

# **Integrated Water Flow Model (IWFM): A Hydrologic Modeling Toolset for Today's Water Resources Management Challenges**

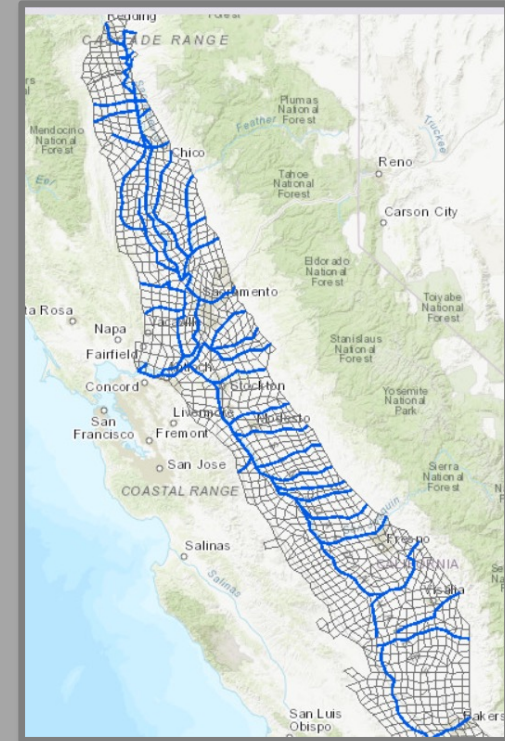
**CWEMF Annual Meeting  
Folsom, California  
April 4 – 6, 2022**

**Emin Can Dogrul  
California Department of Water Resources**



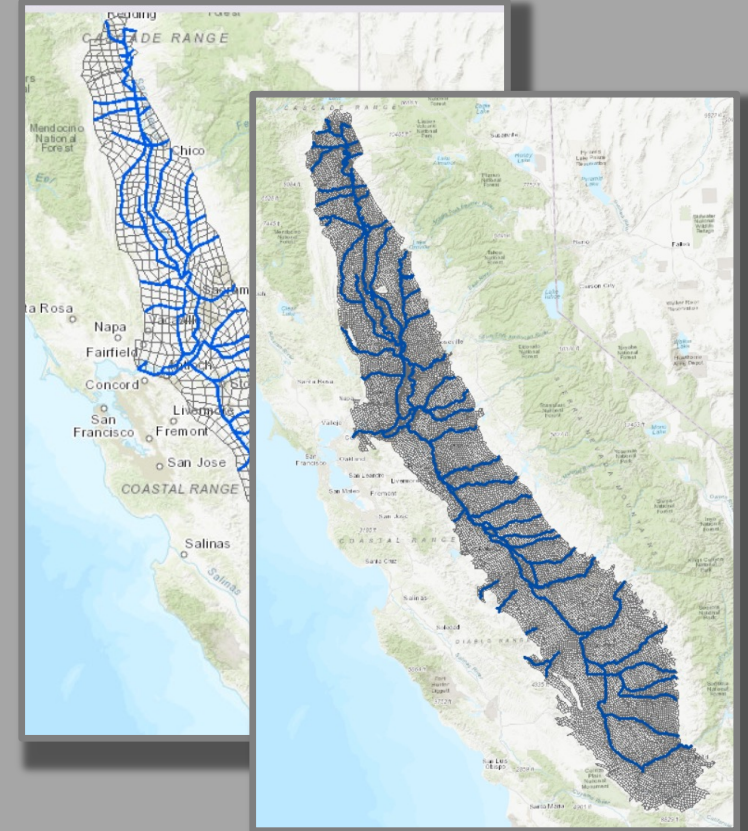
# IWFM: Integrated **W**ater **F**low **M**odel

- Generic integrated hydrologic modeling software
- Simulates water flow within the hydrologic cycle; land surface, root zone, unsaturated zone, groundwater, streams, lakes
- Calculates agricultural and urban water demands; uses stream diversions and groundwater pumping to meet the demands
- Notable applications: C2VSimCG



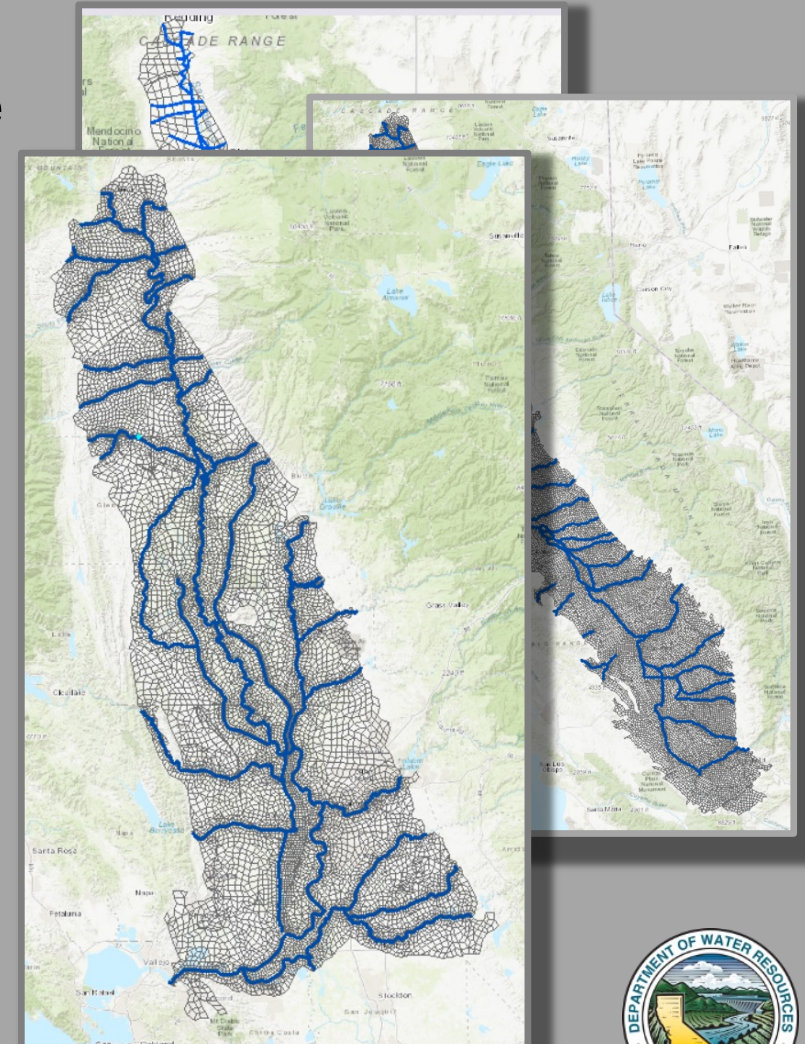
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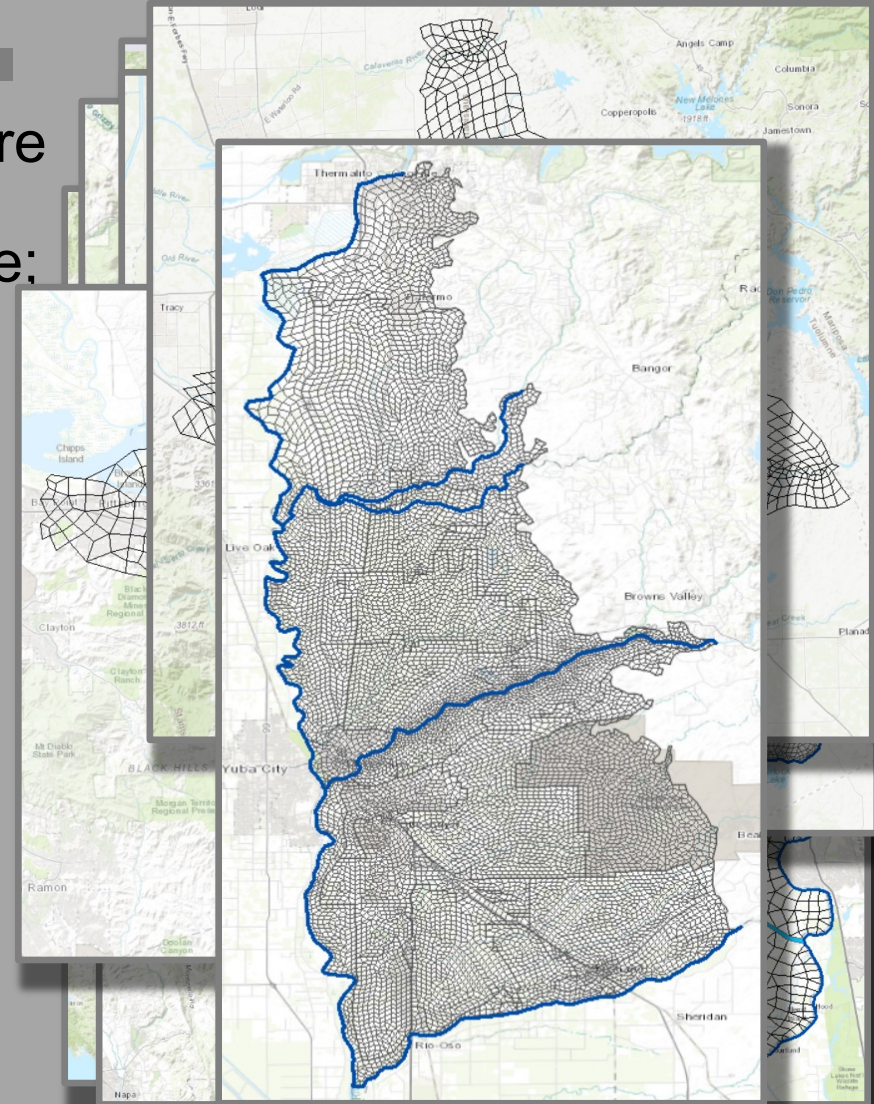
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- Calculates agricultural and urban water demands; uses stream diversions and groundwater pumping to meet the demands
- Notable applications: C2VSimCG, C2VSimFG, SVSim, local models to assist development of GSPs



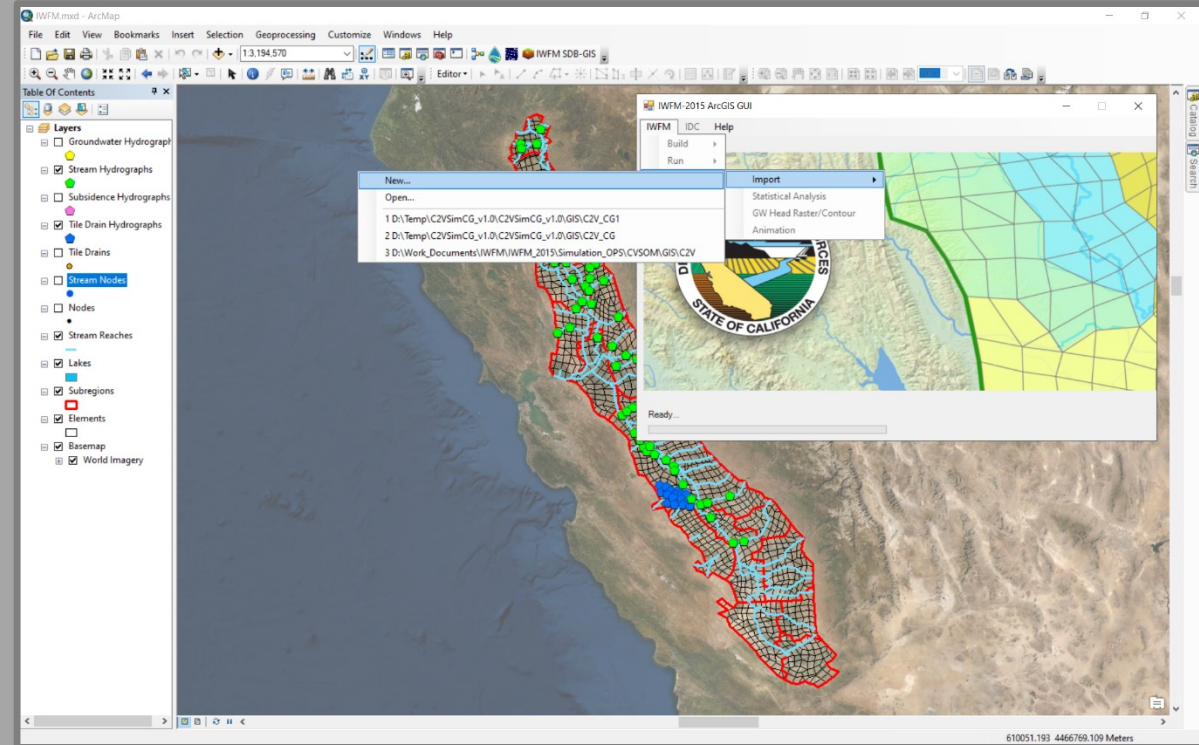
# Some Requirements for IWFM

- Accurate simulation of the physical system
- Reusability: Ability to use the same model codeset for different purposes
  - ❖ Develop applications
  - ❖ Power visualization and analysis tools, graphical user interfaces
  - ❖ Link to other types of models
  - ❖ Callable from different programming languages
- Adoptability: Ability to incorporate new simulation techniques without affecting previously developed applications
- Modularity: Ability to split the model into smaller, stand-alone components
- Speed in running applications and in retrieving results



# Reusability: Post-Processing and Analysis Tools

- Initial need emerged when developing post-processing tools
  - ❖ IWFM ArcMap Graphical User Interface



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  - ❖ IWFM Tools Excel Add-in

The screenshot displays an Excel spreadsheet titled 'IWFM ROOT ZONE PACKAGE (v4.11.0076)'. The spreadsheet contains a table with the following data:

Time	Ag. Area (AC)	Ag. Area (AF)	Water Ag.	Net Return Flow	Ag. Beginning Storage (+) Ag.
10/31/1973 12:00 AM	29499.10		0.00	30.94	16580.27
11/30/1973 12:00 AM	29499.10		0.00	2.56	14546.25
12/31/1973 12:00 AM	29499.10		0.00	2.29	15774.53
01/31/1974 12:00 AM	29499.10		0.00	4.85	15642.14
02/28/1974 12:00 AM	29499.10		0.00	16.02	15458.40
03/31/1974 12:00 AM	29499.10		0.00	21.20	14655.24
04/30/1974 12:00 AM	29499.10		0.00	871.77	15238.40
05/31/1974 12:00 AM	29499.10		0.00	479.69	14366.06
06/30/1974 12:00 AM	29499.10		0.00	513.31	13744.58
07/31/1974 12:00 AM	29499.10		0.00	454.07	13357.44
08/31/1974 12:00 AM	29499.10		0.00	523.55	14586.88
09/30/1974 12:00 AM	29499.10		0.00	445.61	13826.77
10/31/1974 12:00 AM	29499.07	3393.24	4458.93	195.84	2771.55
11/30/1974 12:00 AM	29499.07	2263.14	3819.11	106.83	801.63
12/31/1974 12:00 AM	29499.07	2341.54	11326.58	2802.47	46.37
01/31/1975 12:00 AM	29499.07	3722.55	5389.42	550.16	127.84
02/28/1975 12:00 AM	29499.07	1866.83	21898.62	10240.80	149.66
03/31/1975 12:00 AM	29499.07	2997.62	19337.19	9947.71	421.55
04/30/1975 12:00 AM	29499.07	3650.25	4858.50	520.95	4197.55
05/31/1975 12:00 AM	29499.07	6015.01	343.21	0.51	9083.25
06/30/1975 12:00 AM	29499.07	6303.29	781.23	0.16	9481.48
07/31/1975 12:00 AM	29499.07	6167.60	1245.04	7.50	10116.16
08/31/1975 12:00 AM	29499.07	5492.98	1941.35	9.37	9213.75

The 'Budget To Excel' dialog box is open, showing options for 'Choose Budget HDF5 File', 'Output Conversion Factors and Units', 'Output Begin Date/Time', 'Output End Date/Time', 'Output Interval', 'Location for Data Import', and 'Columns for Data Import'. The 'Columns for Data Import' list includes: All, Subregion 1 (SR1), Subregion 2 (SR2), Subregion 3 (SR3), Subregion 4 (SR4), Ag. Area (AC), Ag. Potential/ET, Ag. Precipitation, and Ag. Runoff.





# Reusability: Post-Processing and Analysis Tools

- Initial need emerged when developing post-processing tools
  - ❖ IWFM ArcMap Graphical User Interface
  - ❖ IWFM Tools Excel Add-in
- Avoid replicating existing logic in a different programming language

The screenshot displays the Microsoft Excel interface with a spreadsheet titled 'IWFM ROOT ZONE PACKAGE (v4.11.0076)'. The spreadsheet contains a table with columns for 'Time', 'Ag. Area (AC.) Ag.', and 'Water Ag. Net Return Flow Ag. Beginning Storage (+) Ag.'. A dialog box titled 'Budget To Excel (v4.0 or later)' is open, showing options for 'Choose Budget HDF5 File', 'Output Conversion Factors and Units', 'Output Begin Date/Time', 'Output End Date/Time', 'Output Interval', 'Location for Data Import', and 'Columns for Data Import'.

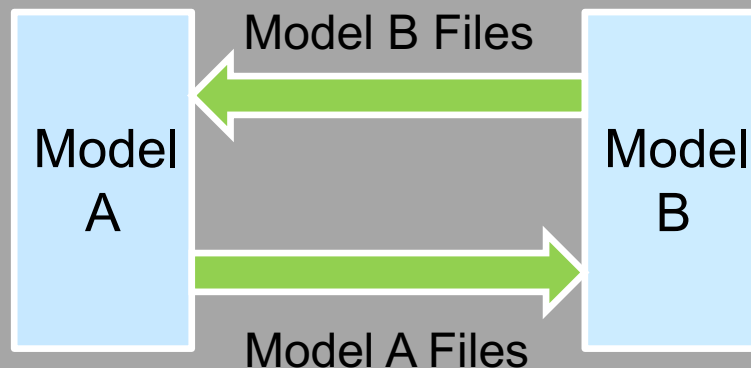
Time	Ag. Area (AC.) Ag.	Water Ag. Net Return Flow Ag.	Beginning Storage (+) Ag.
10/31/1973 12:00 AM	29499.10	0.00	30.94
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# Reusability: Linking Different Types of Models

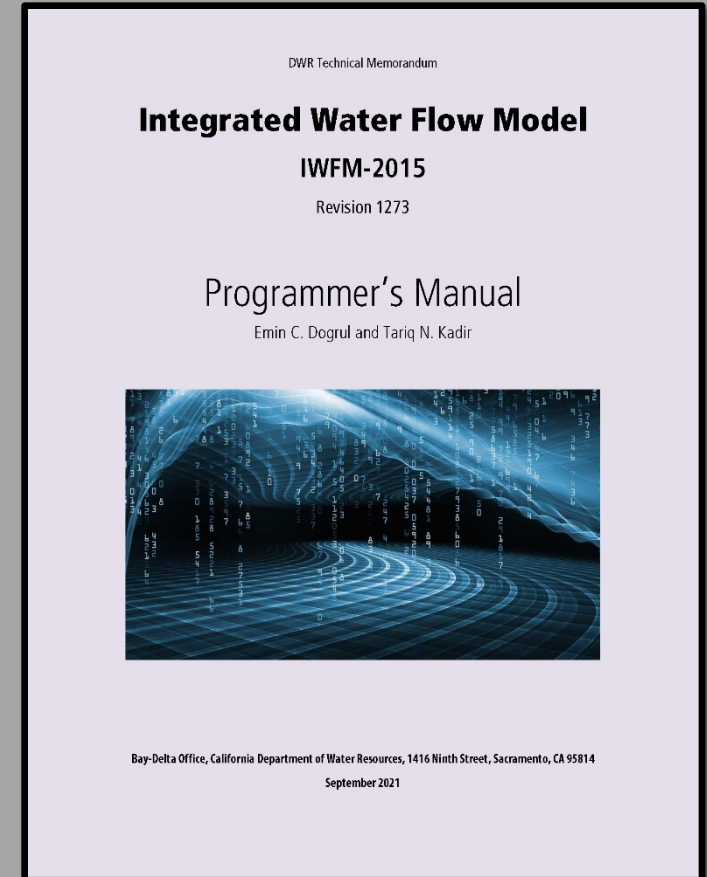
## Traditional Approach: Data Passing via Files

- Requires code modification to generate files and to read files generated by other model(s)
- Model dependent; different files to read and write for different types of linked model
- Difficult to maintain



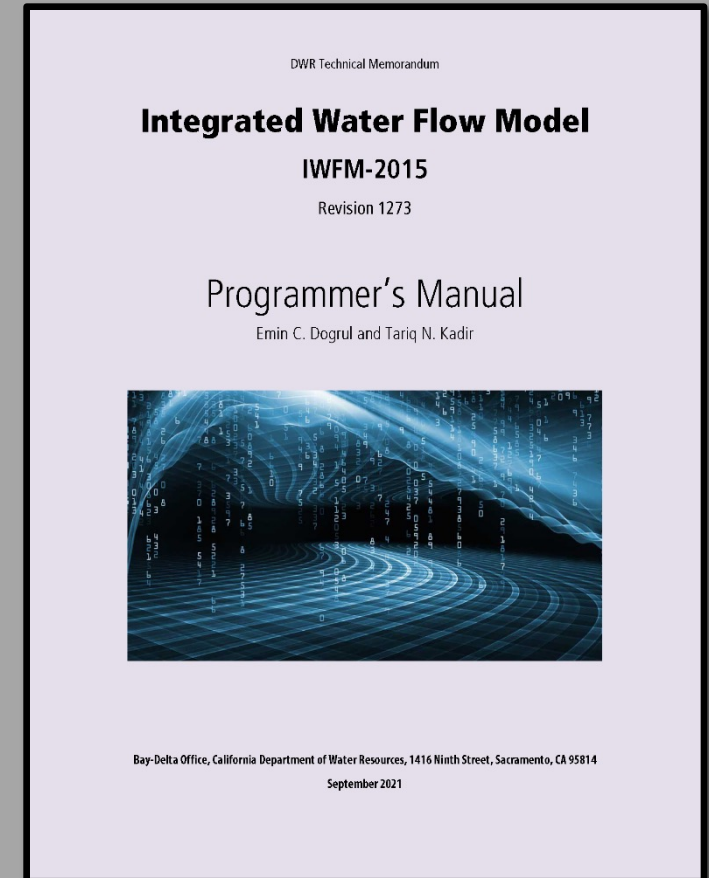
# Reusability: IWFM API

- A library of callable functions
- Functions can be called in different order to achieve different goals
- Same codeset used for different purposes and in different types of applications eliminating repetitive coding and inconsistencies
- Callable from different programming languages
  - ❖ Python
  - ❖ Java
  - ❖ Fortran, C, C++
  - ❖ .NET languages (C#, VB)
  - ❖ Visual Basic for Applications



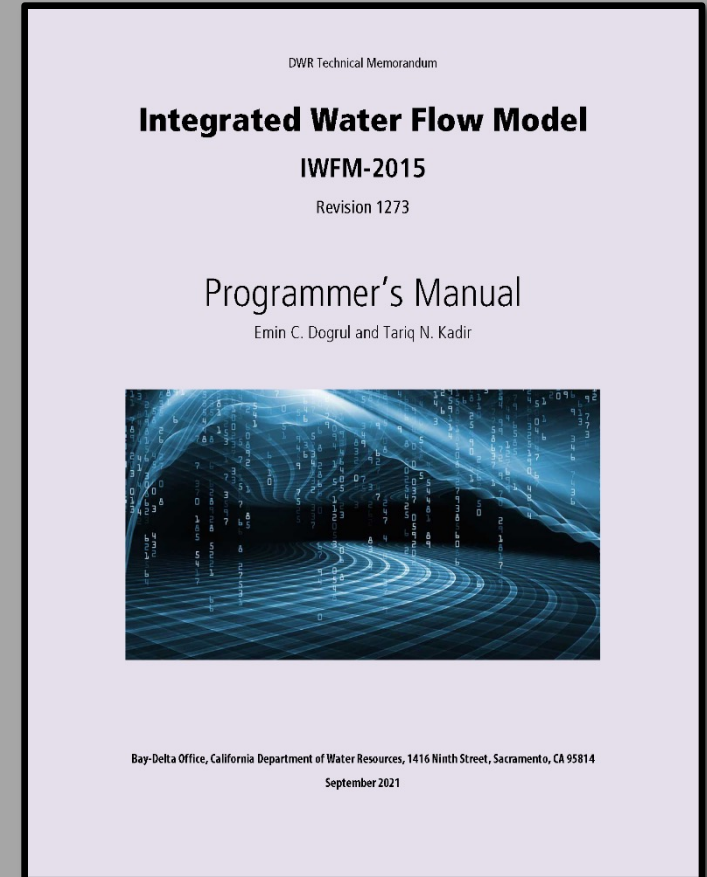
# Reusability: IWFM API

- Allows interacting with an IWFM application during runtime (supports model linkage)
  - ❖ Modify crop areas based on water availability and economics (e.g. linked SWAP-C2VSim)
  - ❖ Modify stream boundary inflows and diversions based on legal and operational constraints (e.g. CVSOM)
  - ❖ Link neighboring IWFM models to simulate boundary flows dynamically (IWFM-MM)
  - ❖ Modify pumping and diversions based on water quality constraints
  - ❖ Dynamic visualization of simulation results



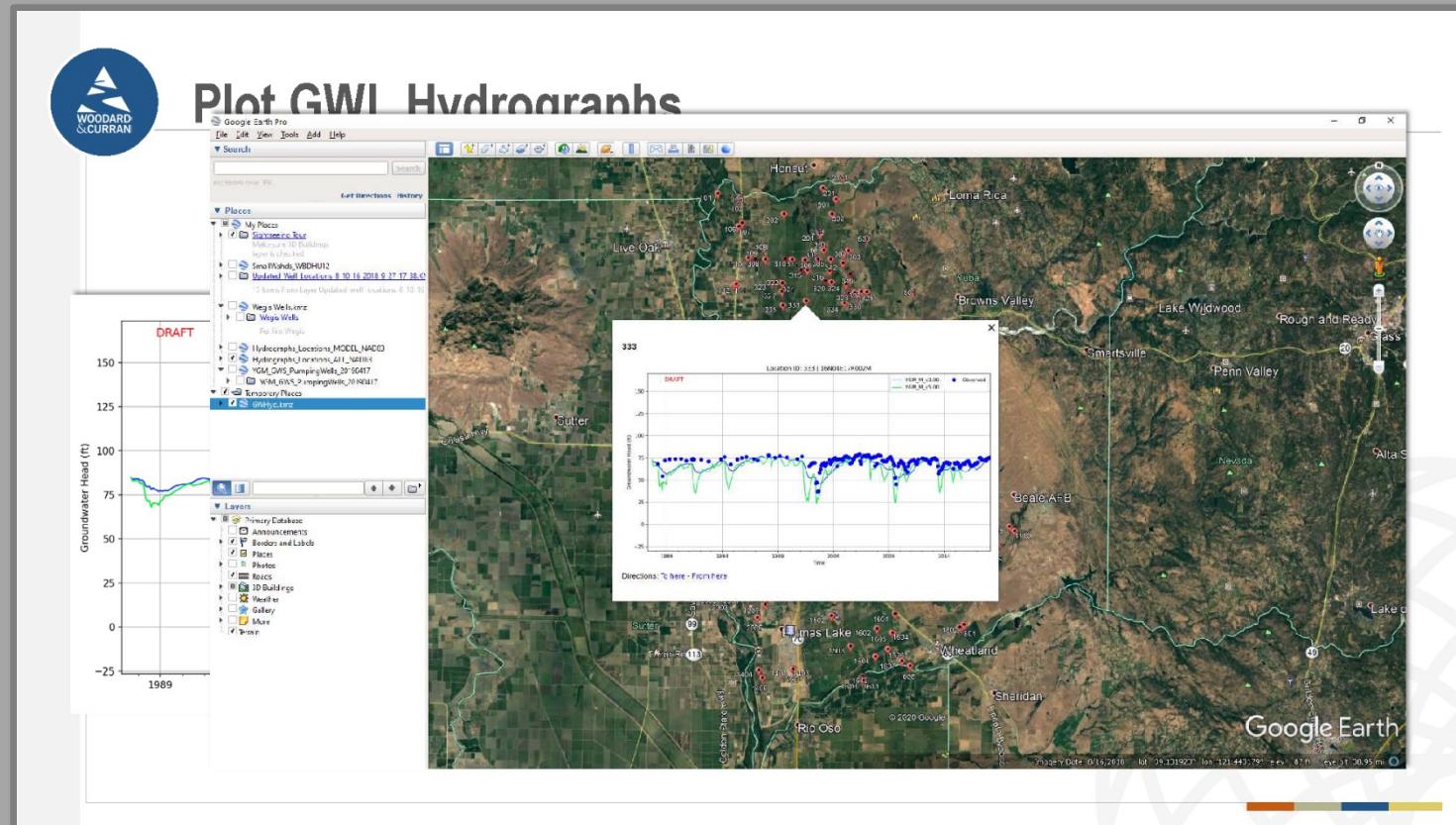
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- Allows interacting with an IWFM application during runtime (supports model linkage)
  - ❖ Pause model in the middle of a run
  - ❖ Simulate the same timestep as many times as needed
  - ❖ Retrieve model results for the timestep simulated last
  - ❖ Modify model input during the runtime
  - ❖ Do all of the above with a wrapper program using a predefined logic



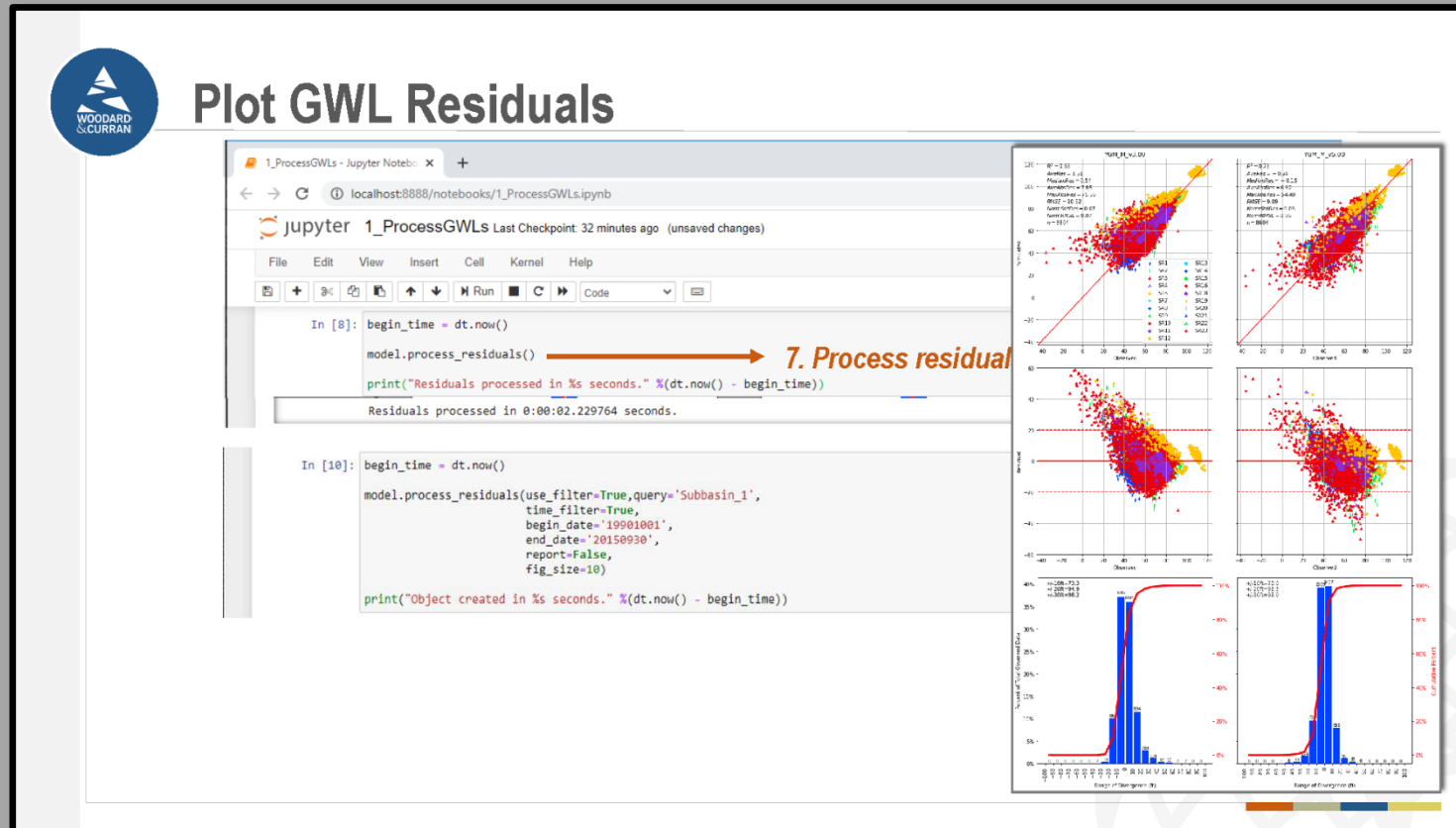
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- “Democratization” of processing, visualization and analysis tools
  - ❖ User-developed Jupyter Notebooks



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  - ❖ A layer between user’s tool and the IWFM model that breaks the dependency between the two; user’s tool don’t depend on IWFM input/output data structure and format



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- Monte-Carlo simulations



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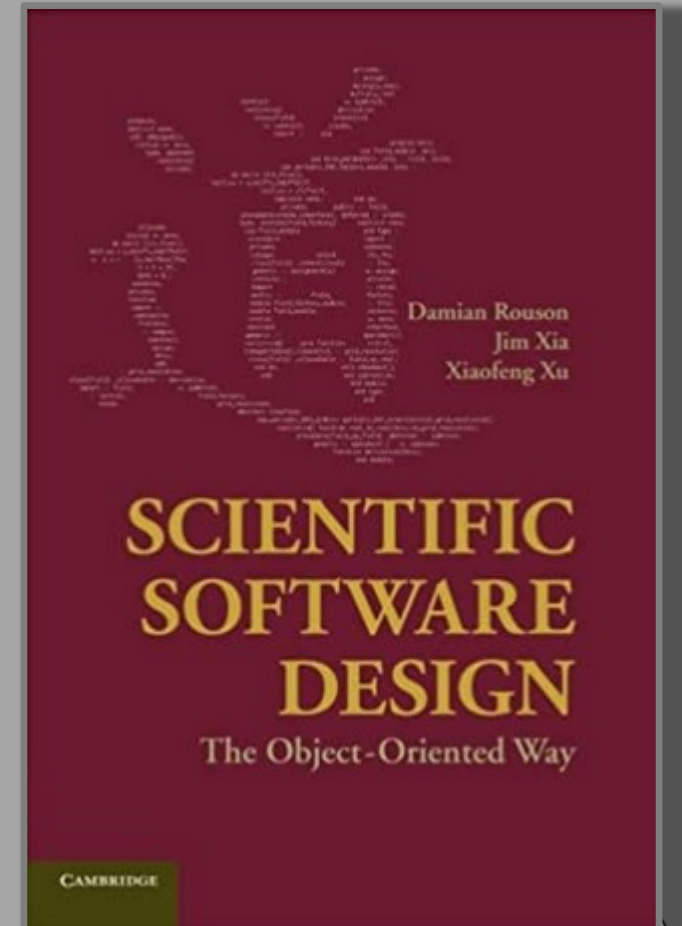
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  - ❖ User-developed Jupyter Notebooks
  - ❖ A layer between user’s tool and the IWFM model that breaks the dependency between the two; user’s tool don’t depend on IWFM input/output data structure and format
- Monte-Carlo simulations
- Development of surrogate models through machine learning



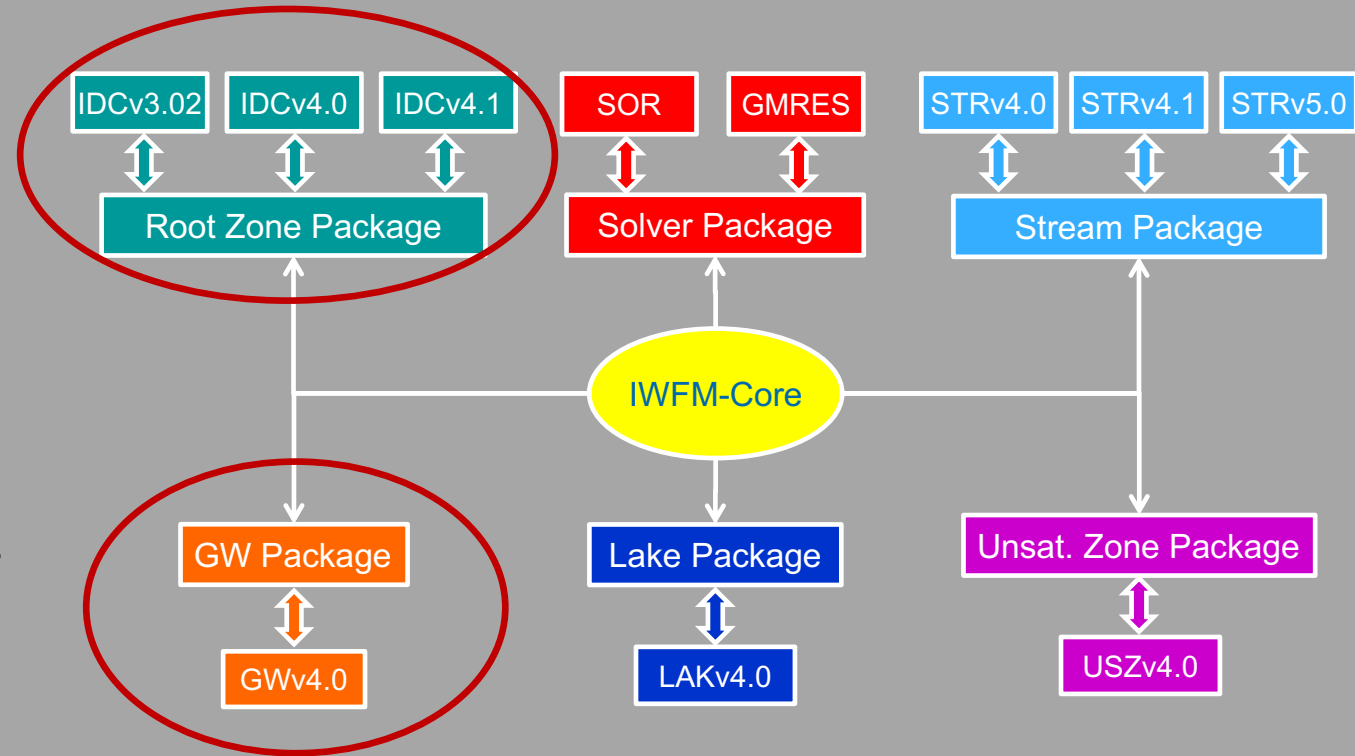
# Adoptability

- Ability to incorporate new simulation techniques without affecting previously developed applications
- Use of Object Oriented Programming concepts
- Use of design patterns
- Code reusability and extension are emphasized
- Allows quick implementation of new simulation methods in addition to existing methods



# Modularity

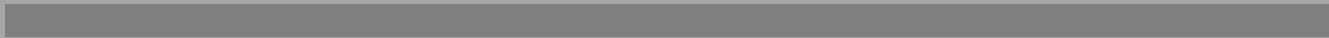
- Ability to split the model into smaller, stand-alone components
  - ❖ IWFM Demand Calculator (IDC)
  - ❖ Groundwater DLL
- Simplifies calibration process (IDC)
- Different components can be linked to different models (groundwater DLL in CalSim 3)



# Speed

- Implementation of HDF files for fast results retrieval
  - ❖ Database designed for scientific applications to store numbers
  - ❖ Very efficient to retrieve data in different ways
    - Retrieve spatial data at a fixed time
    - Retrieve timeseries data at a fixed location
  - ❖ Especially useful in processing Z-Budget data
- Use of parallel processing (OpenMP)
  - ❖ Up to 50% faster runtimes depending on model and hardware





Questions?

