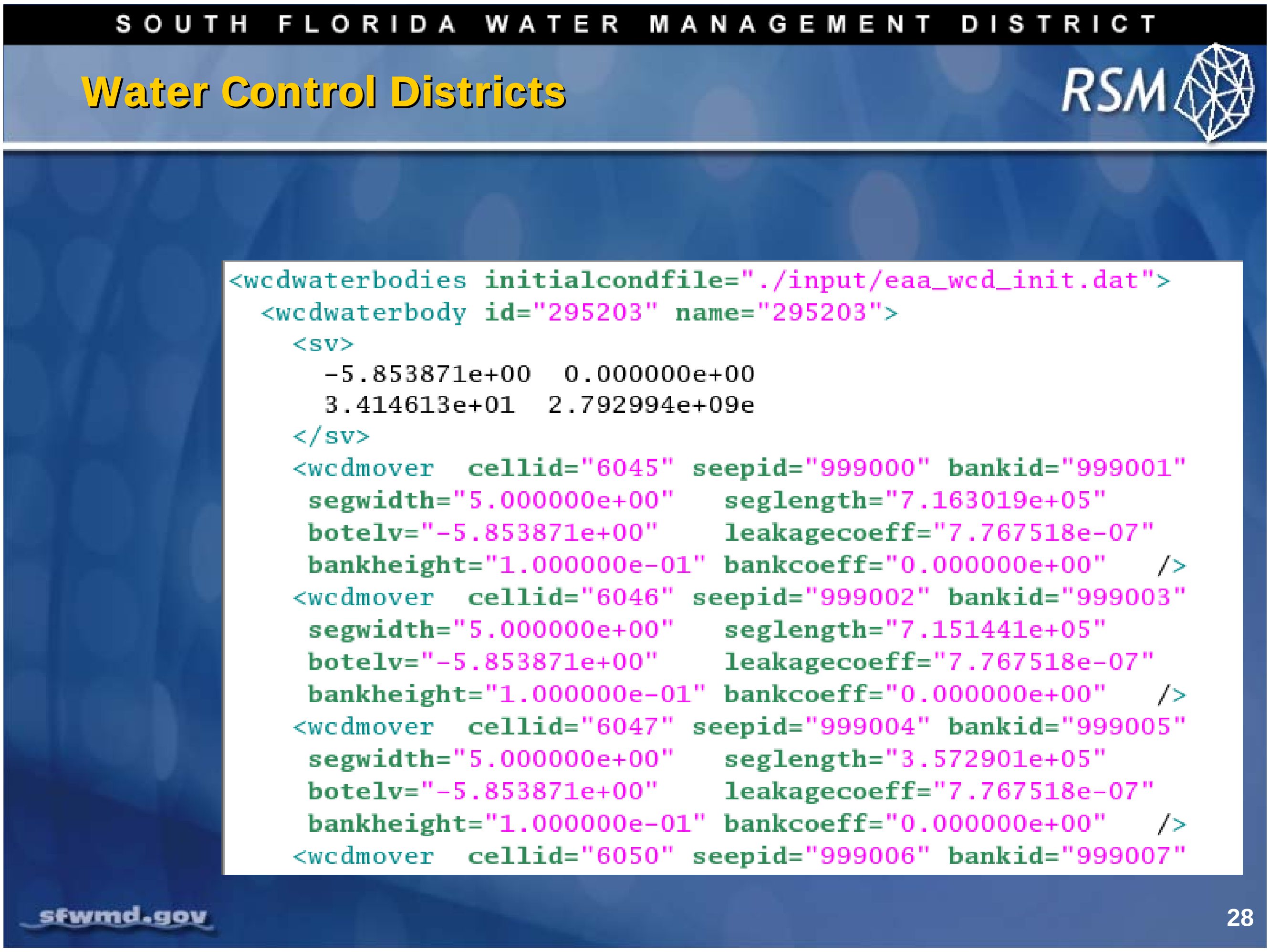
The <leveeSeepage> watermover was created to handle water movement from wetlands to canals through levees. This function creates three distinct watermovers: Q_{ms}, Q_{ds} and Q_{md}, which replace the cell-canal watermovers.

The cell-canal watermovers that are made by default, based on the network/mesh geometry, are disabled so there is no water flow into the canal except through the <leveeSeepage> watermover. Water moves to the canal and the dry cell based on the heads in the marsh cell and segment, and heads in the marsh cell and dry cell respectively; as well as the corresponding conductivities and the length of the cell-canal line interaction.

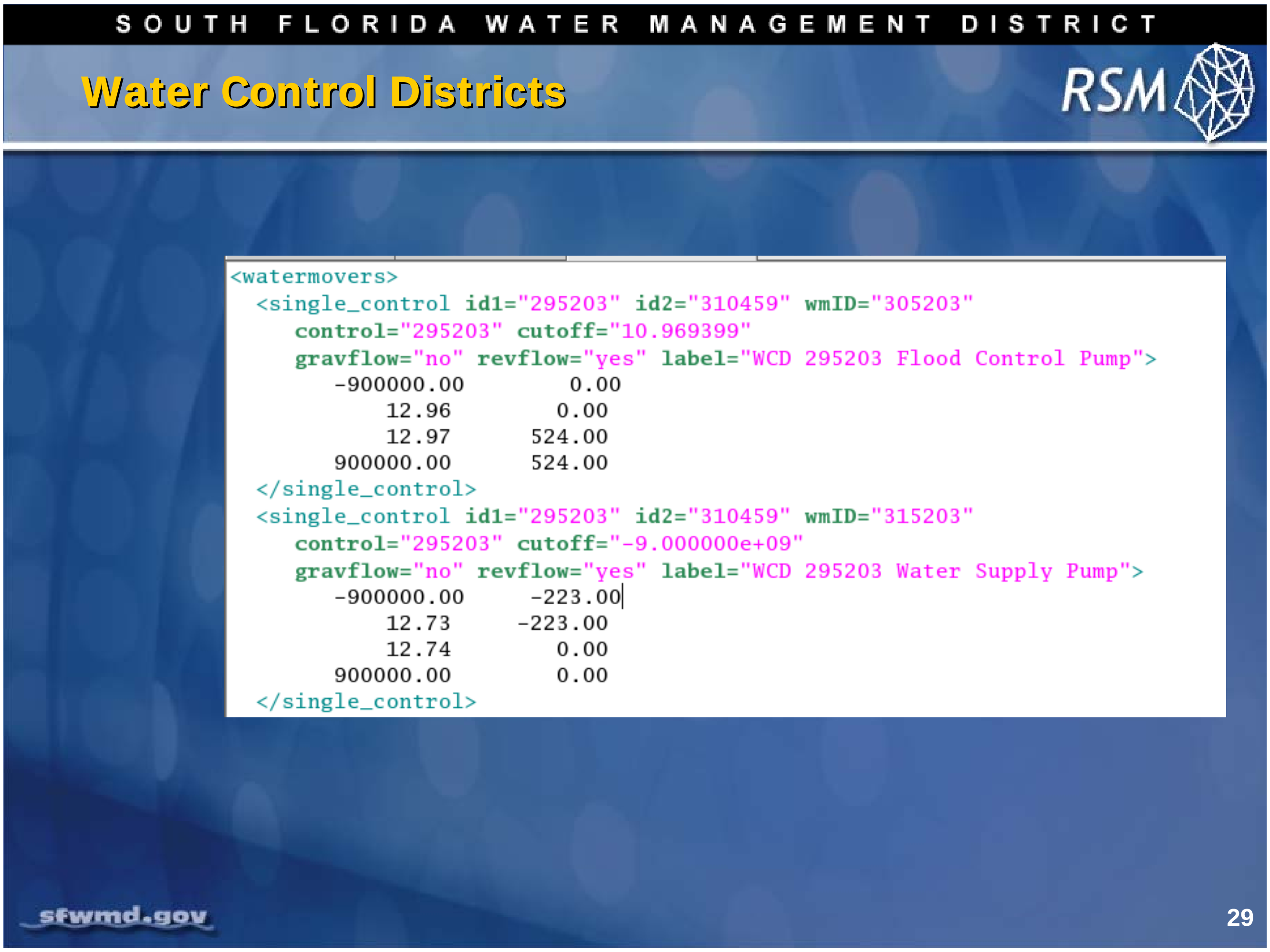
For each levee, a no-flow surface water mesh boundary condition is created so there is no surface water flow between cells, but there is groundwater flow.



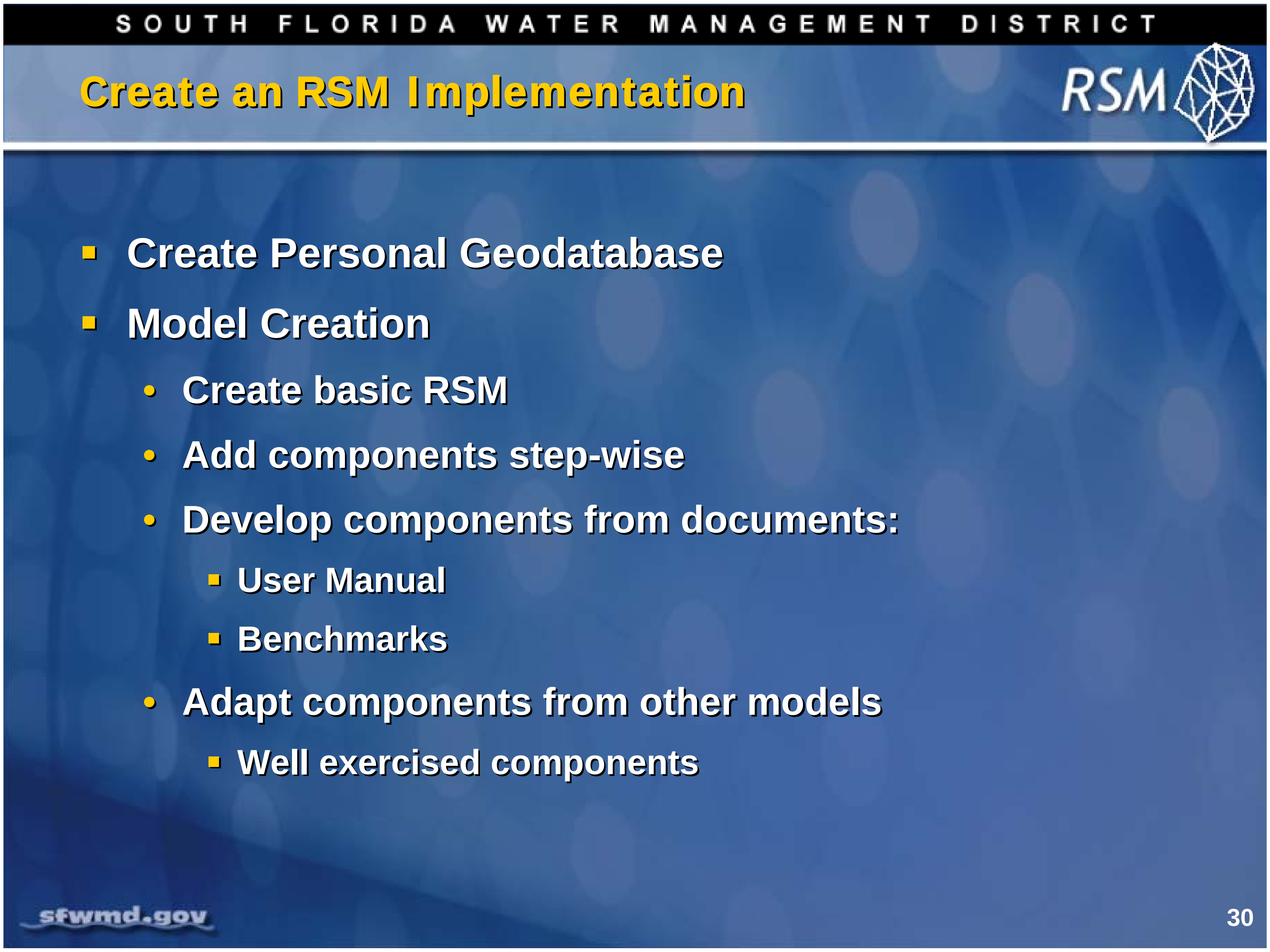
Water Control Districts (WCD) are common in south Florida. They were developed as 298 districts that have taxing authority to provide infrastructure for drainage and/or water supply for agriculture or urban developments. They have a central canal system that acts as water collection and storage. The WCDs are separated from, but connected to, the regional system through pumps and gated weirs. In the WCD, the canal system <wcdwaterbody> interacts with each cell in the WCD and there are structures that interact with the RSM canal network.



Each WCD is surrounded by an overland, no-flow boundary condition. Within the WCD there is a waterbody that can be a canal, detention pond or wetland. The <wcdwaterbody> has a stage-volume relationship, the bottom of which is typically below ground. The <wcdwaterbody> interacts with the cells in the WCD through <wcdmovers > that model seepage and overbank flow. The <seglength> attribute defines the length of the cell-wcdwaterbody interface.



The <wcdwaterbodies> are connected with the canal network using two user-specified watermovers, one for inflow and one for outflow. This page includes the syntax for implementing a pair of pumps.



Creation of a complete RSM implementation requires a geodatabase with the necessary spatial attribute features. An RSM implementation should begin small and add components in steps, to obtain the necessary complexity.

For regional simulation, the available data may not support a complex model structure. The components and the syntax for the components can be obtained from the HSE User Manual, the benchmarks and other RSM implementations.

Knowledge Assessment

1. What are the key elements of the <control> block?
2. What are the key elements of the <mesh> block?
3. How are rainfall and refET included in the model?
4. How are spatial data entered into RSM?
5. How are time series data entered into RSM?
6. What are the three groups of hydrologic process modules?
7. What is the purpose of HPMs?
8. What are elements of the <network> block?
9. What are the key components of the <output> block?
10. How does the leveeSeepage watermover work?
11. How are secondary drainage systems modeled in RSM?

Answers

1. The <control> block includes the start and end time, time step, units and MSE control parameters.

2. The <mesh> block includes the mesh topology including surface and bottom elevations, initial head, boundary conditions including rain and refET, SV-converter, resistance terms, and HPMs.

3. The rain and refET are typically included as a “gridio” binary file that provides an interpolated value for each mesh cell. However, rain and refET can be implemented as constants or simple time series.

4. Spatial data can be entered as 1) constant values, 2) zonal data, or 3) continuous data using “gms” format or indexed data.

5. Time series data can be entered as constant values, waterbody-indexed, gridio, DSS files or netCDF files.

6. The three major groups of HPMs are HPMs for urban, agricultural and native landuse/land cover types.

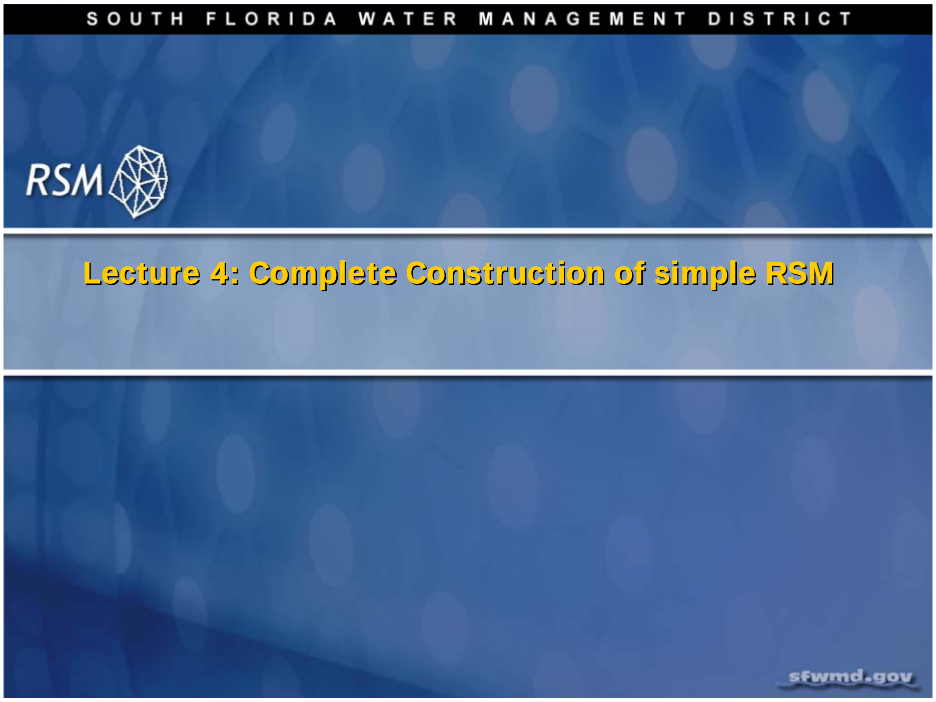
7. The HPMs are implemented to model surface hydrologic processes including irrigation and drainage that are important to the regional implementation of the model.

8. The <network> block contains the following elements:
   - <geometry>, topology of the canal network,
   - <initial>, initial conditions
   - <network_bc>, boundary conditions for the canal network
   - <arc>, Manning’s n and canal-aquifer interaction terms.

9. The <output> block contains three elements: monitors for recording the value of any state or dynamic variable, water budgets for waterbodies and HPMs, and globalmonitors that record the value for selected state variables for every waterbody at each time step.

10. The <leveeSeepage> watermover has three watermovers: MarshtoSegment, MarshtoDrycell and DrycelltoSegment watermovers that operate on a noflow boundary between two cells.

11. The secondary drainage systems are modeled using WCDs.



Lab 4: Build a Complete RSM

Time Estimate: 4 hours

Training Objective: Create the components of a simple RSM

A simple Regional Simulation Model can be built from components of previous RSMs. In the case of a simple RSM, the benchmarks can be used as templates for the XML file. In this lab, you will build a complete model for the Everglades Agricultural Area-Miami Canal (EAA-MC) Basin.

In the lab exercises in Module 3, you built the mesh and the canal network. If you did not complete building the mesh and network, the mesh and network are provided in the following directory:

`$RSM/../labs/lab4_complete_RSM directory`

NOTE:

For ease of navigation, you may wish to set an environment variable to the directory where you install the RSM code using the syntax

```
setenv RSM <path>
```

For SFWMD modelers, the path you should use for the NAS is:

```
/nw/oomdata_ws/nw/oom/sfrsm/workdirs/<username>/trunk
```

```
setenv RSM /nw/oomdata_ws/nw/oom/sfrsm/workdirs/<username>/trunk
```

Once you have set the RSM environment variable to your trunk path, you can use $RSM in any path statement, such as:

```
cd $RSM/benchmarks
```

Training files are currently located in the following directories:

```
INTERNAL_TRAINING
|
|____data
|          |__geographic
|          |__C111
|          |__rain+et
|          |__glades_lecsa
|          |__losa_eaa
|          |__BBCW
|
|____trunk
|          |___benchmarks
|          |___hpmbud
|
|____labs
```

Files for this lab are located in the **`labs/lab4_complete_RSM`** directory. Additional materials in the directory include:

HSE User Manual (**`hse_userman.pdf`**)

Activity 4.1: Create a Simple RSM

Overview

Activity 4.1 includes three exercises:

- **Exercise 4.1.1** Create a basic RSM
- **Exercise 4.1.2** Create a simple flow condition
- **Exercise 4.1.3** Specify different land uses

A Regional Simulation Model consists of <control>, <mesh> and <output> blocks. You will build a simple RSM using the components from selected benchmarks.

Exercise 4.1.1 Create a basic RSM

1. From the benchmarks, search through several benchmarks to find a suitable control block for a one-year simulation using a daily timestep.
2. Find a suitable **<mesh>** block that contains the required mesh elements:
   - **<geometry>**
   - **<shead>**
   - **<bottom>**
   - **<surface>**
   - **<conveyance>**
   - **<svconverter>**
   - **<transmissivity>**

   The values for the simplest RSM should have constant values:

> **NOTE:**
>
> **Set units = "English" in the** <control> **block.**

   - Bottom = ***-24.0***
   - Surface = ***10.0***
   - Shead = ***13.0*** (flooded)
   - Conveyance a= ***0.500*** dent=***0.001***
   - Transmissivity: unconfined k = ***0.002***
   - SVconverter constsv = ***0.2***
3. Modify the **<geometry>** element to include the mesh you created in Lab 3:

   eaamc.2dm
4. Create the basic components of the <**output**> block. These include head monitors, flow monitors and the waterbudget package.
   - Create a wbbudgetpackage :
     <wbbudgetpackage file="wbbudget.nc"></wbbudgetpackage>
   - Create cell monitors for heads in a cell at the north end (Cell 1), middle (Cell 16), near south (Cell 26) and south end (Cell 30) of the model domain.

- Direct the results to a .DSS time series file: **eaamc.dss**.

```
<cellmonitor id="1"  attr="head" label="c1"><dss file="eaamc" />
</cellmonitor>
```

5. Place the following statement in the **<control>** block:

```
runDescriptor="test"
```

6. Save the XML code as "**eaamc.xml**" in the **lab4_complete_RSM** directory.
7. Run the model using the RSM Graphical User Interface (RSM GUI). (Refer to Lab 1.)
8. Observe the resulting heads using HEC-DSSVue in the RSM GUI toolbar.
9. Create a wbbud water budget using Process Model Output→WBBud in the RSM GUI toolbar. (Refer to Lab 1)

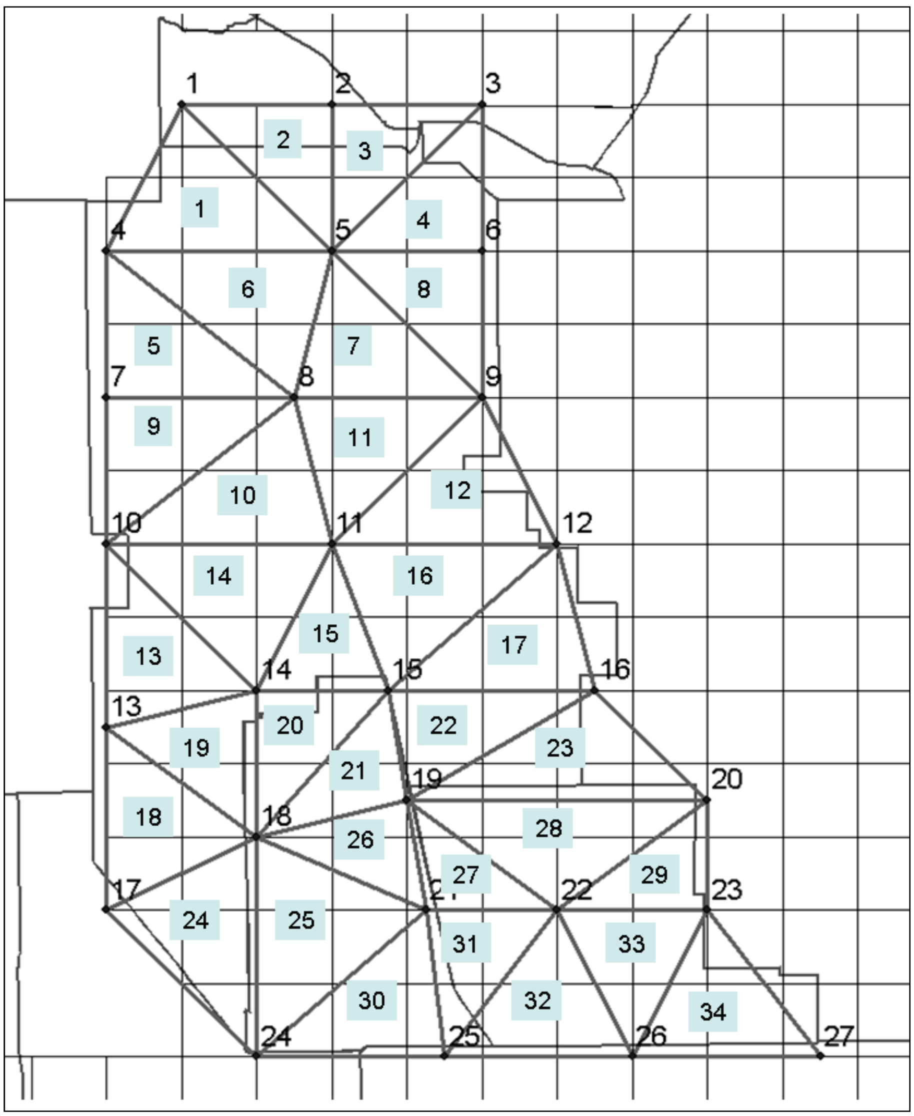


Figure 4.1 Cell and node IDs for a simple EAA-MC Basin mesh.

Exercise 4.1.2 Create a simple flow condition

We will create a head boundary condition at the south ends of the domain. The default condition is no-flow boundary condition around the perimeter of the domain.

1. Create a <**`mesh_bc`**> element and add a wallhead boundary condition with a constant head equal to ***8*** along the south boundary of the mesh:

```
<wallghb value="0.01"  label="WCA3">
   <nodelist> 24 25 26 27 </nodelist>
   <uniform> <const value="8"> </const> </uniform>
</wallghb>
```

> **NOTE:**
>
> **Change the node list to represent the nodes along your mesh boundary.**

2. Run **`eaamc.xml`**.
   - Observe heads in .DSS file. There is now a general decline in water levels over time.
3. Change the conductivity value for the boundary condition from **`0.01`** to **`0.05`** and observe the results.
4. Add upstream **`<wallghb>`** for Lake Okeechobee with a conductivity **`value = 0.05`**, run the model and display the heads. Set a uniform head of **`15`** feet for nodes 1, 2 and 3.
   - Observe the head time series.
5. Add western groundwater boundary condition, no surface water flow [section="gw"] using the node IDs from **Fig. 4.1**. Run the model and display the heads. Your model input file should look like **`eaamc3.xml`** in the **`lab4_complete_RSM`** directory.
6. Add topography to the simple EAA-MC RSM.
   - Create an indexed entry file similar to **Fig. 4.2** for topography by selecting the most representative values for each cell from the topographic data provided in **Fig. 4.3**. The header lines include the appropriate metadata.
   - Using the attached topography map select the most appropriate value for each cell. Change the number of cells, ND, to **`34`** to match your domain.
   - Add the following code to the **`<surface>`** element to replace the <const>:

```
<gms file="./eaamc_topo.dat">
```

7. Run **`eaamc3.xml`** and observe the resulting head time series.
   - Your file should look like **`eaamc_topo.xml`**

```
DATASET
      # File generated by...
      # Program: HSE GUI HSM-1.0
      # Host:
      # Date:  10/2/2006
      # Path:  topo.xml
      # User:  unknown
      # Scenario:
      #
      OBJTYPE 'mesh2d'
      BEGSCL
      ND 4510
      NAME 'topo'
      TS 0 0
      25.347
      24.091
      25.492
      ….
      ENDDS
```

Figure 4.2 Typical indexed input file

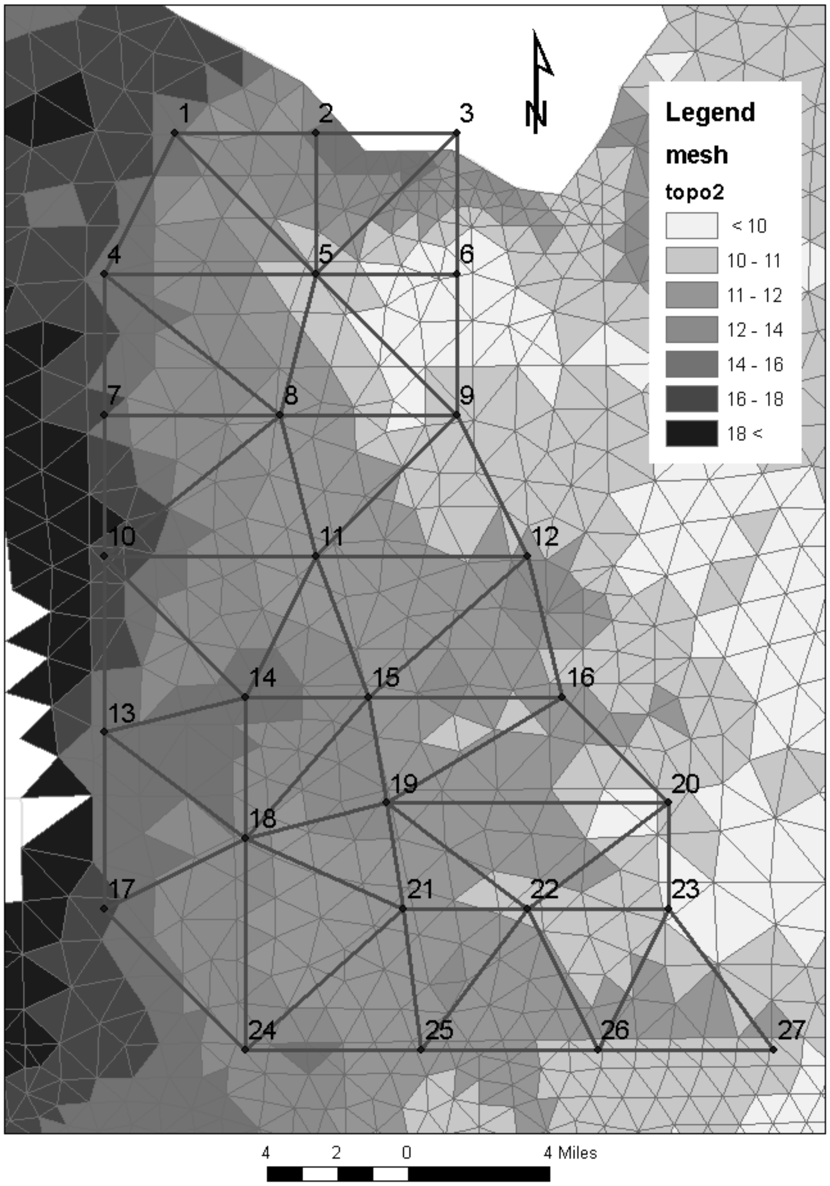
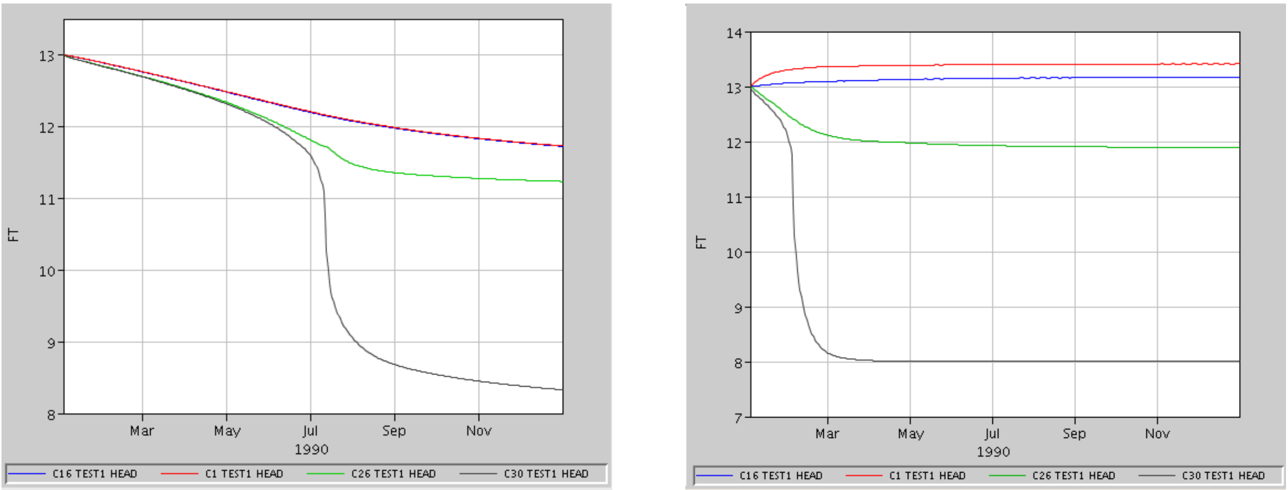


Figure 4.3 Topographic data (in feet) from a finer mesh for the `eaamc.2dm` mesh



a) Simple mesh with downstream boundary conditions **b)** Simple mesh with topography

Figure 4.4 Time series of heads for different locations in the mesh with simple boundary conditions and topography

Exercise 4.1.3 Specify different land uses

Add Hydrologic Process Modules (HPMs) to the model:

1. Change the topography back to a constant value flat condition, remove the western boundary condition and change the Lake Okeechobee boundary condition to **`13`** feet.
2. Add a simple marsh HPM **`<layer1nsm>`** to the model as part of the <mesh> block.
   - See Benchmark 16 for details.
   - Units for rd, xd, and pd are feet.

```
<hpModules>
    <layer1nsm kw="1.0" rd="0.5" xd="2.0" pd="3.0" kveg="0.75"/>
</hpModules>
```

3. Add the rainfall and reference potential evapotranspiration **<refet>.**

   The rain and refet are contained in binary files that are extracted to provide the daily value for each mesh cell.

```
<rain>
  <gridio file="$RSM/../data/rain+et/rain_v2.0_global.bin"
     xorig="237027" yorig="286611" mult=".0833" dbintl="1440">
  </gridio>
</rain>
<refet>
  <gridio file="$RSM/../data/rain+et/ETp_recomputed_tin.bin"
     xorig="237027" yorig="286611" mult=".0833" dbintl="1440">
  </gridio>
</refet>
```

4. Save file as “**eaamc_hpm.xml**”.
5. Run **eaamc_hpm.xml** and observe the resulting head time series and water budgets (see **Figure 4.5a** and **Table 4.1**).
   - The cell heads vary with the seasonal rain for native land. Add the code for creating an HPM monthly budget in the **<output>** block:

```
<hpmbudgetpackage file=”hpmbudget_mon.nc” dbintl”43200”/>
```

   - The water budgets can be created for each cell using the hpmbud utility.
   - A separate file containing the cell numbers has to be created for hpmbud.

```
$RSM/hpmbud/hpmbud –n  hpmbudget_mo.nc –s cell2 –d –m 12
```

Table 4.1 Monthly water budget for Cell 16 for layer1nsm HPM for the EAA-MC basin.

cell16.budget

					Rainfall FT/12	Et FT/12	CellDelta FT/12	WSupply FT/12	CU FT/12	Sewer FT/12	Septic FT/12	Runoff FT/12	Seepage FT/12	Storage Chg FT/12	Residual FT/12
1990	1	31	24	0	1.2695	3.3339	−1.3085	0	0	0	0	0	0	−3.3729	0
1990	2	28	24	0	1.7142	3.3633	−1.4672	0	0	0	0	0	0	−3.1164	0
1990	3	31	24	0	2.1459	4.424	−1.9059	0	0	0	0	0	0	−4.184	0
1990	4	30	24	0	2.113	4.8423	−0.6678	0	0	0	0	0	0	−3.397	−2.2957e−06
1990	5	31	24	0	5.8684	4.8779	−0.10708	0	0	0	0	0	0	0.88342	−2.2957e−06
1990	6	30	24	0	3.806	4.896	−0.58491	0	0	0	0	0	0	−1.6749	2.2957e−06
1990	7	31	24	0	7.0692	4.8549	−0.81649	0	0	0	0	0	0	1.3978	0
1990	8	31	24	0	7.3471	4.7845	−1.0235	0	0	0	0	0	0	1.5391	0
1990	9	30	24	0	2.3072	3.9891	−0.78694	0	0	0	0	0	0	−2.4688	0
1990	10	31	24	0	1.9472	3.3284	−0.27625	0	0	0	0	0	0	−1.6574	2.2957e−06
1990	11	30	24	0	0.93704	2.9101	−0.21197	0	0	0	0	0	0	−2.1851	0
1990	12	31	24	0	0.44606	2.6945	0.13622	0	0	0	0	0	0	−2.1122	2.2957e−06

6. Change the HPM from marsh to sugarcane.
   - Comment-out the marsh HPM (**layer1nsm)** using **[<!-- comment -->]** syntax
7. Add the sugarcane HPM code.
   - Create the appropriate **lu.index** file based on lab exercises in Module 3.

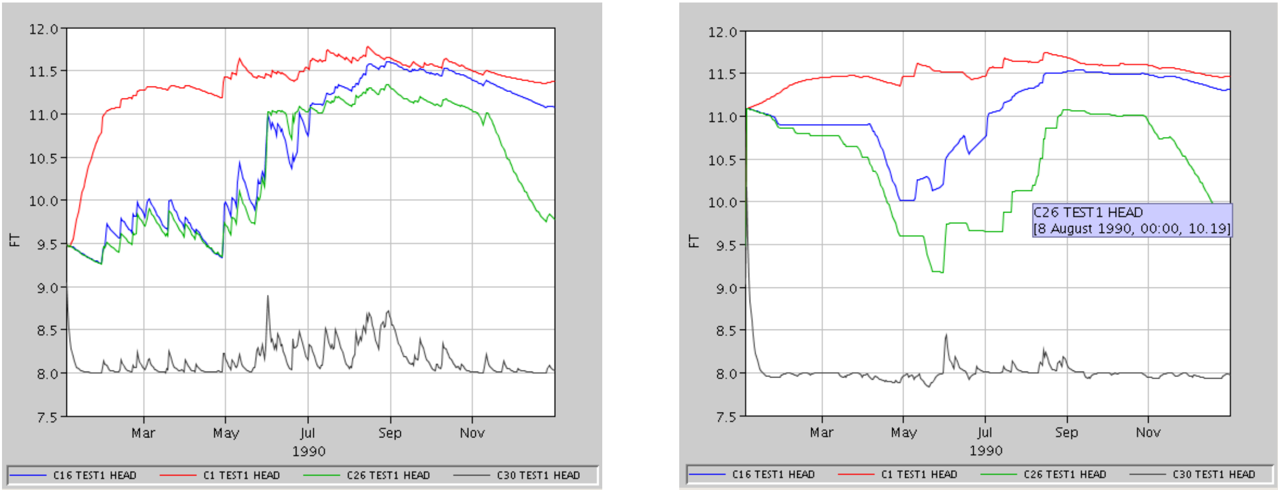
```
<hpModules>
     <indexed file="lu.index">
         <hpmEntry id="6" label="sugar - subirrigation">
            <afsirs>
                <afcrop label="sugar"  id="15" j1="01-01" jn="12-31"
                        depth1="18" depth2="36">
                    <kctbl>
                          0.47  0.33  0.42  0.52  0.77  0.96
                          0.71  0.66  0.68  0.50  0.52  0.55
                    </kctbl>
                    <awdtbl>
                          0.65  0.65  0.35  0.35  0.35  0.50
                          0.65  0.65  0.65  0.65  0.65  0.65
                    </awdtbl>
               </afcrop>
               <afirr label="SEEPAGE, SUBIRRIGATION" wtd="8.0">
                    <irrmeth id="7" eff="0.5" arzi="1.0"
                             exir="1.0"></irrmeth>
                    <irrmgmt trigcode="0"></irrmgmt>
               </afirr>
               <afsoil label="MUCK SOILS" depth="96" minwc=".20"
                       maxwc=".50" cond="1"> </afsoil>
           </afsirs>
      </hpmEntry>
   </indexed>
</hpModules>
```

Figure 4.6 The XML code for the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS): sugarcane HPM.

   - Save file as **eaamc_sc.xml**
8. Run **eaamc_sc.xml** with sugar cane and observe the resulting head time series and water budgets (see **Figure 4.5b** and **Table 4.2**)..

The head time series is smoother (**Fig. 4.5**) as the Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS) HPM maintains a soil water budget separate from the cell unlike the **<layer1nsm>**.

The HPM water budgets can be compared to values of ET, irrigation requirement and runoff that are expected from sugarcane.



a) Simple mesh with layer1nsm HPM

b) Simple mesh with sugar cane HPM

Figure 4.5 Time series for head with different cells in the simple mesh for marsh HPM and flood-irrigated sugar cane HPM

Table 4.1 Monthly water budget for Cell 16 for sugarcane HPM for the EAA-MC Basin.

cell16_sugarcane_bud

					Rainfall	Et	CellDelta	WSupply	CU	Sewer	Septic	Runoff	Seepage	Storage Chg	Residual
					FT/12	FT/12	FT/12	FT/12	FT/12	FT/12	FT/12	FT/12	FT/12	FT/12	FT/12
1990	1	31	24	0	1.2695	1.9159	0	1.4484	0	0	0	4.8	0	-3.998	0
1990	2	28	24	0	1.7142	1.6486	0	0	0	0	0	0.00059986	0	0.064927	-1.1478e-06
1990	3	31	24	0	2.1459	2.6156	0	0	0	0	0	0	0	-0.46966	-3.4435e-06
1990	4	30	24	0	2.113	3.4211	0	2.1838	0	0	0	0	0	0.87566	1.1478e-06
1990	5	31	24	0	5.8684	4.8691	0	0.47471	0	0	0	1.1938	0	0.28013	0
1990	6	30	24	0	3.806	5.5686	0	0.68628	0	0	0	0.039678	0	-1.116	0
1990	7	31	24	0	7.0692	4.8715	0	0	0	0	0	2.3023	0	-0.10465	1.1478e-06
1990	8	31	24	0	7.3471	4.6654	0	0	0	0	0	1.972	0	0.70974	1.1478e-06
1990	9	30	24	0	2.3072	3.4702	0	0.2734	0	0	0	0	0	-0.88955	-3.4435e-06
1990	10	31	24	0	1.9472	2.4919	0	0.39212	0	0	0	0	0	-0.15259	5.7392e-06
1990	11	30	24	0	0.93704	2.0172	0	1.0801	0	0	0	0	0	0	1.1478e-06
1990	12	31	24	0	0.44606	2.0035	0	1.5574	0	0	0	0	0	0	0

Activity 4.2: Add a canal network to the EAA-MC Basin RSM

Overview

Activity 4.2 includes one exercise:

- Exercise 4.2.1 Add a canal network

The simple canal network consisting of a single canal reach was created in the Lab 3. This canal will be added to the eaamc.xml RSM and the various features will be examined.

Exercise 4.2.1 Add a canal network

The components of the network can be found in several benchmarks, including BM4, BM11 and BM34. For many components of the RSM, a snippet of XML script can be copied from a reliable source, such as a benchmark, and edited as necessary.

1. Add the following network component to **eaamc.xml**:

```
<network>
   <geometry file="canal3x3.map"> </geometry>
   <initial file="canal3x3.init"> </initial>
   <arcs>
      <indexed file="arcs.index">
         <xsentry id="1">
            <arcflow n="0.2"></arcflow>
            <arcseepage leakage_coeff="0.000405" />
            <arcoverbank bank_height="0.001" bank_coeff="0.001"/>
         </xsentry>
      </indexed>
   </arcs>
</network>
```

2. Change the map file to **eaamc.map**. Also change the **canal3x3.init** file.

   Create a new initial conditions file by copying the one from BM4 and adding the necessary values for each of the 13 segments. The initial head can be uniformly set to **9.0** feet.

3. Create an **arcs.index** file that contains the value **"1"** in a row for each of the 13 segments, which will apply the arc parameters to each of the segments in the network.
4. Save the file as **eaamc_net.xml**.
5. Run **eaamc_net.xml** using the RSM GUI and graph the head time series using HEC-DSSVue.

6. Add boundary conditions.

   Add a simple head **<segmenthead>** boundary condition element in **<network_bc>** element inside **<network>** block for **Segment 300013** (see BM10 for details).

```
<network_bc>
   <segmentghb id="300013" bcID="1" kcoef="0.001" label="S8 gbh">
      <const value="8.0"></const>
   </segmentghb>
</network_bc>
```

7. Run **eaamc_net.xml**.
8. Add segment head monitors to the **<output>** block.

```
<segmentmonitor id="300013" attr="head" label="s300013">
                <dss file="eaanet" />
</segmentmonitor>
```

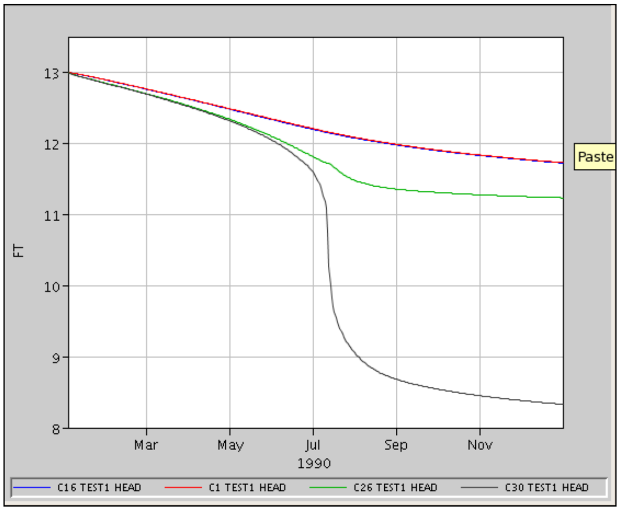
9. Add a flow monitor to **<output>** block for the segment boundary condition.

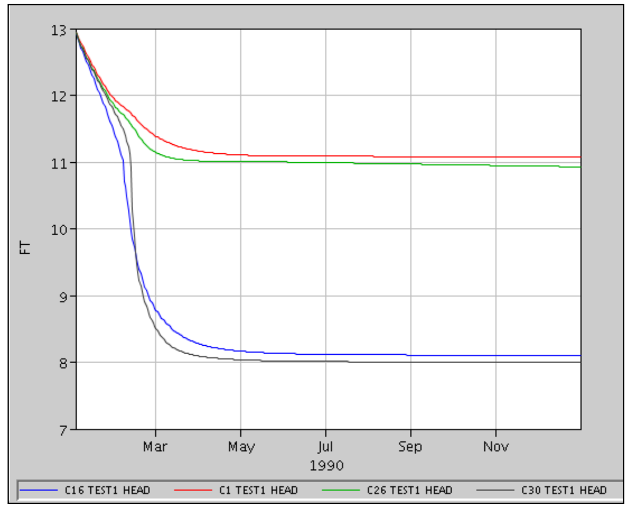
   Although flow cannot be monitored in the final segment, flow can be monitored in the boundary condition.

```
<bcmonitor bcID="1" attr="head" label="bc1"><dss file="eaamcnet" />
</bcmonitor>
```

   - Observe the cell and segment heads and flow.
   - Save as **eaamc_net.xml**.

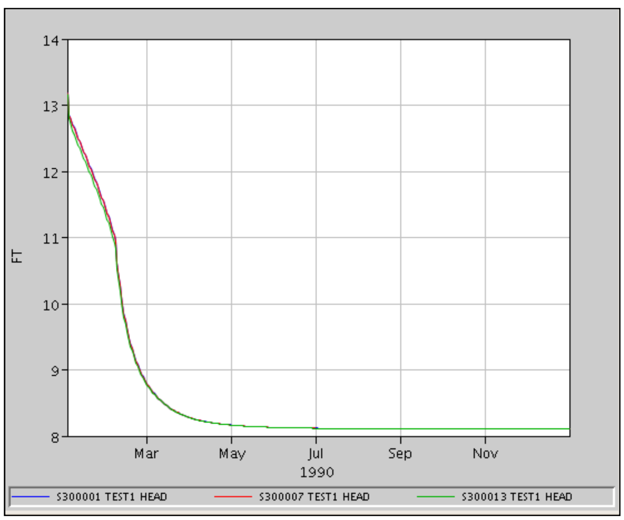
10. Run **eaamc_net.xml**.
    - Observe the cell and segment heads and flow.
11. Change the segment properties: Manning's n and bottom width (**eaamc.map**) and observe how they affect the EAA-MC cell heads and segment heads.
12. Change canal bed leakage (arcseepage attribute **leakage_coeff**) and observe how the change affects the EAA-MC cell heads and segment heads.
13. Add HPMs to the mesh.
    - Compare layer1nsm HPMs to AFSIRS (sugarcane) HPMs.

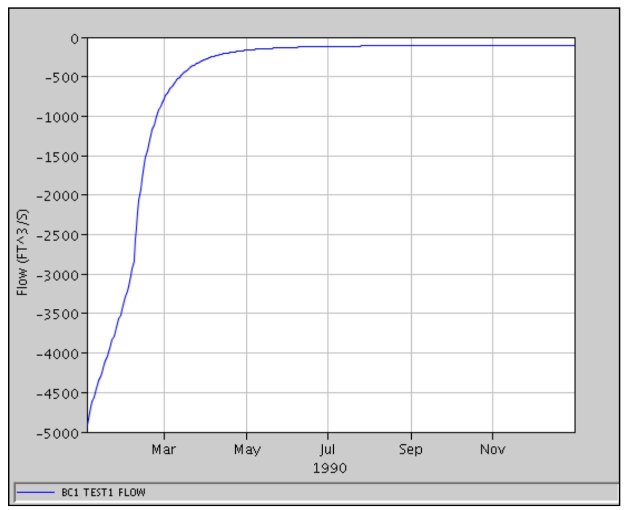




a) EAA-MC RSM model without canal drainage

b) EAA-MC RSM with canal drainage

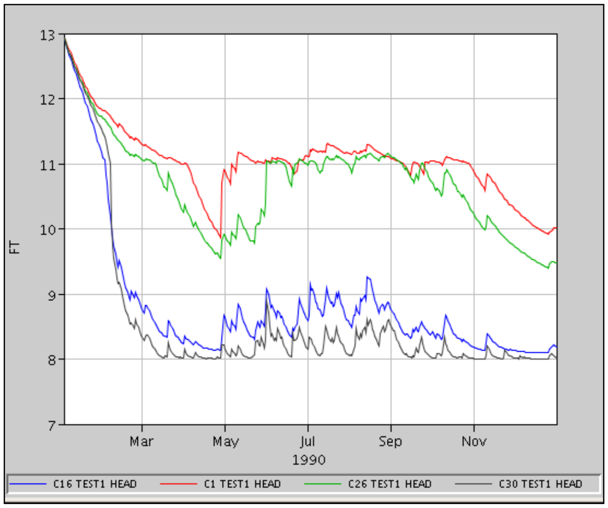




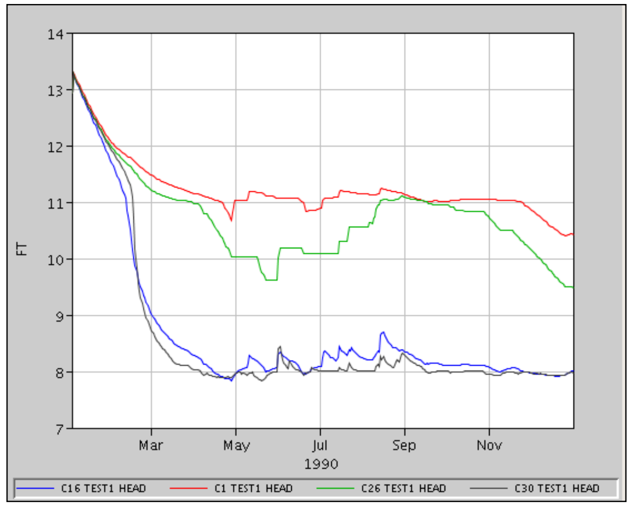
c) Segment head in EAA-MC RSM

d) Flow from final segment in EAA-MC RSM

Figure 4.6. Impact of simple network on heads in simple EAA-MC mesh.



a) With layer1nsm (marsh) HPM



b) With AFSIRS (sugarcane) HPM

Figure 4.7. Impact of assigning marsh or sugarcane HPMs on the cell heads in the simple EAA-MC RSM.

The <**`layer1nsm`**> HPM shows the effect of rain and evapotranspiration (ET) on the water tables in the various cells. The AFSIRS HPM shows the effect of agricultural water management on the water tables.

The final **`eaamc_net.xml`** should have the components similar to the **`eaamc_net2.xml`** file in the **`labs/lab4_complete_RSM`** directory.

Answers for Lab 4

Exercise 4.1.1

2. Use components from BM16 run3x3.xml.

8. The results are constant heads, nothing is moving.

Exercise 4.1.2

1. See BM34 for syntax

6. Topography strongly affects the water flow. Changing the upstream boundary condition does not affect the results.

Exercise 4.1.3

<no questions>

Exercise 4.2.1

11. Observe how a change in segment properties affects the EAA-MC cell heads and segment heads.

The changes to the canal width and Manning's n coefficients (a and b) did not drastically change the pattern (shape) of the head curves, providing the new values are within a realistic range. They do, however, alter the slope of the curves (how fast they change). As expected, higher Manning's n values and smaller widths lead to more pronounced differences in head between the segments and cells, while larger widths and lower roughness damps the differences. The final heads do not vary significantly based on changes in roughness and width.

12. Observe how a change in canal bed leakage affects the EAA-MC cell heads and segment heads.

As the leakage coefficient decrease the heads begin to resemble those in **Figure 4.6a** (no leakage condition), where the heads decrease slower through time. However, even large increases (original k = 0.01, new k = 10.0) do not cause significant change in the heads.

Index