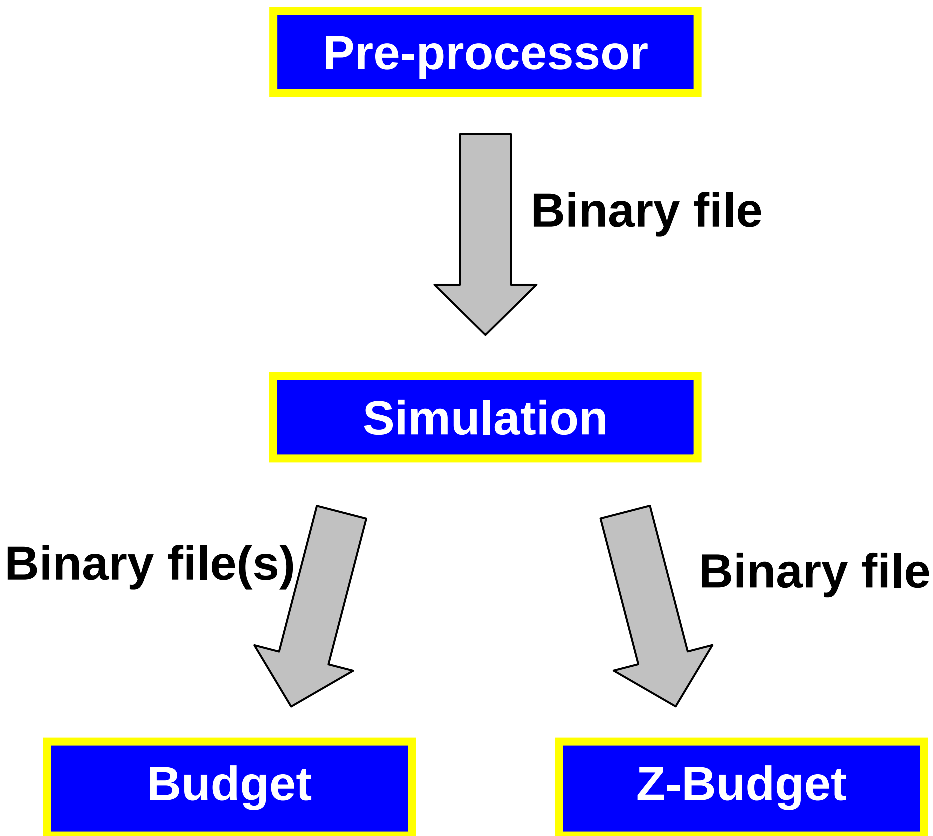
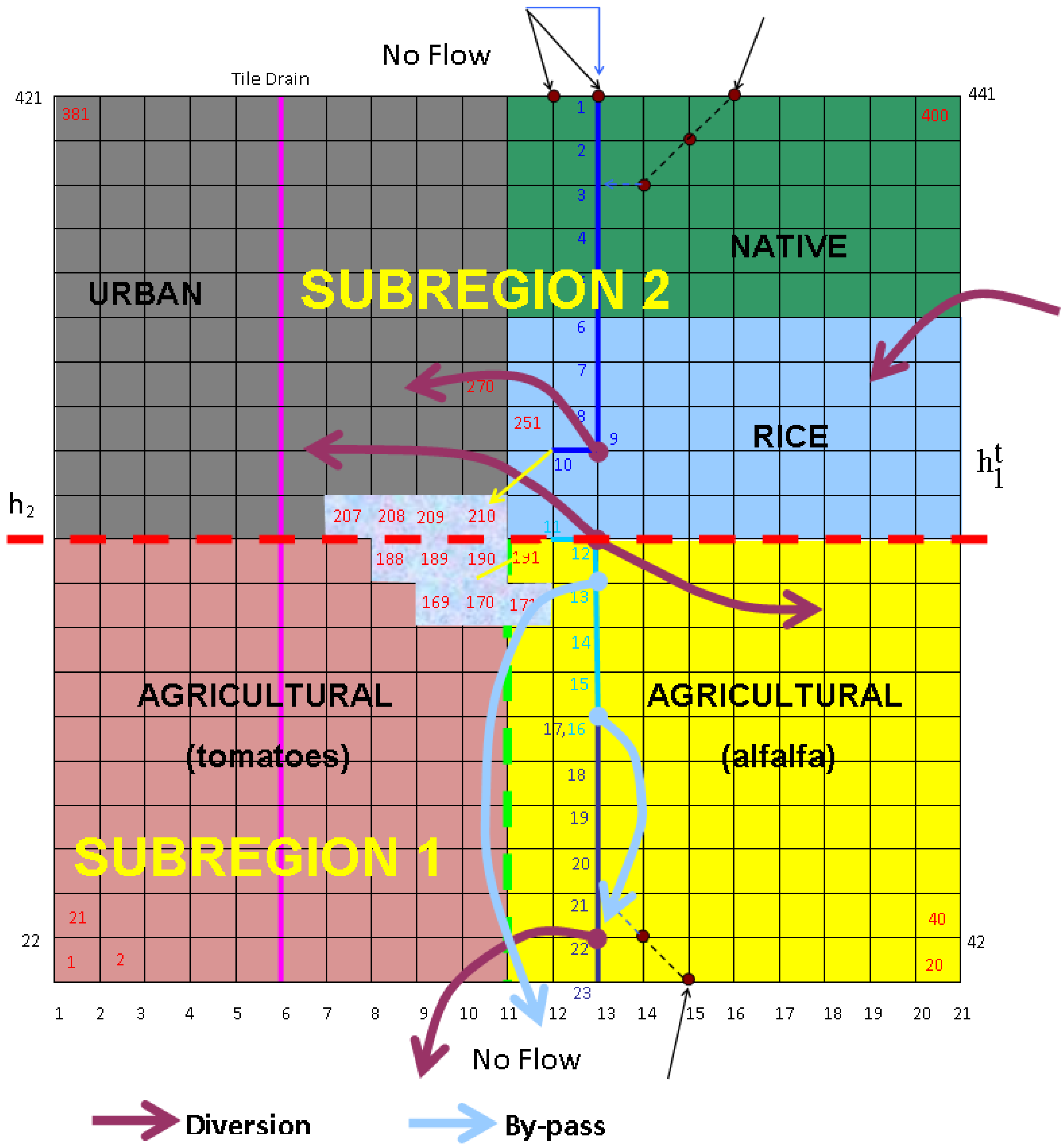
IWFM Program Execution



Sample Problem



Description:

Simulation control parameters:

- Time step = 1 day
- Simulation period = 10 years
- Simulation begin date and time = September 30, 1990 midnight (09/30/1990_24:00)
- Simulation ending date and time = September 30, 2000 midnight (09/30/2000_24:00)
- Matrix inversion method: Generalized Preconditioned Conjugate Gradient method
- Maximum number of iterations for the solution of system of equations = 1500
- Maximum number of iterations for supply adjustment = 50
- Convergence criteria for groundwater, stream and lake head difference = 0.0001 ft
- Convergence criteria for iterative supply adjustment = 0.001
- Both pumping and diversions are adjusted to meet urban and agricultural water demand.

Finite Element Mesh:

- 400 elements with 441 nodes. $\Delta x = \Delta y = 2000$ ft
- The model area is divided into 2 subregions. Elements 1-200 belong to subregion 1 and elements 201-400 belong to subregion 2.

Stratigraphy:

- The ground surface elevation is at 500 ft and the first layer aquifer thickness is 500 ft except at the following nodes:

Node	Ground surface elevation (ft)	Aquifer thickness (ft)
177	270	270
178	270	270
179	270	270
180	270	270
197	270	270
198	270	270
199	250	250
200	270	270
201	270	270
217	270	270
218	270	270
219	250	250
220	250	250
221	270	270
238	270	270
239	270	270
240	270	270
241	270	270
242	270	270

- The thickness of first layer aquiclude is zero.
- The thickness of second layer aquiclude is 10 ft at nodes 1-231, and zero at nodes 232-441.
- Thickness of the second layer aquifer is 100 ft.

Streams:

There are 23 stream nodes. The following tables list the stream reach and stream node characteristics:

Reach #	Upstream node	Downstream node	Outflow node
1	1	10	Lake #1
2	11	16	17
3	17	23	0

Stream node #	Bottom elevation (ft)	Groundwater node
1	300	433
2	298	412
3	296	391
4	294	370
5	292	349
6	290	328
7	288	307
8	286	286
9	284	265
10	282	264
11	282	222
12	280	223
13	278	202
14	276	181
15	274	160
16	272	139
17	272	139
18	270	118
19	268	97
20	266	76
21	264	55
22	262	34
23	260	13

- The following rating table is used at all stream nodes:

Stream depth (ft)	Q (cfs)
0	0
2	734.94
5	3299.29
15	19033.60
25	41568.45

- Hydraulic conductivity of the stream bed material, thickness of the bed material and wetted perimeter at all stream nodes are 10 ft/day, 1 ft and 150 ft, respectively.
- There is constant inflow of 1000 cfs into stream node 1.

Lakes:

- There is a single lake being modeled that spans elements 207, 208, 209, 210, 188, 189, 190, 169, 170 and 171.
- Maximum lake elevation is 285 ft and spill from the lake flows into stream node 11.
- Hydraulic conductivity and the thickness of the lake bed material are 2 ft/day and 1 ft, respectively.
- Initial lake elevation is 280 ft.
- Lake evaporation and precipitation are given in the following table for a water year. The same values are used for all simulation years.

Month	Evaporation (in)	Precipitation (in)
October	3.7	4.0
November	1.8	5.0
December	1.2	6.0
January	1.1	5.0
February	1.8	60.0
March	2.8	70.0
April	3.9	80.0
May	5.1	4.0
June	7.2	1.0
July	7.5	5.0
August	6.4	0.0
September	4.8	0.0

Aquifer parameters:

- Both layers of aquifer are homogeneous and have the following characteristics:

Horizontal hydraulic conductivity	50 ft/day
Specific storage	1×10^{-6} 1/ft
Specific yield	0.25
Aquitard vertical hydraulic conductivity	0.2 ft/day
Aquifer vertical hydraulic conductivity	1.0 ft/day
Elastic storage coefficient of interbed layers	5×10^{-6} 1/ft
Inelastic storage coefficient of interbed layers	5×10^{-5} 1/ft
Interbed thickness	10 ft
Minimum interbed thickness	2 ft
Pre-compaction head	Equal to the initial groundwater head

- There are no anomalies in the hydraulic conductivity.

Unsaturated zone parameters:

- Convergence criterion as a fraction of the total porosity is 1×10^{-6} with maximum number of iterations at 150.
- The unsaturated zone is modeled in 2 layers. Both layers are homogeneous and have the following characteristics:

Thickness of unsaturated layer	20 ft
Total porosity	0.3 ft/ft
Pore size distribution index	0.35
Saturated hydraulic conductivity	10 ft/day

- van Genuchten-Mualem equation is used to model hydraulic conductivity-moisture content curve
- The unsaturated zone is initially dry.

Tile drains:

- Tile drains are located at 280 ft elevation in the first layer parallel to y-axis at x = 10000 ft (corresponds to 6th column from left in the finite element mesh used for this problem). The conductance of the interface between the tile drains and the aquifer is 20000 ft^2/day. Flow from tile drains contribute to stream node 20.

Groundwater boundary and initial conditions:

- The left boundary at the first aquifer layer has a specified head of 290 ft. The right boundary of the first aquifer layer has specified head of 310 ft between September 30, 1990 midnight – September 30, 1995 midnight and 350 ft between September 30, 1995 midnight – September 30, 2000 midnight. All other boundaries are defined as no flow boundaries.
- The initial head in the first and second aquifer layers are 280 ft and 290 ft, respectively.

Small watersheds

- There are 3 small watersheds simulated. The characteristics of 3 small watersheds are given as follows:

Small watershed #	Surface area (ft^2)	Contributes to stream node	Groundwater nodes for direct subsurface contribution	Groundwater nodes for contribution as percolation from surface water	Max. percolation from surface water (ft^3/day)
1	6000000	1	432 433	none	none
2	5000000	3	436	414 392	10000 5000
3	5000000	21	15	35	2000

- The following parameters are used for the small watersheds:

Parameter	Small Watershed 1	Small Watershed 2	Small Watershed 3
WPS	0.10	0.02	0.05
FLDCAS	0.13	0.08	0.11
TPOROS	0.20	0.10	0.22
LAMDAS	0.18	0.18	0.21
CROOT	3.0	8.0	5.0
SOILKS	5.0	5.0	8.0
RHCS	2	2	2
CN	80	75	71
GWSOS	10.0	7.0	12.0
GWSOX	20.0	15.0	21.0
SWKS	0.4	0.3	0.4
GWKS	0.002	0.003	0.001

- Convergence criterion for the root zone in small watersheds is 1×10^{-3} times the total porosity with maximum number of iterations at 150.
- Evapotranspiration and precipitation in small watersheds are given as follows:

Month	Evaporation (in)	Precipitation (in)
October	3.4	4.0
November	1.6	5.0
December	1.2	6.0
January	1.1	5.0
February	1.8	60.0
March	2.8	70.0
April	3.9	80.0
May	5.1	4.0
June	7.2	1.0
July	7.5	5.0
August	6.4	0.0
September	4.8	0.0

Above values are valid throughout the entire simulation period.

- Initial soil moisture for all small watersheds is at field capacity (given as the variable FLDCAS above). The initial groundwater depth for all small watersheds is at 7.0 ft.

Root zone characteristics:

- The model area has 4 types of soil: i) elements 1 – 100 are sandy loam, ii) elements 101 – 200 are silt loam, iii) elements 201 – 300 are clay, and iv) elements 301 – 400 are silty clay loam. The following values have been defined for the modeled soil types in the root zone:

Elements	Wilting point (ft/ft)	Field capacity (ft/ft)	Total Porosity (ft/ft)	Pore Size Distribution Index	Hydraulic Conductivity (cm/hr)
1 – 100	0.0	0.20	0.45	0.62	2.60
101 – 200	0.0	0.33	0.50	0.36	0.68
201 – 300	0.0	0.40	0.48	0.29	0.01
301 - 400	0.0	0.37	0.47	0.32	0.15

- van Genuchten-Mualem equation is used to represent the hydraulic conductivity versus moisture content curve
- First 10 elements are associated with rain gage 1. Rest of the elements are associated with rain gage 2. Rainfall factor for all elements are 1.0. The precipitation at these gages are as follows:

Time (month)	Rainfall at station 1 (in/month)	Rainfall at station 2 (in/month)
October	1	4
November	2	5
December	3	6
January	2.5	5
February	25	60
March	35	70
April	40	80
May	2	4
June	0.5	1
July	2.5	5
August	0	0
September	0	0

- Surface flow from elements 1-200 drain into stream node 18, whereas elements 201-400 drain into stream node 6.
- Convergence criteria for the solution of the non-linear root zone moisture mass balance equation is 0.001 times the total porosity.
- Maximum number of iterations is 150.

Non-ponded crop characteristics:

- Lower left quadrant of the model area is used for growing tomatoes whereas alfalfa is grown in the lower right quadrant (see the accompanying figure). This distribution does not change over the simulation period. Also note that lake areas are considered to be part of native vegetation type land use.
- The rooting depths for tomatoes and alfalfa are 5.0 and 6.0 ft, respectively.
- Curve numbers for both crops are 65 for elements 1 – 100, 75 for elements 101 – 200, 90 for elements 201 – 300, and 85 for elements 301 – 400.
- The following crop management parameters are defined:

	Tomatoes			**Alfalfa**		
Month	**ET (in)**	**Irrigation Period**	**Min. Soil Moisture (ft/ft)**	**ET (in)**	**Irrigation Period**	**Min. Soil Moisture (ft/ft)**
October	3.4	0	0.6	3.5	1	0.45
November	1.6	0	0.6	1.6	0	0.45
December	1.0	0	0.6	1.0	0	0.45
January	1.0	0	0.6	1.0	0	0.45
February	1.8	0	0.6	1.8	0	0.45
March	3.0	0	0.6	3.0	1	0.45
April	4.5	1	0.6	4.1	1	0.45
May	5.9	1	0.6	5.4	1	0.45
June	7.3	1	0.6	6.8	1	0.45
July	7.9	1	0.6	7.7	1	0.45
August	6.6	1	0.6	6.8	1	0.45
September	5.2	1	0.6	5.4	1	0.45

- Return flow for both crops is 10% of the applied water.
- Re-use for both crops is 6% of the applied water.
- Initial soil moisture is at field capacity. 90% of this moisture is due to previous precipitation events.

Ponded crop characteristics:

- Rice with no decomposition is grown in the lower half of the upper right quadrant of the model area.
- Rooting depth for rice is 2.0 ft.
- Curve numbers are 65 for elements 1 – 100, 75 for elements 101 – 200, 90 for elements 201 – 300, and 85 for elements 301 – 400.
- The following ET, ponding depth, irrigation period, return flow and re-use values are utilized:

Month	ET (in)	Pond Depth (in)	Irrigation Period	Return Flow (in)	Re-use (in)
October	2.2	0.0	0	0.0	0.0
November	1.6	0.0	0	0.0	0.0
December	1.0	0.0	0	0.0	0.0
January	1.0	0.0	0	0.0	0.0
February	1.8	0.0	0	0.0	0.0
March	3.0	0.0	0	0.0	0.0
April	8.0	0.0	0	0.0	0.0
May	9.1	3.0	1	2.0	0.0
June	10.4	5.0	1	2.0	0.0
July	9.7	8.0	1	2.0	0.0
August	7.0	0.0	0	0.0	0.0
September	1.9	0.0	0	0.0	0.0

- Initial soil moisture is at field capacity. 90% of this moisture is due to previous precipitation events.

Urban water demand and water use characteristics:

- Upper left quadrant of the model area is urbanized.
- Rooting depth for the urban outdoors is 2.0 ft.
- 50% of the urban area is pervious.
- The total population is 1000. For the first 6 months of each calendar year per capita water use is 0.3 ac-ft/month, and 0.4 ac-ft/month for the rest of the year. This pattern is valid for the entire simulation period.
- Urban water is distributed equally to all urban grid cells.
- 70% of water delivered to urban areas is used indoors at all times.
- 15% of the urban outdoors applied water becomes return flow. Return flow from urban outdoors is not re-used.
- Curve numbers are 65 for elements 1 – 100, 75 for elements 101 – 200, 90 for elements 201 – 300, and 85 for elements 301 – 400.
- The following ET values are used:

Month	**ET (in)**
October	3.4
November	1.6
December	0.5
January	0.5
February	1.8
March	3.0
April	4.5
May	5.9
June	7.3
July	7.9
August	6.6
September	5.2

- Initial soil moisture is at field capacity. 90% of this moisture is due to previous precipitation events.

Native vegetation characteristics:

- Upper half of the upper right quadrant of the model domain is covered with native vegetation.
- Rooting depth is 3.0 ft.
- Curve numbers are 65 for elements 1 – 100, 75 for elements 101 – 200, 90 for elements 201 – 300, and 85 for elements 301 – 400.
- The following ET values are used:

Month	**ET (in)**
October	3.4
November	1.6
December	1.0
January	1.0
February	1.8
March	3.0
April	4.5
May	5.9
June	7.3
July	7.9
August	6.6
September	5.2

- Initial soil moisture is at field capacity.

Water supply due to surface water diversions:

- There are 5 diversions to meet the urban and agricultural water demand. The diversion specifications are as follows (recharge locations of recoverable losses are the same):

Diversion ID	Stream node	Total diversion amount (tac-ft/month)	Fraction of diversion for recoverable loss	Fraction of diversion for non-recoverable loss	Delivery subregion	Fraction of diversion that is actually delivered	Fraction of delivery used for irrigation
1	9	3.0	0.01	0.01	2	0.98	0.0
2	12	3.0	0.02	0.02	2	0.96	0.0
3	12	3.0	0.01	0.02	1	0.97	1.0
4	22	3.0	0.00	0.01	outside	0.99	1.0
5	0	3.0	0.00	0.01	elements with rice	0.99	1.0

- The portions of the diversions that become recoverable loss are allowed to contribute to the groundwater at the following elements:

Diversion ID	Elements for recharge	Relative proportion of the recoverable loss to be applied to the element
1	251 270	1.0 1.0
2	191	1.0
3	193 174 155	1.0 1.0 1.0
4	none	none
5	none	none

By-passes:

- There are 2 by-pass flows defined. 1 by-pass flow originates from stream node 13 and ends outside the model area. 6000 ac-ft/month of water is required to be by-passed. There are no recoverable or non-recoverable losses. Another by-pass flow originates from stream node 17 and ends in stream node 22. There are no recoverable losses and 10% of the by-pass flow is assigned as non-recoverable loss. This by-pass flow is given as a rating table as follows:

Stream flow (ac-ft/day)	By-pass flow (ac-ft-/day)
0.0	0.0
1.0	0.5
18.0	9.0
8000.0	4000.0

Water supply due to pumping:

- There are 3 elemental pumping defined at elements 73, 193 and 333. Also, there are 2 elemental recharge defined at elements 134 and 274.
- The following pumping and recharge schedule is used for each year of the simulation period:

Month	Pumping (tac-ft/month)	Recharge (tac-ft/month)
October	3.5	0
November	3.5	0
December	3.5	0
January	3.5	0
February	3.5	0
March	3.5	0
April	0	6
May	0	6
June	0	6
July	0	6
August	0	6
September	0	6

  Above pumping schedule is repeated for each year. Both pumping and recharge are distributed equally between pumping and recharge elements.

- Both pumping and recharge are distributed equally between 2 layers at each element.
- Pumping from element 73 and 193 are delivered to subregion 1 and 100% of it is used for irrigation. Pumping from element 333 is delivered to subregion 2 and used 100% to meet the urban water demand.

Output:

- When Simulation is executed, the following text output files are generated:
  - (i) Element face flows at selected element faces (FaceFlow.out)
  - (ii) Flow hydrographs at selected boundary nodes (BoundaryFlow.out)
  - (iii) Tile drain hydrographs at groundwater nodes 6, 69, 132, 195, 258 and 321 (TileDrainFlows.out)
  - (iv) Stream flow hydrographs at all stream nodes (StrmHyd.out)
  - (v) Groundwater hydrographs at selected groundwater nodes (GWHyd.out)
  - (vi) Groundwater hydrographs at all groundwater nodes (GWHeadAll.out)
  - (vii) Vertical flows between layers (VerticalFlow.out)
  - (viii) Final simulation results for each of the components (FinalGWHeads.out, FinalSubsidence.out, FinalLakeElev.out, FinalRootZoneMoist.out, FinalUnsatZoneMoist.out)
- When Budget is executed, the following budget tables are generated under the *Budget* folder:
  - (i) Groundwater (GW.bud)
  - (ii) Stream reach (Strm.bud)
  - (iii) Stream at selected nodes (StrmNode.bud)
  - (iv) Root zone (RootZone.bud)
  - (v) Root zone for tomatoes (RootZone_TO.bud)
  - (vi) Land and water use (LWU.bud)
  - (vii) Land and water use for tomatoes (LWU_TO.bud)
  - (viii) Lake (Lake.bud)
  - (ix) Diversion detail (DiverDetail.bud)
  - (x) Small watershed (SWShed.bud)
  - (xi) Unsaturated zone (UnsatZone.bud)

- When Z-Budget is executed, the following zone budget tables are generated under the *Z-Budget* folder:

  (i) Annual groundwater zone budget with simulated subregions as zones (GW_ZBudget.bud)

  (ii) Monthly land and water use zone budget with elements 1-10 as one zone LWU_ZBudget.bud)

  (iii) Daily root zone zone budget with elements 1-10 as one zone (RootZone_ZBudget.bud)

  (iv) Annual unsaturated zone zone budget with the fist unsaturated layer in subregion 1 as a zone (UnsatZone_ZBudget.bud)