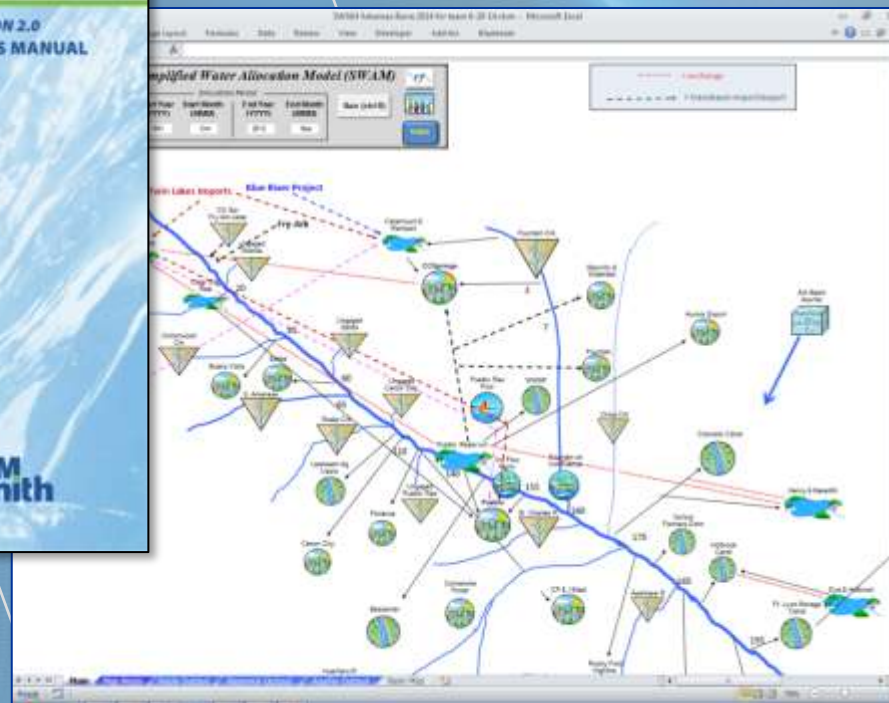
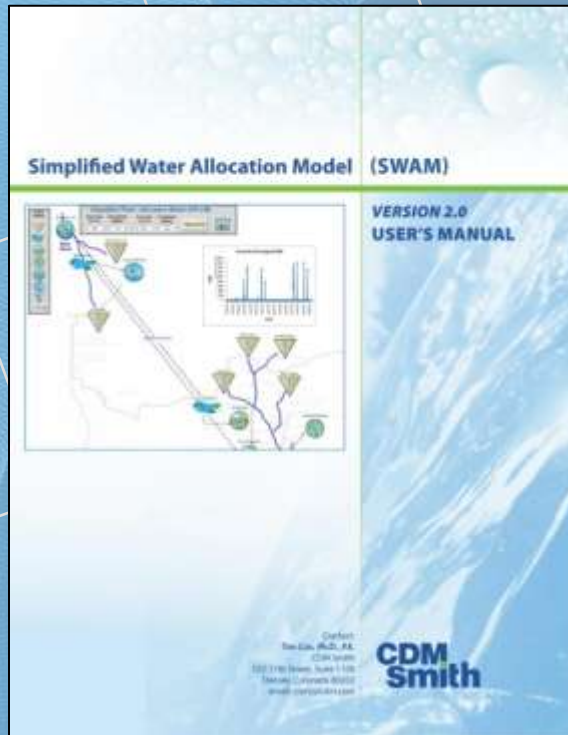


Overview of the Simplified Water Allocation Model (SWAM)

South Carolina Surface Water Quantity Model Project

Kirk Westphal, PE
John Boyer, PE, BCEE
December 3, 2014

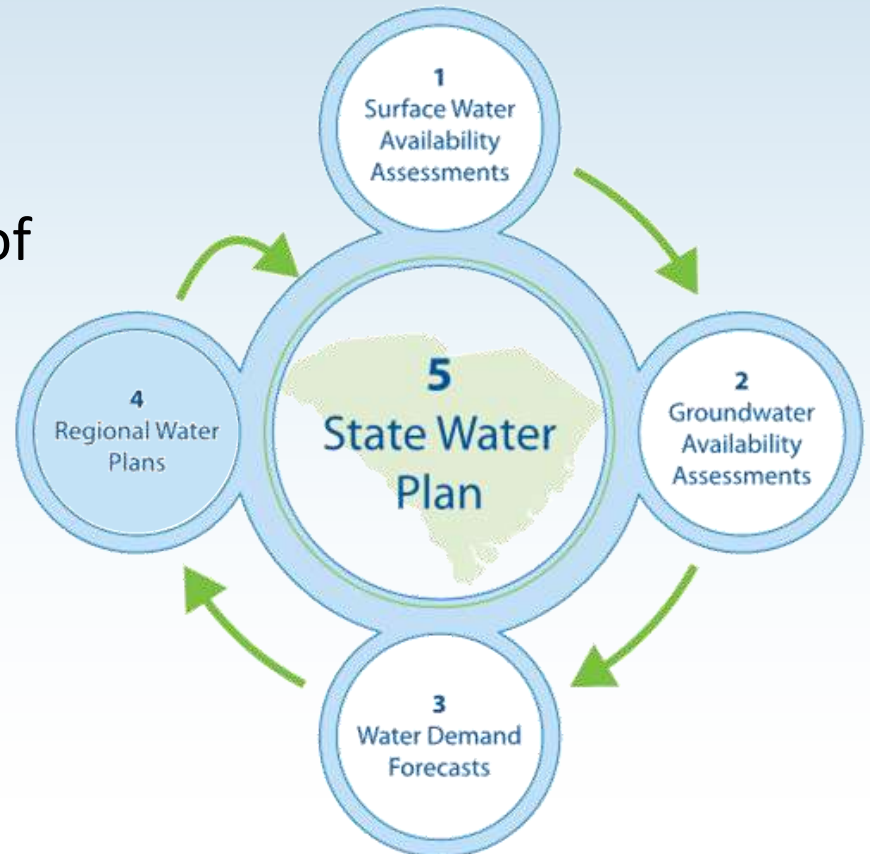


Project Purpose

- Build models 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.
- CDM Smith’s contract ends after the models are built and training is conducted

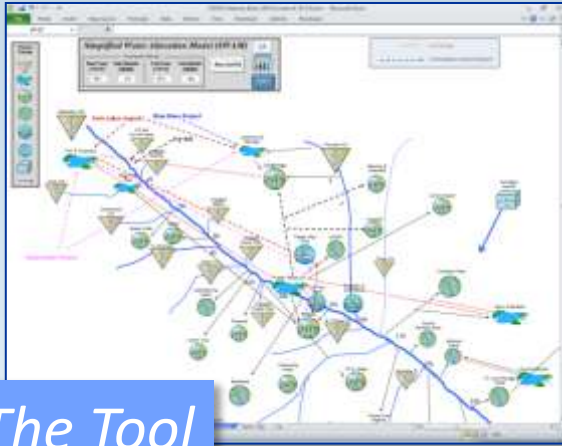
Project Purpose

- Once they are built and accepted by DNR/DHEC, the models will be made available for use by water utilities, energy producers, river basin organizations, and other stakeholders.
- The surface water models, and other available tools, can be used to support development of regional water plans

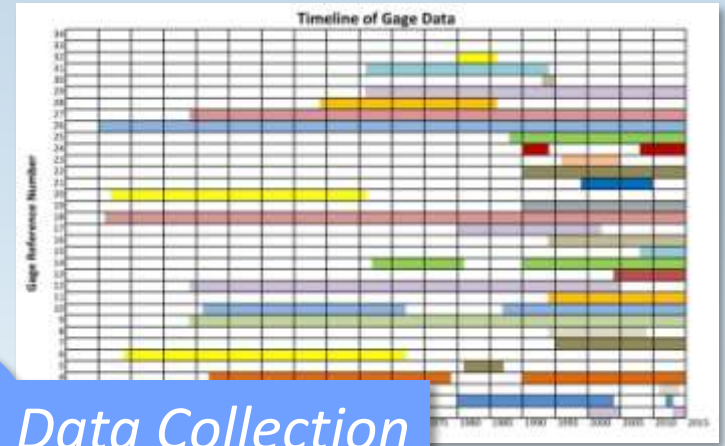


Development of Surface Water Quantity Models

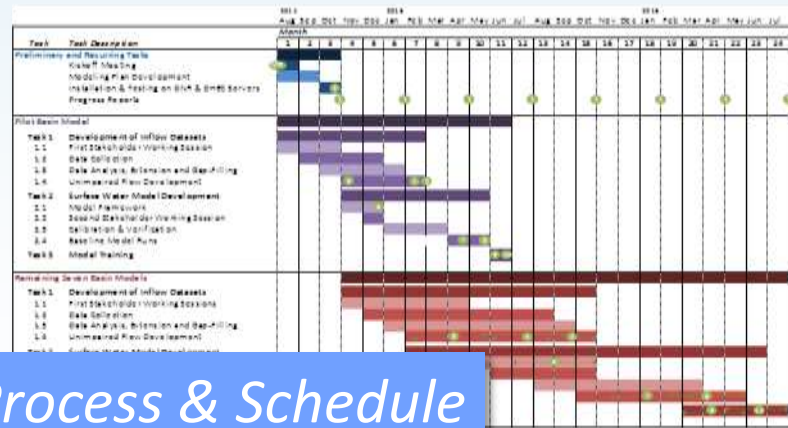
1 *The Tool*



3 *Data Collection*

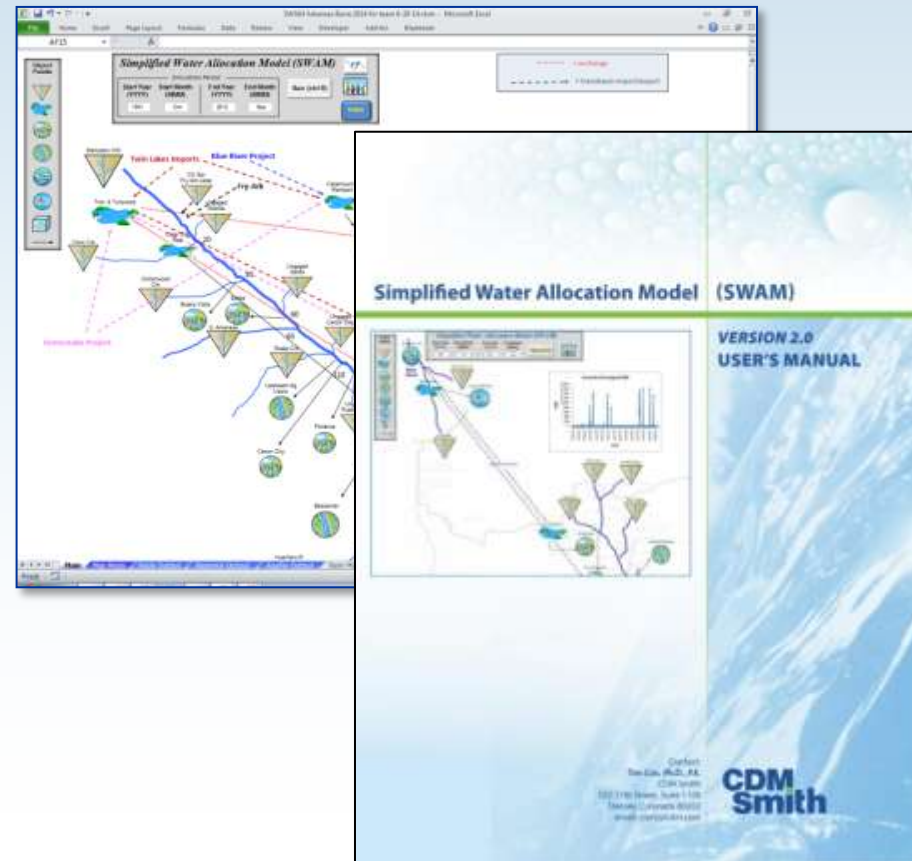


2 *Process & Schedule*



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



River Basin Flow and Operations Models

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

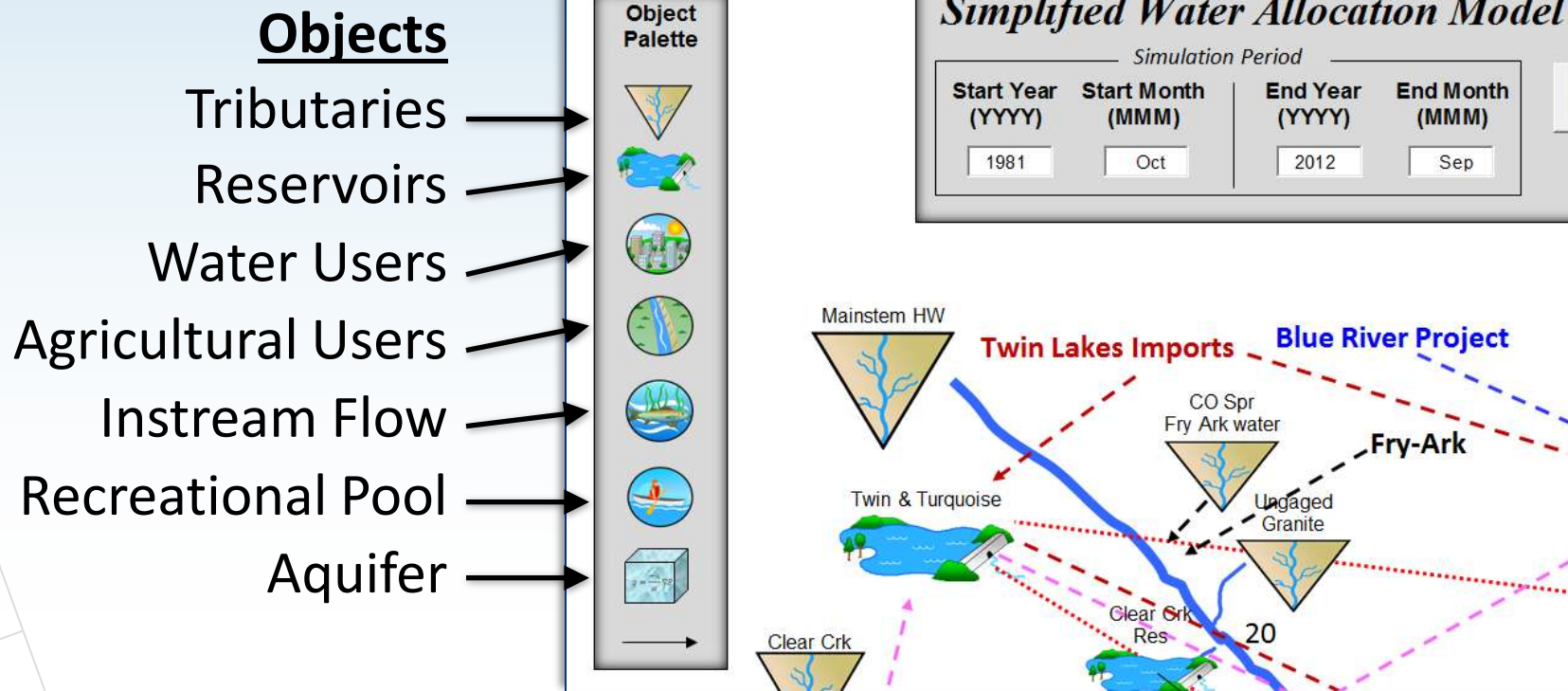
- Tailored specifically for hydropower
 - Energy Calculations
 - Reservoir Tracking
- Familiar Visual Basic programming

RiverWare

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

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



Simplified Water Allocation Model (SWAM)

- **Intuitive & Transparent** Resides within and interfaces directly with Microsoft Excel
- **Ease-of-Use** Point-and-click setup and output access
- **Simple & Robust** Mass balance calculations, but handles operating rules, use priorities, etc.

Input Forms

Agricultural Water User

Main | Source Water | Return Flows |

User Name: **Delete Node** Multiple Sources of Water ?

Supplemental Supply/Demand Alternatives Demands

Agricultural Water User

Main | Source Water | Return Flows |

Source Stream: Source Water Type: Direct River Reservoir

Downstream Location (mi) Priority Date 1/1/2008

Agricultural Water User

Main | Source Water | Return Flows |

Ditch Capacity (AFM) (_CFS)

Return Flow Locations: single point multiple points

Receiving Stream: RF Location (mi) Time Lag (months)

Monthly Return Flows

Return Flow %	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0

Node Output

SWAM Arikas Basin 2014 for team 6-20-14.ahm - Microsoft Excel

	A	B	EY	EZ	FA	FB	FC	FD	FE	FF
Output										
1			Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)		
2		Pueblo4	32	Mainstem	136	420	1,000,000	5,000		
3		Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)	GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)
4		Min	1,200	0	0	0	0	0	0	0
5		Max	423,253	470	420	5,800	0	0	0	0
6		Avg	44,589	117	33	4,340	0	0	0	0
7		Oct-81	14,837	0	0	0	0	0	0	0
8		Nov-81	23,186	0	0	0	0	0	0	0
9		Dec-81	24,424	0	0	0	0	0	0	0
10		Jan-82	17,870	0	0	0	0	0	0	0
11		Feb-82	16,694	0	0	0	0	0	0	0
12		Mar-82	25,120	0	0	0	0	0	0	0
13		Apr-82	11,977	0	0	0	0	0	0	0
14		May-82	35,025	0	0	0	0	0	0	0
15		Jun-82	146,407	0	0	0	0	0	0	0
16		Jul-82	97,301	0	0	0	0	0	0	0

Simplified Water Allocation Model (SWAM)

- Supports multiple layers of complexity for development of a range of systems, for example...

A Reservoir Object can include:

- Basic hydrology dependent calculations
- Operational rules of varying complexity such as prescribed releases, conditional releases, or hydrology dependent releases.

Reservoir

A screenshot of the 'Reservoir' management software interface. The window title is 'Reservoir'. The interface is divided into several sections:

- Top Section:** Includes a 'Reservoir Name' dropdown menu, a 'Delete Node' button, 'Storage Capacity (AF)' and 'Initial Storage (AF)' input fields, and radio buttons for 'Offline' and 'Online'.
- Evaporation Section:** Has radio buttons for 'Inches/day', '% Volume', and 'Input Timeseries'.
- Monthly Rates Section:** A table with columns for 'Month' (Jan to Sep) and 'Evap. Rates (in./day)'.

Month	Evap. Rates (in./day)
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
- Area Capacity Table Section:** Has radio buttons for 'Simple' and 'Detailed'. Below are two tables with columns for 'Volume (AF)' and 'Area (ac)'.

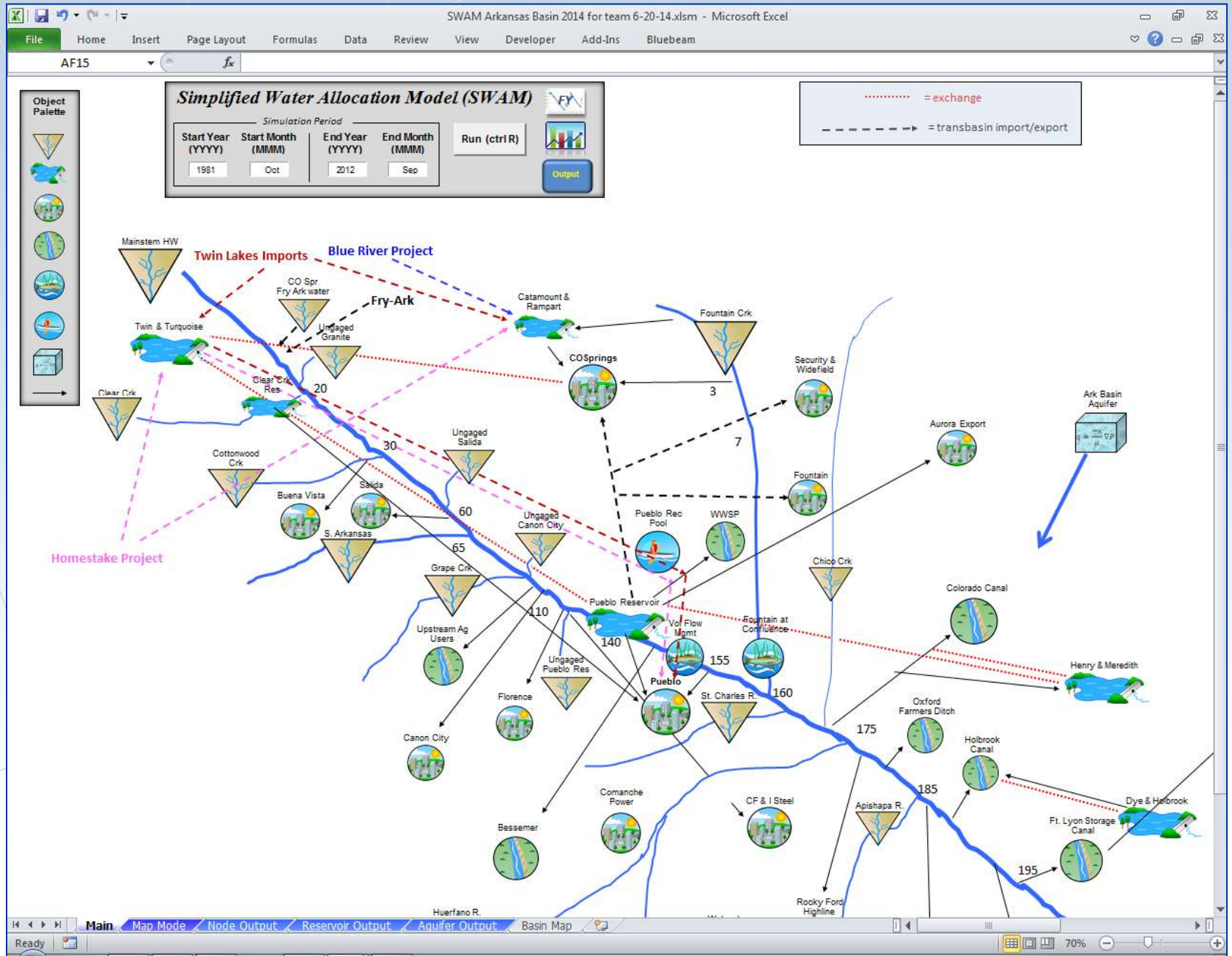
Volume (AF)	Area (ac)
- Reservoir Releases Section:** Includes a 'Receiving Stream' dropdown, radio buttons for 'Simple' and 'Advanced', and a 'Release Location (mi)' input field.
- User Defined Releases Section:** A table with columns for 'Month' (Jan to Sep), 'Min. Release (AFM)', and '(CFS)'.

Month	Min. Release (AFM)	(CFS)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		

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
- Resolve water disputes
- 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

SWAM Model Main Screen



Object Palette

Objects

Tributaries →

Reservoirs →

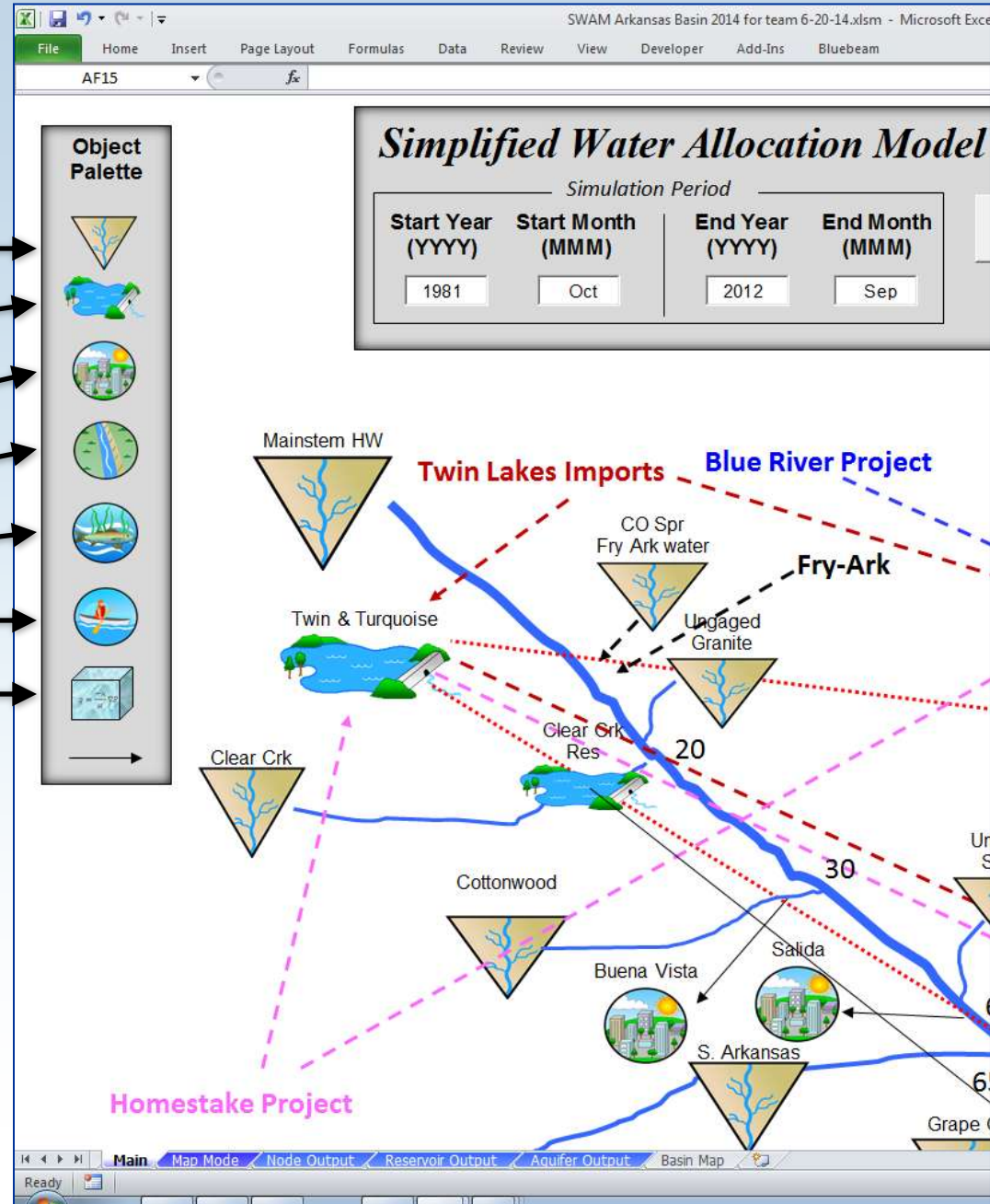
Water Users →

Agricultural Users →

Instream Flow →

Recreational Pool →

Aquifer →



Tributary Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period
Start Year (YYYY): 1981 Start Month (MMM): Oct

Tributary

Tributary Name: **Delete Tributary** **Headwater Flows**

Confluence Stream: Confluence Location (mi):

Spatial Flow Changes

Subbasin Flow Factor (unitless): Reach Length (mi):

Comments:

Save
Close

..... = exchange

Transbasin import/export

Ark Basin Aquifer

Colorado Canal

Henry & Meredith

Holbrook Canal

Dye & Holbrook

Ft. Lyon Storage Canal

Apishapa R. 185

195

Comanche Power

CF & I Steel

Rocky Ford Highline

Huerfano R.

Bessemer

Homestake Project

Clear Crk Res.

Clear Crk

Cottonwood Crk

Bue

Twin & Turquoise

Mainstem HW

Twin Lakes Impo

Fry

Object Palette

Main | Map Mode | Node Output | Reservoir Output | Aquifer Output | Basin Map

Ready

70%

Reservoir Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period: Start Year, Start Month, End Year, End Month

..... = exchange
 -----> = transbasin import/export

Reservoir

Main

Reservoir Name: [Dropdown] **Delete Node** **Storage Capacity (AF)** [Input] **Initial Storage (AF)** [Input] **Offline** **Online**

Evaporation
 Inches/day **% Volume** **Input Timeseries**

Reservoir Releases
Receiving Stream: [Dropdown] **Simple** **Advanced**
Release Location (mi) [Input: 0]

Monthly Rates

Month	Evap. Rates (in./day)
Jan	
Feb	
Mar	
Apr	
May	
Jun	
Jul	
Aug	
Sep	
Oct	
Nov	
Dec	

Area-Capacity Table
 Simple **Detailed**

Month	Volume (AF)	Area (ac)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

User Defined Releases

Month	Min. Release (AFM)	(CFS)
Jan		
Feb		
Mar		
Apr		
May		
Jun		
Jul		
Aug		
Sep		
Oct		
Nov		
Dec		

Comments: [Text Area]

Save **Close**

Homesta

Huerfano R. Highline

Main | Map Mode | Node Output | Reservoir Output | Aquifer Output | Basin Map

Ready 70%

Water User Input Form – Main

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period
Start Year (YYYY): 1981 Start Month (MMM): Oct End Year (YYYY): 2012 End Month: Run (ctrl+R)

..... = exchange
-----> = transbasin import/export

Water User

Main | Water Usage | Source Water | Return Flows

Water User Name: [Dropdown] **Delete Node** Multiple Sources of Water?

Supplemental Supply/Demand Alternatives

- Conservation
- Transbasin Import
- Recapture Reuse
- Water Exchange
- Ag Transfer

Comments:

Save **Close**

Agricultural Water User Input Forms

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period
 Start Year (YYYY) Start Month (MMM) End Year (YYYY) End Month (MMM) Run (ctrlR)

..... = exchange
 -----> = transbasin import/export

Agricultural Water User
 Main | Source Water | Return Flows

User Name: [] Delete Node Multiple Sources of Water ?

Supplemental Supply/Demand Alternatives
 Transbasin Import
 Groundwater

Demands
 user-defined Edit Demands
 ag calculations

Comments:

Agricultural Water User
 Main | Source Water | Return Flows

Source Stream: [] Source Water Type:
 Direct River
 Reservoir
 Groundwater

Downstream Location (mi) [] Priority Date [1/1/2008]

Ditch Capacity (AFM) [] Diversion Right (AFM) [] Seasonal WR
 (_ CFS) (_ CFS)

Save
Close

Agricultural Water User
 Main | Source Water | Return Flows

Return Flow Locations
 single point Receiving Stream: [] RF Location (mi) [0] Time Lag (months) [0]
 multiple points

Monthly Return Flows

Return Flow %	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	0	0	0	0	0	0	0	0	0	0	0	0

Object Palette
 Clear Crk
 Homestake Pr
 Ark Basin Aquifer
 Herbrook

Main | Map Mode | Node Output | Reservoir Out

Ready

Instream Flow Input Form

SWAM Arkansas Basin 2014 for team 6-20-14.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Add-Ins Bluebeam

AF15

Simplified Water Allocation Model (SWAM)

Simulation Period

Start Year (YYYY)	Start Month (MMM)	End Year (YYYY)	End Month (MMM)
1981	Oct	2012	Sep

Run (ctrlR) Output

..... = exchange
-----> = transbasin import/export

Instream Flows

Water Right

Instream Flow Name: [] Delete Node

Target Stream: []

Downstream Location (mi): [0]

Priority Date: [1/1/2007]

Flow Right (AFM) [0] (_CFS)

Rules:
 Seasonal WR
 TNC IHA Methodology

Comments: []

Save Close

Object Palette

Mainstem HW
Twin Lakes
Twin & Turquoise
Clear Crk
Cottonwood Crk
Homestake Project

Ark Basin Aquifer
Henry & Meredith
Dye & Harbrook
Ft. Lyon Storage Canal
195

Huerfano R.
Rocky Ford Highline

Main Map Mode Node Output Reservoir Output Aquifer Output Basin Map

Ready 70%

Output Tables

Node Output

SWAM Arkansas Basin 2014 for team 6-20-14.xlsx - Microsoft Excel

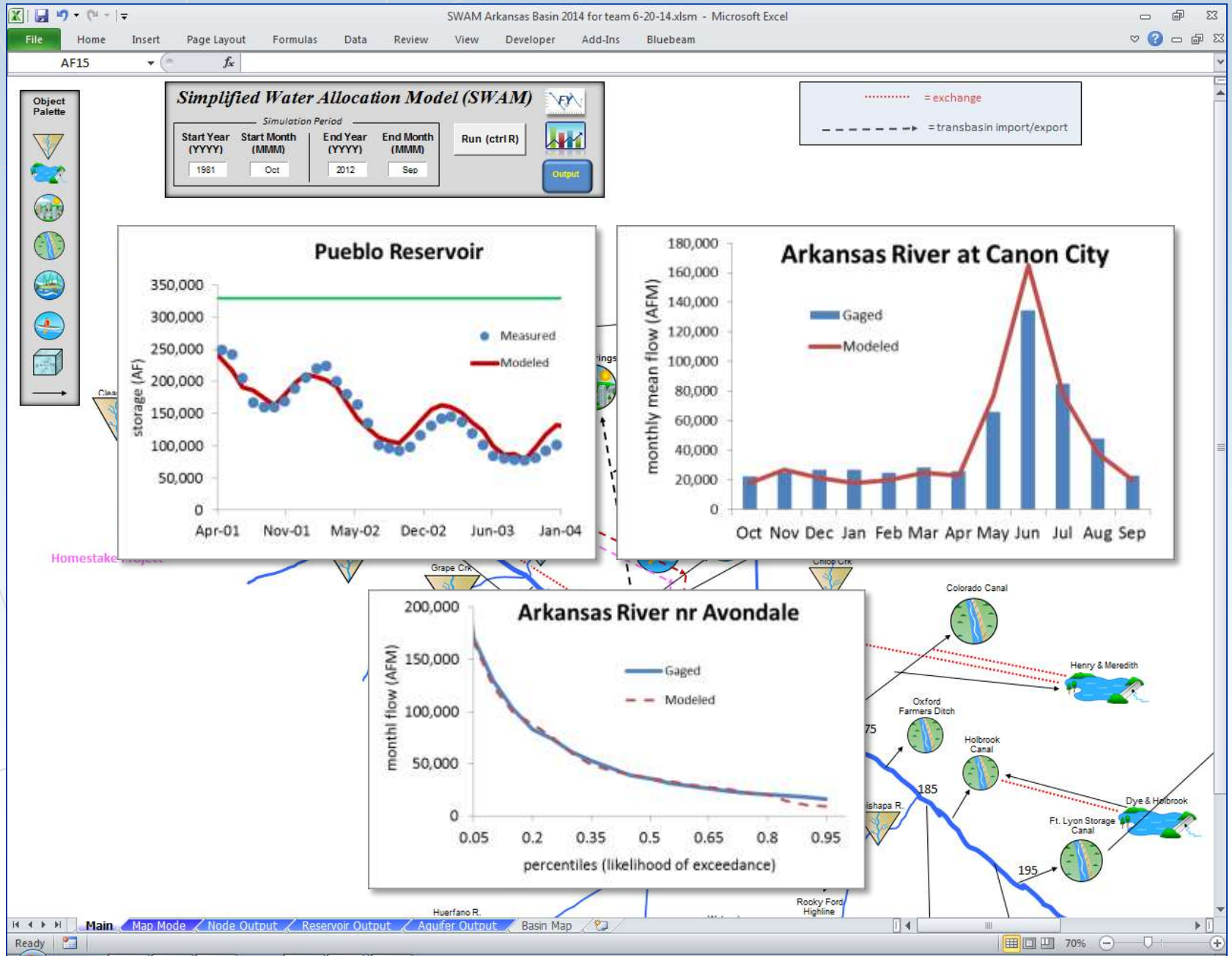
Output	Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)	Return Flow (AFM)	Release (AFM)	Evap Losses (AFM)	Priority Rank	Reach (mi)		
Pueblo4	32	Mainstem	136	420	1,000,000	5,000				Fountain2	44	Mainstem	
Date	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)	Storage (AF)	GW Pumping (AFM)	Demand (AFM)	Shortage (AFM)	Return Flow (AFM)	Release (AFM)	Evap Losses (AFM)	Physically Avail. (AFM)	Legally Avail. (AFM)	Diverted (AFM)
Min	1,200	0	0	0	0	0	0	0	0	0	1,200	0	0
Max	423,253	420	420	5,000	0	0	0	0	52	423,201	0	0	0
Avg	44,508	117	33	4,340	0	0	0	0	21	44,555	0	0	0
Oct-81	14,837	0	0	0	0	0	0	0	0	14,837	0	0	0
Nov-81	23,186	0	0	0	0	0	0	0	0	23,186	0	0	0
Dec-81	24,424	0	0	0	0	0	0	0	0	24,424	0	0	0
Jan-82	17,870	0	0	0	0	0	0	0	0	17,870	0	0	0
Feb-82	16,694	0	0	0	0	0	0	0	0	16,694	0	0	0
Mar-82	25,120	0	0	0	0	0	0	0	0	25,120	0	0	0
Apr-82	11,977	0	0	0	0	0	0	0	0	11,977	0	0	0
May-82	35,025	0	0	0	0	0	0	0	0	35,025	0	0	0
Jun-82	146,407	0	0	0	0	0	0	0	0	146,407	0	0	0
Jul-82	97,301	0	0	0	0	0	0	0	0	97,301	0	0	0
Aug-82	75,150	0	0	0	0	0	0	0	0	75,150	0	0	0
Sep-82	73,884	420	0	0	0	0	0	0	0	73,884	420	0	0
Oct-82	39,997	420	0	0	0	0	0	0	0	39,997	420	0	0
Nov-82	4,595	0	0	0	0	0	0	0	0	4,595	0	0	0
Dec-82	4,215	0	0	0	0	0	0	0	0	4,215	0	0	0
Jan-83	16,663	420	0	0	0	0	0	0	0	16,663	420	0	0
Feb-83	15,069	420	0	0	0	0	0	0	0	15,069	420	0	0
Mar-83	26,208	420	0	0	0	0	0	0	0	26,208	420	0	0
Apr-83	42,386	420	0	0	0	0	0	0	0	42,386	420	0	0
May-83	47,647	420	0	0	0	0	0	0	0	47,647	420	0	0
Jun-83	349,601	420	0	0	0	0	0	0	0	349,601	420	0	0
Jul-83	178,891	420	0	0	0	0	0	0	0	178,891	420	0	0
Aug-83	93,139	420	0	0	0	0	0	0	0	93,139	420	0	0
Sep-83	21,418	0	0	0	0	0	0	0	0	21,418	0	0	0
Oct-83	13,990	0	0	0	0	0	0	0	0	13,990	0	0	0
Nov-83	1,200	0	0	0	0	0	0	0	0	1,200	0	0	0
Dec-83	1,200	0	0	0	0	0	0	0	0	1,200	0	0	0
Jan-84	18,621	420	0	0	0	0	0	0	0	18,621	420	0	0
Feb-84	17,647	420	0	0	0	0	0	0	0	17,647	420	0	0
Mar-84	40,025	420	0	0	0	0	0	0	0	40,025	420	0	0
Apr-84	61,011	420	0	0	0	0	0	0	0	61,011	420	0	0
May-84	224,609	420	0	0	0	0	0	0	0	224,609	420	0	0
Jun-84	261,443	420	0	0	0	0	0	0	0	261,443	420	0	0
Jul-84	147,595	420	0	0	0	0	0	0	0	147,595	420	0	0
Aug-84	99,322	420	0	0	0	0	0	0	0	99,322	420	0	0
Sep-84	30,073	0	0	0	0	0	0	0	0	30,073	0	0	0
Oct-84	37,219	420	0	0	0	0	0	0	0	37,219	420	0	0
Nov-84	1,200	0	0	0	0	0	0	0	0	1,200	0	0	0
Dec-84	4,940	420	0	0	0	0	0	0	0	4,940	420	0	0
Jan-85	22,847	420	0	0	0	0	0	0	0	22,847	420	0	0

Reservoir Output

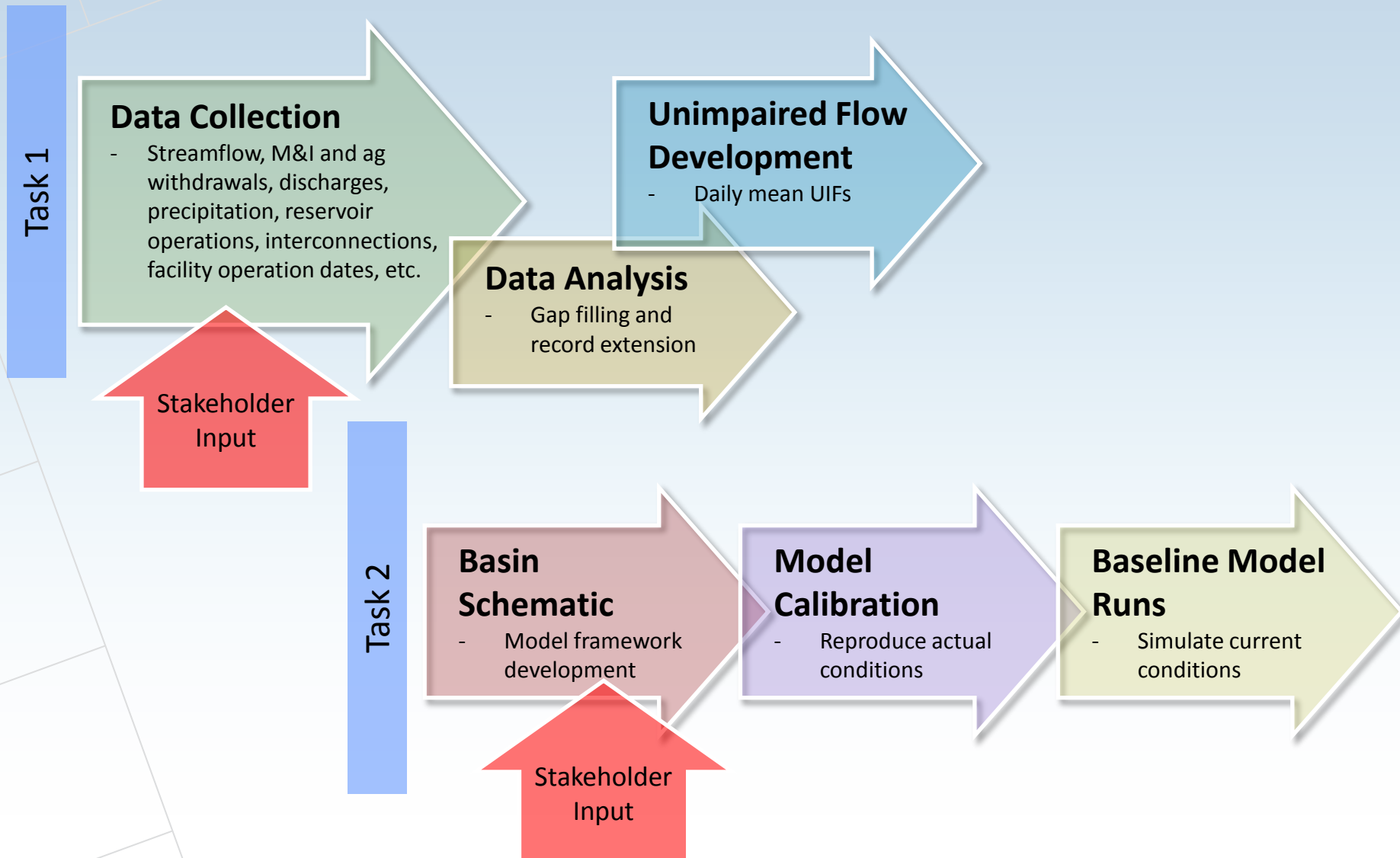
SWAM Arkansas Basin 2014 for team 6-20-14.xlsx - Microsoft Excel

Output	Priority Rank	Reach (mi)	Location	Water Right (AFM)	Ditch Capacity (AFM)	Storage Capacity (AF)	Return Flow (AFM)	Release (AFM)	Evap Losses (AFM)	Priority Rank	Reach (mi)
Pueblo Reservoir				330,000.0	143.0						
Date	Storage (AF)	Excess Volume (AF)	Overflow (AFM)	Total Inflow (AFM)	Total Withdrawal (AFM)	Release (AFM)	Outflow (AFM)	Evap (AFM)	Storage (AF)		
Min	37,367	0	0	2,862	4,373	0	0	0	7,545		
Max	330,000	0	19,692	303,831	101,197	0	7,000	3,451	450,000		
Avg	212,993	0	1,352	46,753	39,940	0	4,281	1,009	132,387		
Oct-81	92,749	0	0	40,265	46,985	0	0	532	200,277		
Nov-81	90,783	0	240	14,646	16,371	0	0	0	176,741		
Dec-81	88,111	0	680	11,817	13,808	0	0	0	154,539		
Jan-82	86,610	0	680	8,105	8,927	0	0	0	134,969		
Feb-82	87,315	0	680	7,549	6,165	0	0	0	119,018		
Mar-82	88,019	0	680	10,218	8,834	0	0	0	107,688		
Apr-82	82,264	0	614	24,650	29,220	0	0	571	98,144		
May-82	64,852	0	624	55,732	71,830	0	0	690	90,661		
Jun-82	62,620	0	728	98,054	98,922	0	0	637	95,890		
Jul-82	52,251	0	525	79,954	89,142	0	0	655	94,416		
Aug-82	42,029	0	600	61,795	70,950	0	0	466	102,863		
Sep-82	38,780	0	810	50,284	52,424	0	0	299	110,282		
Oct-82	53,544	0	1,087	56,442	40,384	0	0	206	107,965		
Nov-82	82,590	0	1,384	44,561	12,995	0	1,136	0	97,376		
Dec-82	100,657	0	1,384	31,635	10,432	0	1,752	0	87,514		
Jan-83	110,347	0	1,384	19,931	6,721	0	2,135	0	90,684		
Feb-83	118,421	0	1,384	17,965	6,165	0	2,341	0	83,248		
Mar-83	127,482	0	1,384	22,397	9,440	0	2,512	0	89,077		
Apr-83	136,429	0	1,213	43,943	30,270	0	2,687	827	97,669		
May-83	132,169	0	936	74,268	73,580	0	2,870	1,144	108,757		
Jun-83	330,000	0	728	303,831	101,197	0	2,776	1,299	258,390		
Jul-83	330,000	0	525	103,845	84,042	0	6,027	3,451	271,590		

Calibration Result Graphs

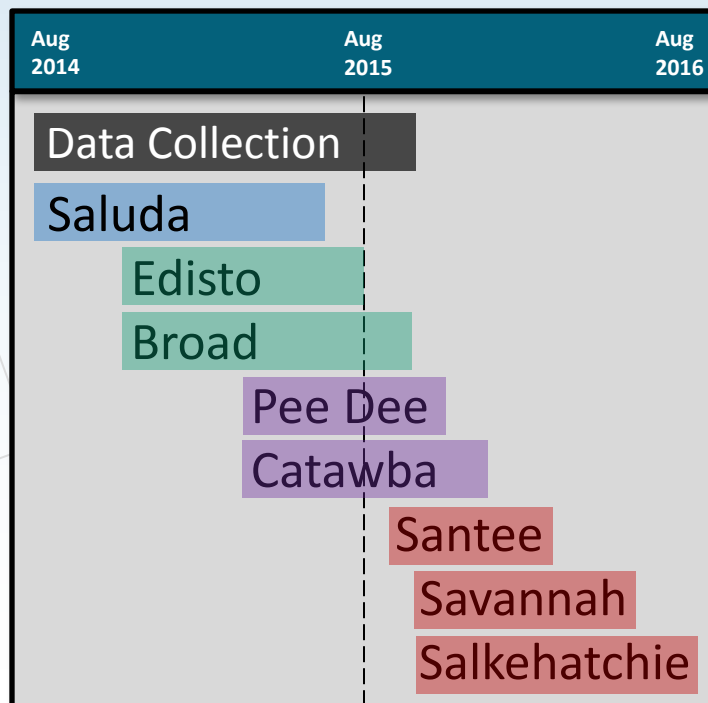


Major Tasks



Schedule for Developing the Models

- ***Pilot Model*** of the Saluda River Basin
- Other models to follow, with order based on data availability
- 2-year schedule requires that groups of models be constructed in parallel



Schedule for Developing the Pilot Model

<u>Task/Deliverable</u>	<u>Date</u>
• Unimpaired Flow (UIF) Methodology	Dec 1, 2014
• Model Framework	Jan 15, 2015
• UIF Dataset	Mar 1, 2015
• Baseline Model Runs	May 1, 2015
• Final Calibrated Model	June 1, 2015
• Model Training and Users Manual	July 1, 2015

Data is Needed to Support...

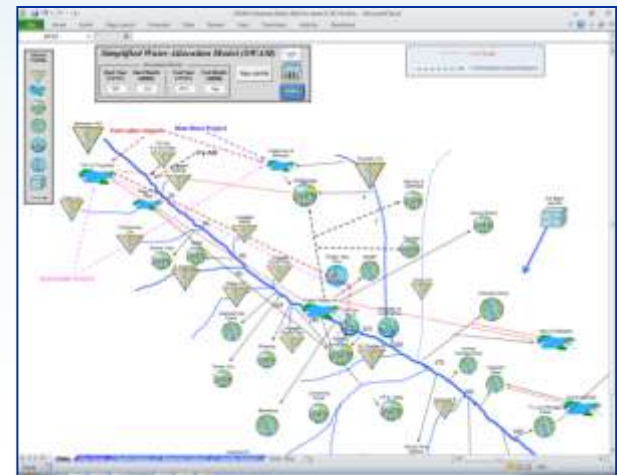
1. Development of Unimpaired Flows (UIFs)

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

2. Development of each baseline model

- A. Withdrawal and return amounts and locations
- B. Current reservoir operating rules
- C. Drought Management Plans and Requirements
- D. Instream flow requirements



Data Needed to Support Unimpaired Flows



Streamflow, dating back to earliest continuous gage data



Historical withdrawals (>100,000 gpd) and discharges for M&I, thermoelectric, agriculture, hydropower



Reservoirs

- a) Operating rules and elevation-storage-area curves
- b) Historical elevation release data
- c) Precipitation and evaporation records



Interconnections

Data Collection

1. Permitted surface water users will be contacted by CDM Smith to:
 - A. Confirm the history of your water source(s) and operation
 - B. Collect additional data that may be useful to characterize and quantify historical water withdrawals and discharges for UIF development
2. CDM Smith will follow-up with an e-mail confirming our understanding of your data

