

IGSM2 Enhancements (Version 2.0)

California Water and Environmental Modeling Forum

Asilomar Conference Center, California

February 24 - 26, 2004

Can Dogrul

California Department of Water Resources



Categories of Enhancements to IGSM2

- Enhancements in theory and numerical methods
- Changes in source code to enhance the portability and applicability
- Improvements in the input and output files for clarity; additional output files for the extraction of simulation results; improved documentation
- Additional features that can be utilized during simulation



Modifications/Improvements in IGSM2 v2.0

- Any time step can be used
- Dynamic dimensioning of Fortran arrays (allows efficient use of memory and avoids re-dimensioning of arrays at compile time for individual applications)
- Options to print out tile drain hydrographs, boundary node flows, vertical flows between layers and simulation results at the last time step
- Improvements in computation and appearance of budget tables



Theoretical Enhancements in IGSM2 v2.0: *Groundwater, Streams and Lakes*

- **Solution of non-linear groundwater equation**
- **Changes and improvements in the simulation of stream flows and lake storages**
- **Non-linear stream-groundwater and lake-groundwater interactions**
- **Simultaneous solution of groundwater, stream and lake equations using fully-implicit method and Newton-Raphson linearization technique for robust computation of interactions among these components**



Theoretical Enhancements in IGSM2 v2.0: *Groundwater, Streams and Lakes (continued)*

- Coupled stream, lake and groundwater equations:

$$\left. \begin{aligned} \left[\mathbf{X}_s^{t+1} \right] \left\{ \mathbf{h}_s^{t+1} \right\} + \left\{ \mathbf{F}_s^{t+1} \right\} &= \mathbf{0} \\ \left[\mathbf{X}_{lk}^{t+1} \right] \left\{ \mathbf{h}_{lk}^{t+1} \right\} + \left\{ \mathbf{F}_{lk}^{t+1} \right\} &= \mathbf{0} \\ \left[\mathbf{X}_g^{t+1} \right] \left\{ \mathbf{h}_g^{t+1} \right\} + \left\{ \mathbf{F}_g^{t+1} \right\} &= \mathbf{0} \end{aligned} \right\} \Rightarrow \left[\mathbf{X}^{t+1} \right] \left\{ \mathbf{H}^{t+1} \right\} + \left\{ \mathbf{F}^{t+1} \right\} = \mathbf{0}$$

$$\left\{ \mathbf{H}^{t+1} \right\}^T = \left\{ \mathbf{h}_{s_1}^{t+1}, \dots, \mathbf{h}_{s_{NS}}^{t+1}, \mathbf{h}_{lk_1}^{t+1}, \dots, \mathbf{h}_{lk_{NLK}}^{t+1}, \mathbf{h}_1^{t+1}, \dots, \mathbf{h}_{N \times NL}^{t+1} \right\}$$



Theoretical Enhancements in IGSM2 v2.0: *Groundwater, Streams and Lakes (continued)*

- Newton-Raphson iteration technique for the solution of coupled system of equations:

$$\left[\left(X^{t+1} \right)^k \right] \left\{ \left(\Delta H^{t+1} \right)^{k+1} \right\} = \left\{ \left(F^{t+1} \right)^k \right\}$$

$$\text{where } \left(\Delta H_i^{t+1} \right)^{k+1} = \left(H_i^{t+1} \right)^{k+1} - \left(H_i^{t+1} \right)^k$$

$$\left(F_i^{t+1} \right)^k = \sum_{j=1}^{N \cdot m} \left(X_{i,j}^{t+1} \right)^k \left(H_j^{t+1} \right)^k + \left(F_i^{t+1} \right)^k$$

$$\left(X_{i,j}^{t+1} \right)^k = \left(\frac{\partial F_i^{t+1}}{\partial H_j^{t+1}} \right)^k$$



Theoretical Enhancements in IGSM2 v2.0:

Water Demand and Supply

- Irrigation fractions for pumping and surface water diversions are defined as time series data
- Program termination if water supply is specified for agricultural or urban area where such area is zero
- Iterative computation of actual pumping amount at drying wells for proper computation of water supply to agricultural and urban areas



Theoretical Enhancements in IGSM2 v2.0: *Automated Adjustment of Water Supply*

- Stream diversions and/or groundwater pumping can be adjusted to minimize the discrepancy between the water demand and supply
- Diversions and pumping can be adjusted to meet only agricultural demand, only urban demand, or both
- Adjustment of diversions and pumping can be pre-specified to turn on or off throughout the simulation period
- IGSM2 proportionally distributes the difference between the demand and supply among adjusted diversions and pumping



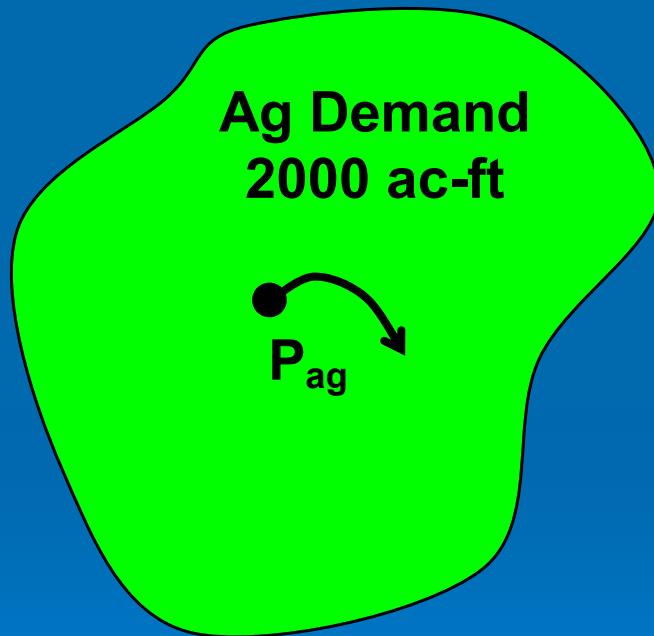
Theoretical Enhancements in IGSM2 v2.0: *Automated Adjustment of Water Supply (cont.)*

- IGSM2 adjusts “required” amount of diversions and pumping to meet the demand; there can still be shortages depending on the availability of water in the system
- Adjustment of supply is performed until the ratio of actual supply to the demand is smaller than a user-defined tolerance value
- Irrigation fractions specified by the user are altered during supply adjustment

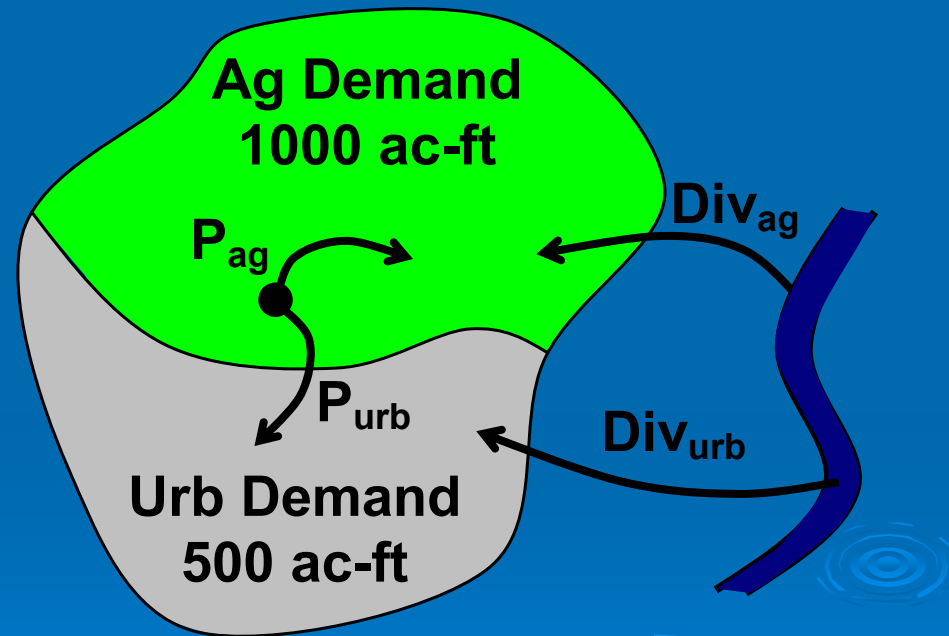


Theoretical Enhancements in IGSM2 v2.0: *Automated Adjustment of Water Supply (cont.)*

Year = 2005



Year = 2010



Future Enhancements

- Computation of velocity field based on simulated groundwater head field to report mass balance at individual nodes (*in progress*)
- Choice of solvers for matrix equations (*partially completed*)
- Option to run IGSM2 simultaneously for adjacent model areas
- Inclusion of reservoir simulation and water rights module

