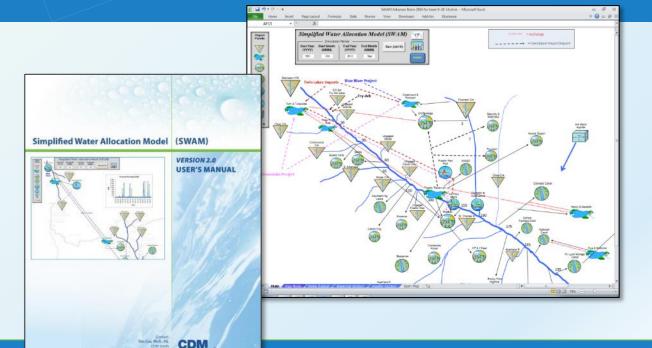
# South Carolina Environmental Conference 2015

Planning for the Future

An Update on the Status of South Carolina's

Surface Water Quantity Models

John Boyer, PE, BCEE





#### **Presentation Outline**

- Project Purpose, Schedule, and Approach
- The Modeling Tool
- Saluda River Basin Unimpaired Flows and Pilot Model
- Stakeholder Involvement Opportunities





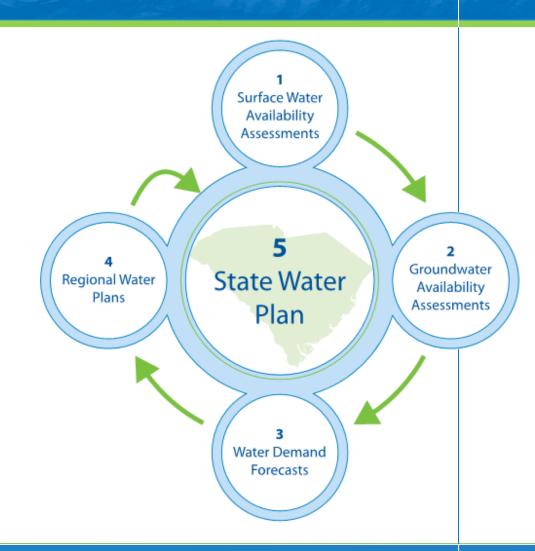


## **Project Purpose**

- Build surface water quantity models capable of:
  - Accounting for inflows and outflows from a basin
  - Accurately simulating streamflows and reservoir levels over the historical inflow record
  - Conducting "What if" scenarios to evaluate future water demands, management strategies and system performance.
- The models will be made available for use by all stakeholders to assist with planning and management

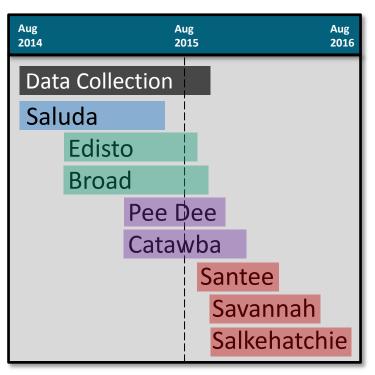
## **Project Purpose**

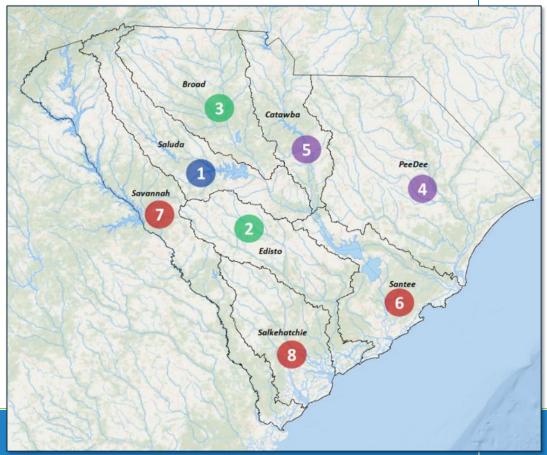
- This phase of the State
   Water Plan development
   only involves baseline
   surface water model
   development
- The surface water models, and other available tools, will eventually be used to support development of regional water plans



## Schedule for Developing the Models

- Pilot Model of the Saluda River Basin is underway
- Groups of models will be constructed in parallel
- August 2016 Finish





#### **Data Collection**

Streamflow, municipal and agricultural withdrawals, discharges, reservoir levels, interconnections, facility operation dates, etc.

# Unimpaired Flow Development

Daily mean UIFs

#### **Data Analysis**

Gap filling and record extension

Task 2

#### Basin Schematic

Model framework development

# Model Calibration

Reproduce actual conditions

## Baseline Model Runs

Simulate current conditions

Stakeholder Meeting #1

Stakeholder Meeting #2

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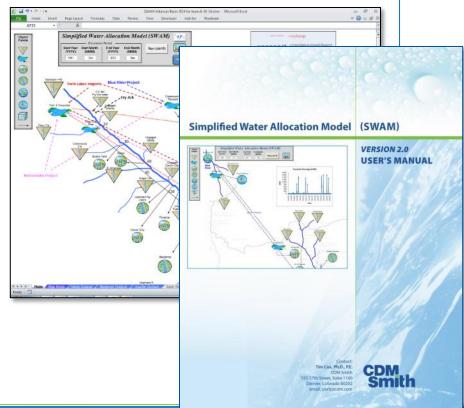


## Simplified Water Allocation Model (SWAM)

 Developed in response to an increasing need for a desktop tool to facilitate regional and statewide water allocation analysis

 Calculates physically and legally available water, diversions, storage consumption and return flows at user-defined nodes

 Used to support large-scale planning studies in Colorado, Oklahoma, Arkansas and Texas



## Simplified Water Allocation Model (SWAM)

#### Similarities between SWAM, OASIS, CHEOPS, and RiverWare:

- Used in major river basin studies and/or statewide water plans
- Operating Rules of varying complexity
- Monthly and Daily Timesteps
- Visual Depiction of the River Network

#### **Unique Features:**

#### **SWAM**

- Familiar and adaptable environment: Visual Basic and Spreadsheets
- Built in functions for reservoirs, river operations, discharges, irrigation, return flows, etc.

#### **OASIS**

- Built in Probability Analysis for Real-Time Ops
- Optimization toward objectives in each timestep

#### **CHEOPS**

- Tailored specifically for hydropower
  - Energy Calculations
  - Reservoir Tracking
- Familiar VisualBasic programming

#### **RiverWare**

- Fully linked graphical network development
- 3 modes:
  - Pure simulation
  - Rules-based simulation
  - Optimization

## The Simplified Water Allocation Model is...

- a water accounting tool
- a WHAT-IF simulation model
- a network flow model that traces water through a natural stream network, simulating withdrawals, discharges, storage, and hydroelectric operations
- not precipitation-runoff model (e.g., HEC-HMS)
- not a hydraulic model (e.g. HEC-RAS)
- not a water quality model (e.g., QUAL2K)
- not an optimization model
- not a groundwater flow model (e.g., MODFLOW)

#### The Models Can Be Used To...

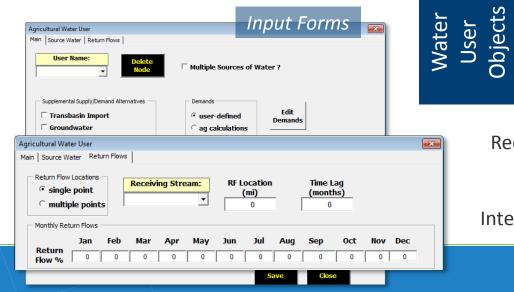
- Determine surface-water availability
- Predict where and when future water shortages would occur
- Test alternative water management strategies, new operating rules, and "what-if" scenarios
- Consolidate hydrologic data
- Evaluate the impacts of future withdrawals on instream flow needs
- Evaluate interbasin transfers
- Support development of Drought Management Plans
- Compare managed flows to natural flows

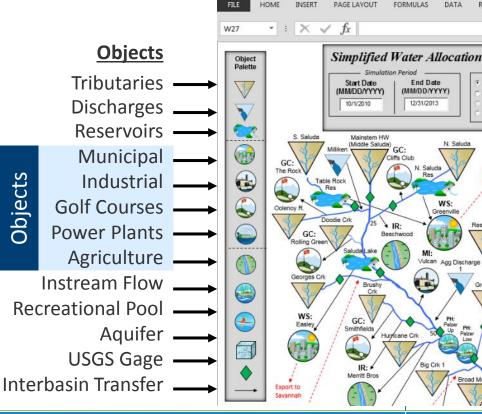
## Simplified Water Allocation Model (SWAM)

 Object-oriented tool in which a river basin and all of its influences can be linked into a network with user defined priorities

Resides within Microsoft Excel

 Point and click setup and output access

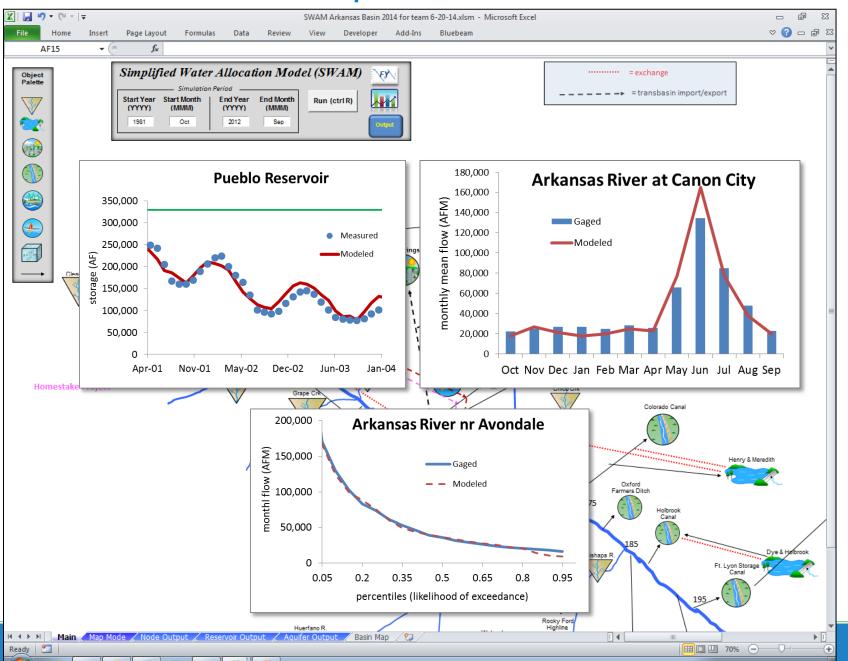




## **Output Tables**

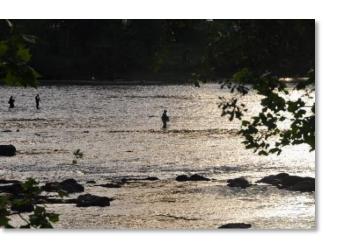
| C7    | Home Inse  |  | ut Formulas  | Data Rev      |  | Arkansas Basi<br>Develope      |   |   |   | osoft Excel   |  | Node  | e Out                                       | put   | X [  |      |
|-------|--|--|--|---------------|--|--------------------------------|---|---|---|---|--|---|---|---|--|------|
| Α     | В  | EY   | EZ   | FA            | FB   | FC                             | FD  | FE  | FF  | FG  | FH F   | FJ FJ   | FK  | FL  | <u> </u>   |      |
| Outpu |  | Pueblo4  | Priority Rank<br>32  |               | Location<br>136  | Water<br>Right<br>(AFM)<br>420 | Ditch<br>Capacity<br>(AFM)<br>1,000,000   | Storage   |   |   |  | Founta  | Priority Ran                                |   |  |      |
|       | Date   | Physically<br>Avail. (AFM)   | Legally<br>Avail. (AFM)  | Diverted (AFM |  | GW<br>Pumping<br>(AFM)         | Demand<br>(AFM)   | Shortage<br>(AFM)   | Return<br>Flow<br>(AFM)   | (AFM)   | Evap<br>Losses<br>(AFM)  | Physica<br>Avail. (A  |   | Diverted (A   | AFI  |      |
|       | Min<br>Max   | 1,200<br>423,253   | 0<br>420   | 0<br>420      | 0<br>5,000   | 0                              | 0   | 0   | 0   | 0   | 0<br>52  | 1,200<br>423,20   | 0   | 0   |  |      |
|       | Avg  | 44,588   | 117  | 33            | 4,340  | 0                              | 0   | 0   | 0   | 0   | 21   | 44,55   |   | 0   |  |      |
|       | Oct-81   | 14,837   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 14,83   |   | 0   |  |      |
|       | Nov-81   | 23,186   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 23,18   |   | 0   |  |      |
|       | Dec-81   | 24,424   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 24,42   |   | 0   | _  |      |
|       | Jan-82<br>Feb-82   | 17,870<br>16,694   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 17,87<br>16,69  |   | 0   |  |      |
|       | Mar-82   | 25,120   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 25,12   |   | 0   |  |      |
|       | Apr-82   | 11,977   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 11,97   |   | 0   |  |      |
|       | May-82   | 35,025   | 0  | 0             | 0  | 0                              | 0   | 0   | 0   | 0   | 0  | 35,02   |   | 0   |  |      |
|       | Jun-82   | 146,407  | 0  | )<br>         | -  | ^                              | ٥   | 0   | ٥   | SWAM  | n<br>Arkansas Rasin 201  | 4 for team 6-20-1   | vlsm - Microsoft                            | Fxcel   |  |      |
|       | Jul-82<br>Aug-82   | 97,301<br>75,150   | 0 =  |               |  |                                |   |   | _   |   |  |   | Dos   | OKL   | oir Ou   | tout |
|       | Sep-82   | 73,884   | 420  | File Home     | Insert   | Page Layor                     | ut Form   | iulas Dat   | ta Rev  | riew View   | Developer  | Add-Ins Blue  | beam RES                                    | ervo  | oir Ou   | LDUL |
|       | Oct-82   | 39,997   | 420  | Q19           | ▼ (6   | $f_x$                          | 26140.14  | 184375  |   |   |  |   |   |   |  |      |
|       | Nov-82   | 4,595  | 0  | Α             | В  | С                              | D   |   | E   | F   | G  | Н   |   | J   | K  | L    |
|       | Dec-82   | 4,215  | 0  |               |  | _                              |   |   |   |   |  |   |   |   |  |      |
|       | Jan-83   | 16,663   | 420  | Output        |  |                                |   |   |   | <u>Total</u>  | Release  |   |   |   |  |      |
|       | Feb-83<br>Mar-83   | 15,069<br>26,208   | 420<br>420 1   |               |  |                                |   |   |   | Capacity (AF  | <u>Location</u>  |   |   |   |  |      |
|       | Apr-83   | 42,386   | 420 2  |               |  | P                              | ueblo Res   | ervoir  |   | 330000.0  | 143.0  |   |   |   |  |      |
|       | May-83   | 47,647   | 420  |               |  |                                |   | _   |   | 0 11  | T  | Total   | D 1   | 0.40  |  |      |
|       | Jun-83   | 349,601  | 420  |               |  |                                |   | ⊢ Ex  | cess  |   | Total Inflow   | Withdrawl   | Release                                     | Outflow   |  |      |
|       | Jul-83   | 178,891  |  |               | Data   |                                | Ctor  |   |   | Overflow  |  |   |   |   | Europ (ACM)  | C+   |
|       |  |  | 420 3  |               | Date   |                                | Storage   |   | me (AF)   | (AFM)   | (AFM)  | (AFM)   | (AFM)                                       | (AFM)   | Evap (AFM)   | Sto  |
|       | Aug-83   | 93,139   | 420 3<br>420 4   |               | Min  |                                | 37,367  | (AF) Volui  | me (AF)   | (AFM)   | (AFM)<br>2,862   | (AFM)<br>4,373  | (AFM)                                       | (AFM)   | 0  |      |
|       | Sep-83   | 93,139<br>21,418   | 420 3<br>420 4<br>0 5  |               | Min<br>Max   |                                | 37,367<br>330,00  | (AF) Volui<br>7<br>0  | me (AF)<br>0<br>0   | (AFM)<br>0<br>19,692  | (AFM)<br>2,862<br>303,831  | (AFM)<br>4,373<br>101,197   | (AFM)<br>0<br>0                             | (AFM)<br>0<br>7,000   | 0<br>3,451   |      |
|       |  | 93,139   | 420 3<br>420 4<br>0 5<br>0 6   |               | Min<br>Max<br>Avg  |                                | 37,367<br>330,00<br>212,99  | (AF) Volui<br>7<br>0<br>3   | me (AF)<br>0<br>0<br>0  | (AFM)<br>0<br>19,692<br>1,352   | (AFM)<br>2,862<br>303,831<br>46,753  | (AFM)<br>4,373<br>101,197<br>39,940   | (AFM)<br>0<br>0<br>0                        | (AFM)<br>0<br>7,000<br>4,281  | 0<br>3,451<br>1,009  | 4    |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7  |               | Min<br>Max<br>Avg<br>Oct-81  |                                | 37,367<br>330,00<br>212,99<br>92,749  | (AF) Volui<br>7<br>0<br>3   | me (AF)<br>0<br>0   | (AFM)<br>0<br>19,692<br>1,352<br>0  | (AFM)<br>2,862<br>303,831<br>46,753<br>40,265  | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985   | (AFM)<br>0<br>0<br>0                        | (AFM)<br>0<br>7,000<br>4,281<br>0   | 0<br>3,451   | Sto  |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9  |               | Min<br>Max<br>Avg<br>Oct-81<br>lov-81  |                                | 37,367<br>330,00<br>212,99<br>92,749<br>90,783  | (AF) Volum<br>7<br>0<br>3<br>9  | me (AF) 0 0 0 0   | (AFM)<br>0<br>19,692<br>1,352<br>0<br>240   | (AFM)<br>2,862<br>303,831<br>46,753<br>40,265<br>14,646  | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985<br>16,371   | (AFM)<br>0<br>0<br>0                        | (AFM)<br>0<br>7,000<br>4,281  | 0<br>3,451<br>1,009<br>532   |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9  |               | Min<br>Max<br>Avg<br>Oct-81  |                                | 37,367<br>330,00<br>212,99<br>92,749  | (AF) Volum<br>7<br>0<br>3<br>9<br>3   | 0<br>0<br>0<br>0<br>0   | (AFM)<br>0<br>19,692<br>1,352<br>0  | (AFM)<br>2,862<br>303,831<br>46,753<br>40,265  | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985   | (AFM)<br>0<br>0<br>0<br>0                   | (AFM)<br>0<br>7,000<br>4,281<br>0   | 3,451<br>1,009<br>532<br>0   |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84<br>Mar-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 420   |               | Min<br>Max<br>Avg<br>Oct-81<br>Jov-81  |                                | 37,367<br>330,00<br>212,99<br>92,749<br>90,783<br>88,117  | (AF) Volui<br>7<br>0<br>3<br>9<br>3<br>1                                    | 0<br>0<br>0<br>0<br>0   | (AFM)<br>0<br>19,692<br>1,352<br>0<br>240<br>680  | (AFM)<br>2,862<br>303,831<br>46,753<br>40,265<br>14,646<br>11,817  | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985<br>16,371<br>13,808   | 0<br>0<br>0<br>0<br>0                       | (AFM)  0  7,000  4,281  0  0  0   | 0<br>3,451<br>1,009<br>532<br>0  |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84<br>Mar-84<br>Apr-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 10<br>420 11<br>420 11  |               | Min<br>Max<br>Avg<br>Oct-81<br>Iov-81<br>Jec-81<br>an-82   |                                | 37,367<br>330,00<br>212,99<br>92,749<br>90,783<br>88,111<br>86,610  | (AF) Volui<br>7<br>0<br>3<br>9<br>3<br>1<br>0<br>5                          | 0<br>0<br>0<br>0<br>0<br>0<br>0   | (AFM)<br>0<br>19,692<br>1,352<br>0<br>240<br>680<br>680   | (AFM)<br>2,862<br>303,831<br>46,753<br>40,265<br>14,646<br>11,817<br>8,105   | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985<br>16,371<br>13,808<br>8,927  | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0               | (AFM)  0  7,000  4,281  0  0  0  0  | 0<br>3,451<br>1,009<br>532<br>0<br>0   |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84<br>Mar-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025   | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 10<br>420 11<br>420 12<br>420 12                                  |               | Min<br>Max<br>Avg<br>Oct-81<br>lov-81<br>lec-81<br>lan-82<br>feb-82<br>Mar-82<br>Apr-82  |                                | 37,36;<br>330,00<br>212,99<br>92,74;<br>90,78;<br>88,11;<br>86,610<br>87,31;<br>88,01;<br>82,264  | (AF) Volum<br>7<br>0<br>3<br>9<br>3<br>1<br>0<br>5<br>9<br>4                | 0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | (AFM) 0 19,692 1,352 0 240 680 680 680 680 680 681  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650  | (AFM)<br>4,373<br>101,197<br>39,940<br>46,985<br>16,371<br>13,808<br>8,927<br>6,165<br>8,834<br>29,220  | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0   |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84   | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595  | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 10<br>420 11<br>420 12<br>420 13<br>420 13                        | C C           | Min<br>Max<br>Avg<br>Oct-81<br>Iov-81<br>Ioc-81<br>Ian-82<br>Ieb-82<br>Iar-82<br>Apr-82<br>Iay-82  |                                | 37,36i<br>330,00<br>212,99<br>92,749<br>90,783<br>88,111<br>86,610<br>87,319<br>88,013<br>82,264  | (AF) Volum<br>7<br>0<br>3<br>9<br>3<br>1<br>1<br>0<br>5<br>5<br>9<br>4<br>2 | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 681 684 624  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732   | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830   | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690   |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84<br>Mar-84<br>Apr-84<br>Jun-84<br>Jul-84                               | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322  | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 10<br>420 11<br>420 12<br>420 14<br>420 14                        |               | Min<br>Max<br>Avg<br>Oct-81<br>Iov-81<br>Iec-81<br>Ian-82<br>Feb-82<br>Apr-82<br>Iay-82<br>Iay-82<br>Iun-82  |                                | 37,36i<br>330,00<br>212,99<br>92,749<br>90,783<br>88,111<br>86,610<br>87,319<br>88,019<br>82,264<br>64,852<br>62,620  | (AF) Volum<br>7<br>0<br>3<br>9<br>3<br>1<br>0<br>5<br>5<br>9<br>4<br>4<br>2 | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 614 624 728  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054  | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922  | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637                             |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 Jun-84 Jul-84 Aug-84 Sep-84  | 93,139<br>21,418<br>13,990<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,59<br>99,322<br>30,073  | 420 3<br>420 4<br>0 5<br>0 6<br>0 7<br>0 8<br>420 9<br>420 10<br>420 11<br>420 12<br>420 13<br>420 14<br>420 15<br>0 16      |               | Min<br>Max<br>Avg<br>Oct-81<br>Iov-81<br>Ioc-81<br>Ian-82<br>Feb-82<br>Apr-82<br>Iay-82<br>Iay-82<br>Iay-82<br>Iay-82<br>Iay-82<br>Iay-82<br>Iay-82  |                                | 37,36i<br>330,00<br>212,99<br>92,745<br>90,783<br>88,111<br>86,610<br>87,315<br>82,264<br>64,852<br>62,620<br>52,25   | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 614 624 728 525  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954   | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142   | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0                                   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>5571<br>690<br>637<br>655                     |      |
|       | Sep-83<br>Oct-83<br>Nov-83<br>Dec-83<br>Jan-84<br>Feb-84<br>Mar-84<br>Apr-84<br>Jun-84<br>Jul-84<br>Aug-84<br>Sep-84<br>Oct-84 | 93,139<br>21,418<br>13,990<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219   | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 16 420 17                                      |               | Min<br>Max<br>Avg<br>Oct-81<br>Iov-81<br>Iov-81<br>Iov-81<br>Ian-82<br>Ian-82<br>Iar-82<br>Iar-82<br>Iay-82<br>Iun-82<br>Iun-82  |                                | 37,36;<br>330,00<br>212,99<br>92,74;<br>90,78;<br>88,11:<br>86,61(<br>87,31;<br>88,01;<br>82,264<br>64,852<br>62,62(<br>52,25;<br>42,02;  | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795  | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950  | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0                                 | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466                    |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 Jun-84 Jul-84 Aug-84 Sep-84  | 93,139<br>21,418<br>13,990<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,59<br>99,322<br>30,073  | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 15 0 18  |               | Min Max Avg Oct-81 lov-81 lov-81 lose-82 lor-82 lay-82 lun-82 lun |                                | 37,36i<br>330,00<br>212,99<br>92,744<br>90,78i<br>88,111<br>86,611<br>87,31!<br>88,011<br>82,266<br>64,852<br>62,620<br>52,255<br>42,025<br>38,780  | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810  | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284   | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424   | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0                           | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299             |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Jan-85                       | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,592<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847                    | 420 3 420 4 0 5 0 6 0 7 0 8 420 12 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19                                |               | Min Max Avg Oct-81 Jov-81 Jov-81 Jov-81 Jov-81 Jov-82 Jor-82 Jor- |                                | 37,36i<br>330,00<br>212,99<br>92,745<br>90,785<br>88,11'<br>86,610<br>87,315<br>82,266<br>64,852<br>62,620<br>52,25'<br>42,025<br>38,788<br>53,544  | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM) 0 19,692 1,352 0 240 680 680 680 680 681 624 728 525 600 810 1,087                                      | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442  | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384  | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0                           | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299                  |      |
| b bi  | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jun-84 Aug-84 Sep-84 Oct-84 Dec-84                       | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 11 420 12 420 13 420 15 0 16 420 17 0 18 420 19  |               | Min Max Avg Oct-81   Iov-81   Iov-81   Iov-81   Iov-82    |                                | 37,36i<br>330,00<br>212,99<br>92,745<br>90,783<br>88,111<br>86,610<br>87,314<br>88,019<br>82,264<br>62,620<br>52,257<br>42,029<br>38,780<br>38,780<br>82,590  | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384                               | (AFM) 2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561                                     | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995                                 | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 1,136                                 | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0      |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19 420 20 Output 2 21       |               | Min Max Avg Oct-81   |                                | 37,36i<br>330,00<br>212,99<br>92,745<br>98,71:<br>86,610<br>87,315<br>88,015<br>82,264<br>64,855<br>62,625<br>42,025<br>38,780<br>53,544<br>82,594<br>100,65  | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384                         | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635                             | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432                          | (AFM)  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752                             | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0 |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 12 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19 420 20 0utput 22               |               | Min Max Avg Oct-81   |                                | 37,36i<br>330,00<br>212,99<br>92,74!<br>90,78:<br>88,11:<br>86,61(<br>87,31!<br>88,015<br>82,264<br>64,855;<br>42,025<br>38,78(<br>53,544<br>83,544<br>81,036<br>100,655<br>110,34                              | (AF) Volume 7 0 3 3 3 3 3 3 3 4 4 2 2 5 5 9 4 4 2 2 5 5 7 7 7               | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384                         | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635 19,931                      | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432 6,721                    | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752 2,135                       | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0 |      |
| ► H   | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19 420 20 Output 22         |               | Min Max Avg Oct-81 lov-81 lov-81 loce-81 lan-82 lan-82 lan-82 lan-82 lan-82 lun-82 lun-82 lun-82 lun-82 loce-82 loce-82 lov-82 loce-82 lan-83 leb-83   |                                | 37,36i<br>330,00<br>212,99<br>92,744<br>90,73:<br>88,11:<br>86,611<br>87,31!<br>82,26:<br>64,852<br>62,622<br>52,25:<br>42,02!<br>38,780<br>53,544<br>82,596<br>110,34<br>118,42                                | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384 1,384                   | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635 19,931 17,965               | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432 6,721 6,165              | (AFM)  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752 2,135 2,341                   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0 |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19 420 20 Output 2 21 23 24 |               | Min Max Avg Oct-81 Jov-81 Jov-81 Jov-81 Jov-81 Jov-82 Mar-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-83  |                                | 37,36i<br>330,00<br>212,99<br>92,745<br>90,783<br>88,111<br>86,610<br>87,315<br>88,015<br>82,266<br>64,852<br>62,620<br>52,25*<br>42,025<br>38,786<br>53,544<br>82,590<br>100,65<br>110,34<br>118,422<br>127,48 | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384 1,384                   | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635 19,931 17,965 22,397        | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432 6,721 6,165 9,440        | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752 2,135 2,341 2,512     | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0<br>0      |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 15 0 16 420 19 420 10 20 0utput 2 21 22 24 25                     |               | Min Max Avg   Oct-81   Iov-81   Iov-81   Iov-81   Iov-82   Iov-83   Iov-84   Iov-84   Iov-85   Iov-86   Iov-86   Iov-87    Iov-87   Iov-87    Iov-87   Iov-87    Iov-87   Iov-87    Iov-87    Iov-87    I |                                | 37,36i<br>330,00<br>212,99<br>92,744<br>90,73:<br>88,11:<br>86,611<br>87,31!<br>82,26:<br>64,852<br>62,622<br>52,25:<br>42,02!<br>38,780<br>53,544<br>82,596<br>110,34<br>118,42                                | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384 1,384                   | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635 19,931 17,965               | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432 6,721 6,165              | (AFM) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752 2,135 2,341                   | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0      |      |
|       | Sep-83 Oct-83 Nov-83 Dec-83 Jan-84 Feb-84 Mar-84 Apr-84 May-84 Jun-84 Jul-84 Aug-84 Sep-84 Oct-84 Nov-84 Dec-84 Jan-85         | 93,139<br>21,418<br>13,990<br>1,200<br>1,200<br>1,200<br>18,621<br>17,647<br>40,025<br>61,011<br>224,609<br>261,443<br>147,595<br>99,322<br>30,073<br>37,219<br>1,200<br>4,940<br>22,847 | 420 3 420 4 0 5 0 6 0 7 0 8 420 9 420 10 420 11 420 12 420 13 420 14 420 15 0 16 420 17 0 18 420 19 420 20 Output 2 21 23 24 |               | Min Max Avg Oct-81 Jov-81 Jov-81 Jov-81 Jov-81 Jov-82 Mar-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-82 Jov-83  |                                | 37,36i<br>330,00<br>212,99<br>92,74;<br>90,78i<br>88,11:<br>86,610<br>87,31!<br>88,01!<br>82,266<br>62,620<br>52,25:<br>42,02!<br>38,780<br>100,65<br>110,34<br>118,42<br>136,42                                | (AF) Volume 7 0 3 3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5                       | me (AF) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0   | (AFM)  0 19,692 1,352 0 240 680 680 680 680 614 624 728 525 600 810 1,087 1,384 1,384 1,384 1,384 1,384 1,384 | (AFM)  2,862 303,831 46,753 40,265 14,646 11,817 8,105 7,549 10,218 24,650 55,732 98,054 79,954 61,795 50,284 56,442 44,561 31,635 19,931 17,965 22,397 43,943 | (AFM) 4,373 101,197 39,940 46,985 16,371 13,808 8,927 6,165 8,834 29,220 71,830 98,922 89,142 70,950 52,424 40,384 12,995 10,432 6,721 6,165 9,440 30,270 | (AFM)  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0  | (AFM) 0 7,000 4,281 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1,136 1,752 2,135 2,341 2,512 2,687 | 0<br>3,451<br>1,009<br>532<br>0<br>0<br>0<br>0<br>0<br>571<br>690<br>637<br>655<br>466<br>299<br>206<br>0<br>0 |      |

## **Calibration Result Graphs**



#### **Presentation Outline**

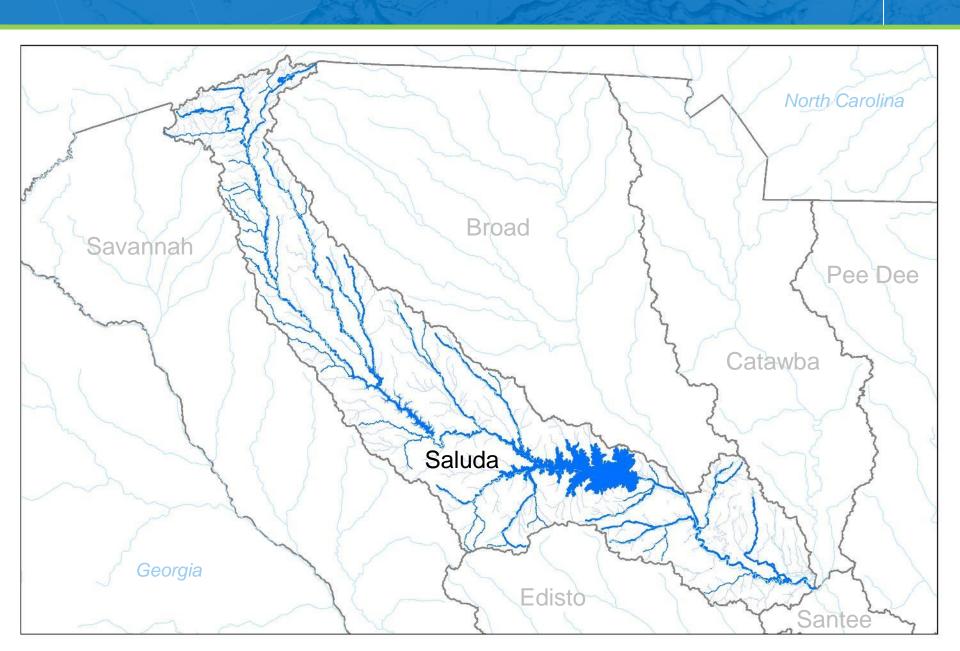
- Project Purpose, Overview and Schedule
- The Modeling Tool
- Saluda River Basin Unimpaired Flows and Pilot Model
- Stakeholder Involvement Opportunities







## Saluda Basin Pilot Model



#### Status of the Saluda Basin Pilot Model

- Data Collection is complete
  - DHEC withdrawal records, 2001 2014 (some back to 1985)
  - NPDES discharge records, 1989 2014
  - Utility-provided historical records, estimates, and start dates
  - Instream flow requirements and minimum releases
  - Streamflow and lake levels
  - Evaporation and precipitation

















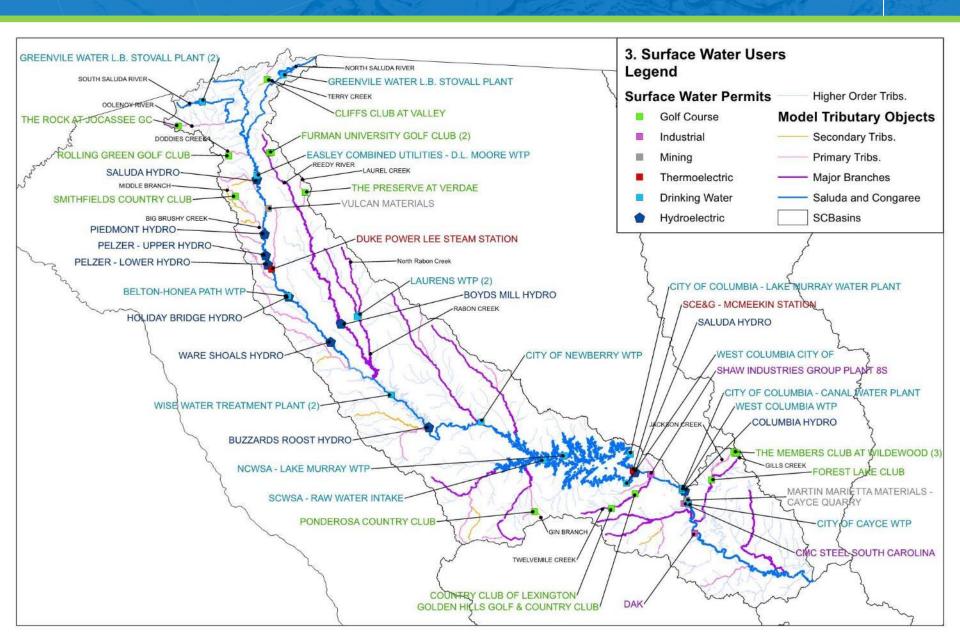
WCRSA/Reedy Import (Savannah)



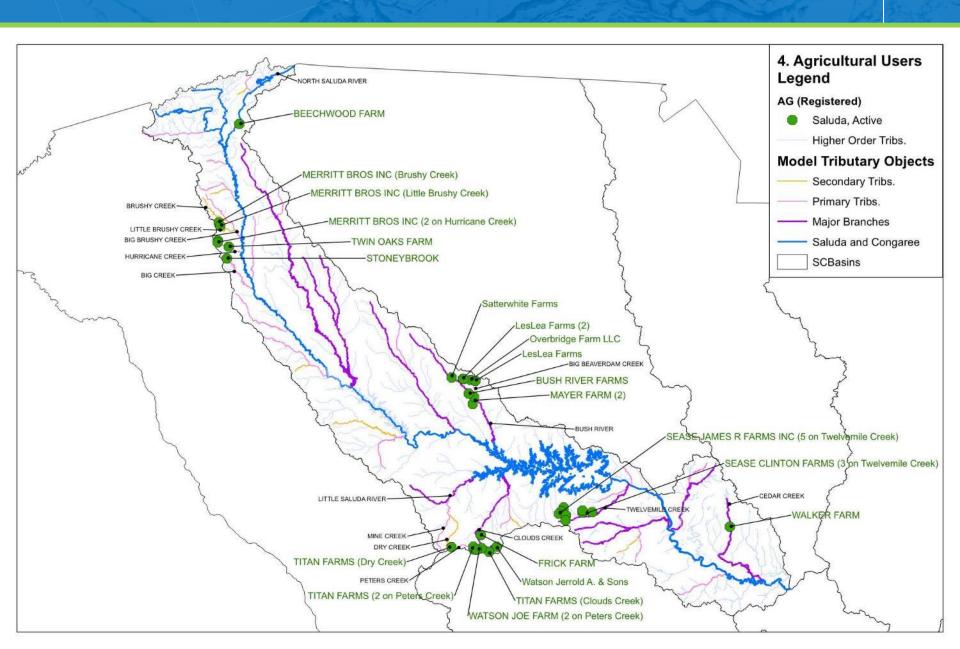
Lake Murray



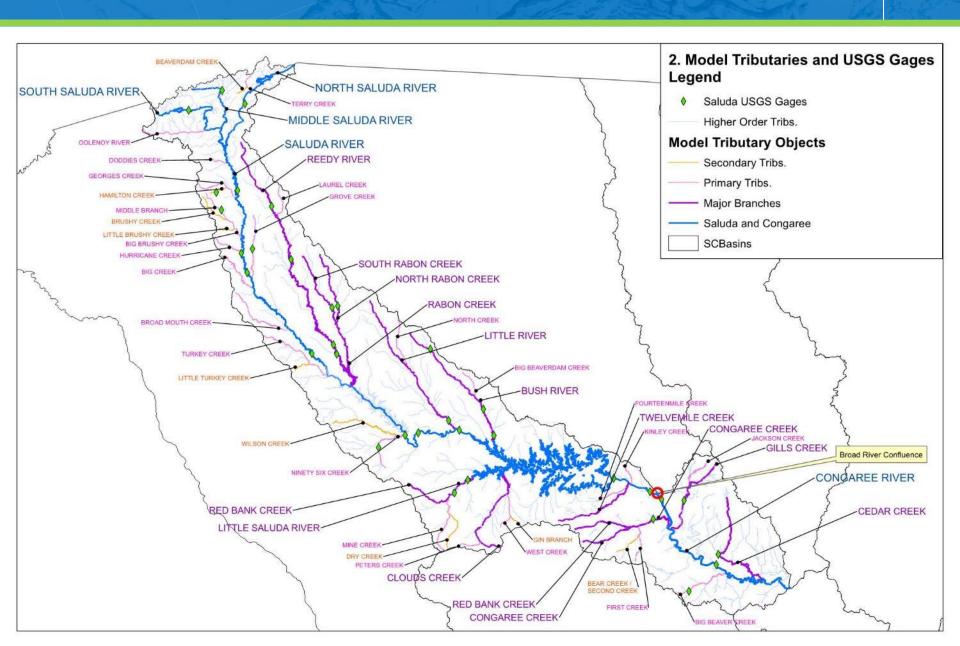
#### Saluda Basin – Permitted Users



## Saluda Basin – Registered Users



#### Saluda Basin – Model Tributaries



## Saluda Basin – Unimpaired Flow Dataset

- Unimpaired Flows (UIFs) are being developed for the Saluda Basin up to the confluence with the Broad River
  - 1925 to 2014

UIF Definitions: - Flow in a river as it would be in a completely unaltered state

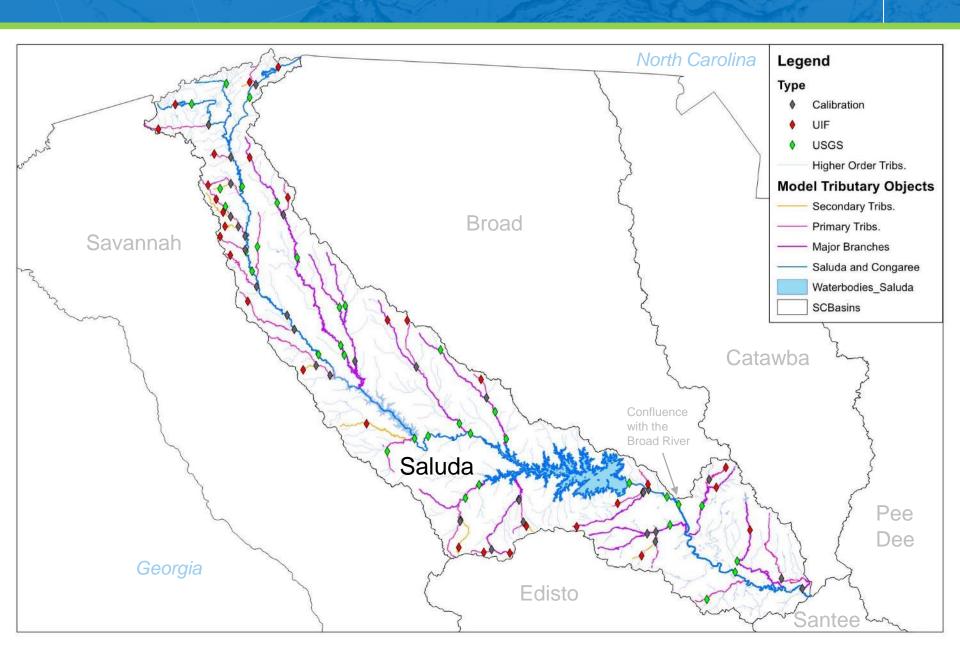
- Historically observed flows with human influences removed

UIFs Provide: - A baseline for evaluating impacts of human use by allowing

analysts to compare altered flows to UIFs

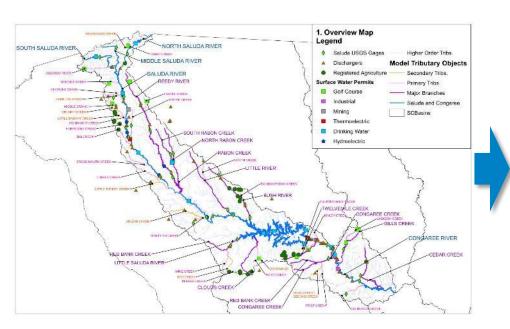
 UIF dataset will be extended into the Congaree River when Broad River UIFs are completed

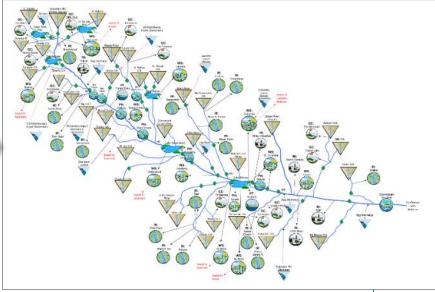
## Saluda Basin Unimpaired Flow Locations



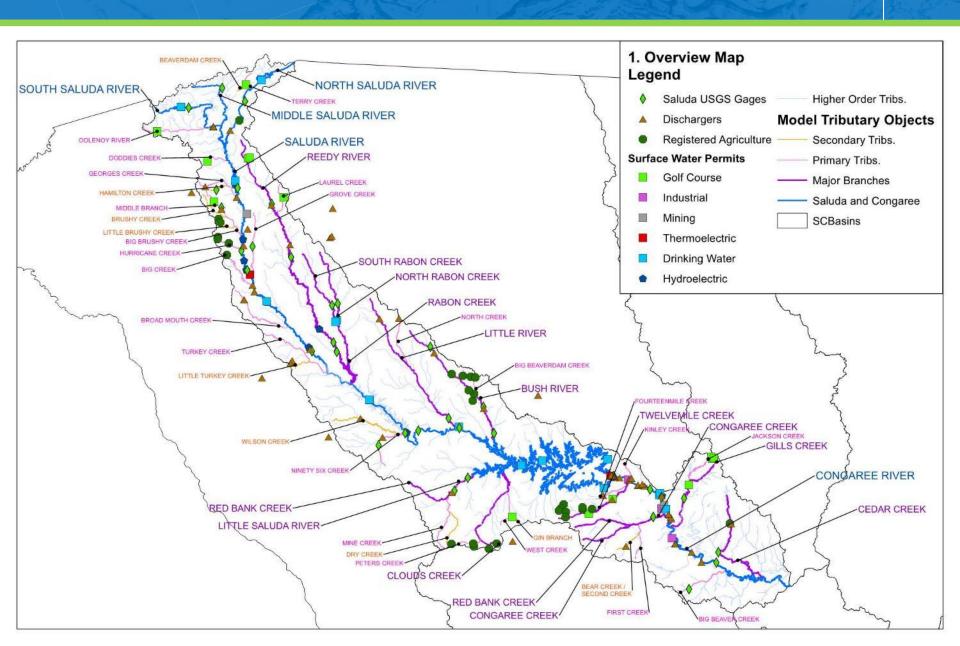
#### Saluda Basin Model Framework

 Draft Model Framework has been prepared for the entire Saluda Basin

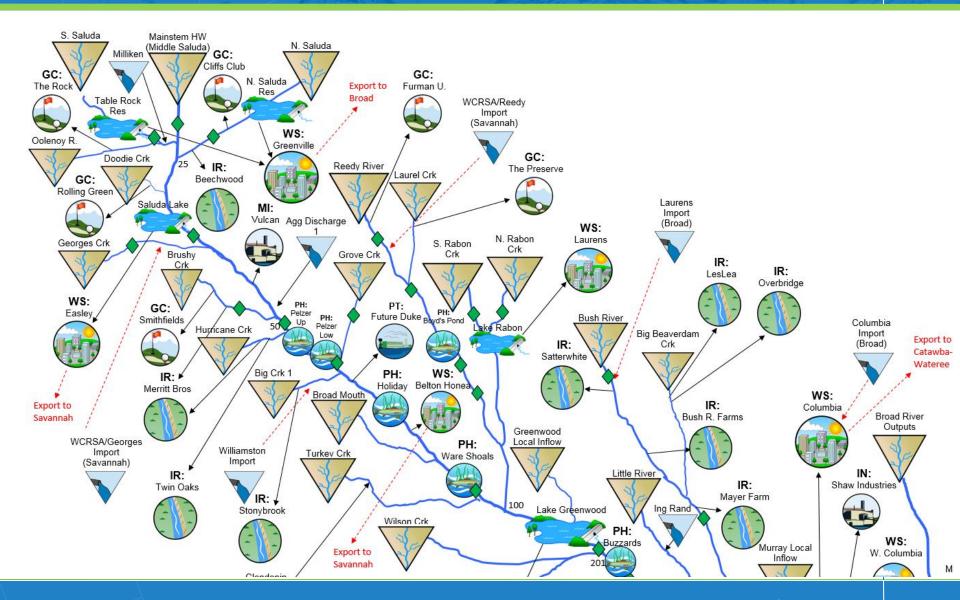




#### Saluda Basin Model Framework

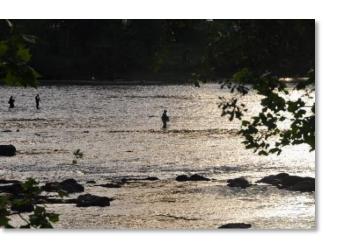


#### Saluda Basin Model Framework



#### **Presentation Outline**

- Project Purpose, Overview and Schedule
- The Modeling Tool
- Saluda River Basin Unimpaired Flows and Pilot Model
- Stakeholder Involvement Opportunities







- Stakeholder engagement is being led by Clemson University
- Two meetings per basin are planned
- A webinar is being developed to provide an introduction to the project.





#### **Project Overview (Webinar)**

Model Development **Baseline Model Basin** Model **Schematic Calibration** Runs Model framework Reproduce actual Simulate current development conditions conditions **Training** Stakeholder Stakeholder Meeting #1 Meeting #2

- Meeting #1 Review of Basin Framework (Workshop Format)
  - Are all interests included in the framework?
  - Are all important tributaries being represented?
  - Are additional model nodes needed for environmental flows?
  - Are there significant data gaps which still need filling?
- Saluda Basin Meeting #1

– Date/Time: Tuesday, April 21<sup>st</sup>, 2:00 - 4:00 pm

– Location: Clemson ICAR

5 Research Drive, Greenville

#### Meeting #2 - Review of Unimpaired Flow Dataset and Baseline Model

- Review of UIF development and gap filling
- Review of baseline model
- Review of model calibration and verification results
- Review of model uses and limitations

#### Training

Training to interested parties will be provided for each basin model

# Project Web Page www.dnr.sc.gov/water/waterplan/surfacewater.html

